

# Vitamin D Deficiency Among Professional Basketball Players

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**Background:** Vitamin D plays an important role in several systems of the human body. Various studies have linked vitamin D deficiency to stress and insufficiency fractures, muscle recovery and function, and athletic performance. The prevalence of vitamin D deficiency in the elite athletic population has not been extensively studied, and very few reports exist among professional athletes.

**Hypothesis:** There is a high prevalence of vitamin D deficiency or insufficiency among players attending the National Basketball Association (NBA) Combine.

**Study Design:** Cross-sectional study; Level of evidence, 3.

**Methods:** This is a retrospective review of data previously collected as part of the routine medical evaluation of players in the NBA Combines from 2009 through 2013. Player parameters evaluated were height, weight, body mass index (BMI), and vitamin D level. Statistical analysis using *t* tests and analysis of variance was used to detect any correlation between the player parameters and vitamin D level. Vitamin D levels were categorized as deficient (<20 ng/mL), insufficient (20-32 ng/mL), and sufficient (>32 ng/mL).

**Results:** After institutional review board approval was submitted to the NBA, the NBA released deidentified data on 279 players who participated in the combines from 2009 through 2013. There were 90 players (32.3%) who were deficient, 131 players (47.0%) who were insufficient, and 58 players (20.8%) who were sufficient. A total of 221 players (79.3%) were either vitamin D deficient or insufficient. Among all players included, the average vitamin D level was  $25.6 \pm 10.2$  ng/mL. Among the players who were deficient, insufficient, and sufficient, the average vitamin D levels were  $16.1 \pm 2.1$  ng/mL,  $25.0 \pm 3.4$  ng/mL, and  $41.6 \pm 8.6$  ng/mL, respectively. Player height and weight were significantly increased in vitamin D-sufficient players compared with players who were not sufficient ( $P = .0008$  and  $.009$ , respectively). Player age and BMI did not significantly differ depending on vitamin D status ( $P = .15$  and  $.77$ , respectively).

**Conclusion:** There is a high prevalence of vitamin D deficiency or insufficiency among participants in the NBA Combines. As a result, there should be a high suspicion for this metabolic abnormality among elite basketball players.

**Clinical Relevance:** Vitamin D level has been linked to bone health, muscle recovery and function, and athletic performance. Because of the high prevalence of vitamin D deficiency in the NBA Combines, clinicians should maintain a high suspicion for vitamin D abnormalities among elite basketball players.

**Keywords:** vitamin D; metabolic; National Basketball Association; professional

Vitamin D is a fat-soluble hormone important in several organ systems of the human body. It is obtained from dietary and supplemental uptake. Inactive vitamin D is either activated by ultraviolet exposure in the skin or by hydroxylation, first in the liver and then subsequently in the kidney. The active form of vitamin D, cholecalciferol,

then circulates in the body and plays a particular role in calcium and phosphate homeostasis. Lack of vitamin D may result from poor dietary intake, lack of adequate sunlight exposure, or a multitude of causes of malabsorption such as inflammatory bowel disease, celiac disease, long-term glucocorticoid use, or gastric surgery.<sup>20</sup> Vitamin D deficiency has been linked to several pathologic processes. These include, but are not limited to, neoplastic and infectious processes,<sup>7,16</sup> multiple sclerosis,<sup>31</sup> rheumatoid arthritis,<sup>28</sup> stroke,<sup>34</sup> cardiovascular disease,<sup>13</sup> and endocrine abnormalities such as diabetes.<sup>35</sup> Of particular importance to the orthopaedic surgeon is the role of vitamin D in the regulation of calcium. Vitamin D deficiency has been linked to a greater risk of fractures in the elderly<sup>8,27</sup> and Finnish military recruits,<sup>37</sup> while potentially increasing the risk of stress fractures among female naval recruits.<sup>24</sup>

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Furthermore, several studies have shown an effect of vitamin D on muscle function and recovery.<sup>9</sup> Wassner et al linked vitamin D deficiency to myofibrillar protein degradation in mice,<sup>39</sup> and Pfeifer et al<sup>33</sup> showed the direct effect of vitamin D on rat myoblasts. In human muscle, Boland<sup>5</sup> found atrophic type 2 muscle fibers in muscle biopsies of vitamin D-deficient individuals. Interestingly, Cannell et al<sup>6</sup> suggest these effects may be reversed in the elderly with vitamin D supplementation.

Taking this a step further, several authors have linked vitamin D to physical performance.<sup>2,6</sup> In rats, Minasyan et al<sup>29</sup> observed vestibular disturbances as a result of abnormal muscle fiber development in vitamin D-receptor knockout mice. Human hand-grip and isometric leg strength was lower in vitamin D-deficient individuals.<sup>1,14</sup> Faster sprint times and higher vertical jump height were observed in athletes supplemented with vitamin D compared with nonsupplemented nonathletes.<sup>12</sup> Similarly, Ward et al<sup>38</sup> found that adolescent girls with vitamin D deficiency exhibited decreased jump velocity and height. Beyond affecting measured athletic performance, vitamin D deficiency has also been linked to susceptibility to the common cold, influenza, and gastroenteritis in a group of collegiate athletes.<sup>17</sup> More recently in the professional athletic population, Maroon et al<sup>26</sup> associated vitamin D deficiency with decreased athletic performance among players in the National Football League (NFL).<sup>26</sup>

While studies have investigated the prevalence of vitamin D deficiency in adult populations, 1 of which cited a prevalence of 41.6% among US adults,<sup>10,15</sup> few studies have particularly looked at its prevalence in elite athletes. Outside the United States, several studies have reported either vitamin D deficiency or insufficiency rates of 58% among Middle Eastern sportsmen,<sup>18</sup> 57% of professional British athletes,<sup>11</sup> 33% of Australian gymnasts,<sup>25</sup> 65% of English Premier League soccer players,<sup>30</sup> and 57% of Spanish basketball players.<sup>3</sup> The only publication to our knowledge on the prevalence of vitamin D deficiency among professional athletes in the United States reports a prevalence of vitamin D deficiency and insufficiency of 68.8% in NFL athletes.<sup>26</sup> To our knowledge, no reports exist among players in the National Basketball Association (NBA). The purpose of this study was to investigate the prevalence of vitamin D deficiency among NBA Combine participants and its potential correlation to player parameters of age, height, weight, and body mass index (BMI).

## METHODS

This was a retrospective study of participants in the NBA Combines from 2009 to 2013. The inclusion criterion was any athlete with a recorded vitamin D level. All player parameters were recorded as part of the routine medical evaluation of all participants in the combines. After receiving institutional review board approval, the NBA released the following deidentified player parameters for analysis: age (in fractional years), height (in inches), weight (in pounds), BMI, and vitamin D level (in ng/mL). One player had multiple vitamin D levels recorded, and the

most recent vitamin D level was used for analysis. For the 6 athletes where the vitamin D level was reported as “<13.0 ng/mL,” a vitamin D level of 13.0 ng/mL was used for analysis. All player data were deidentified by the NBA prior to release to the investigators of this study to preserve player confidentiality.

There is no universally accepted standard definition for vitamin D deficiency, insufficiency, or sufficiency. In our study, vitamin D deficiency, insufficiency, and sufficiency were defined as described by Maroon et al<sup>26</sup> in their investigation of vitamin D deficiency in the NFL. Vitamin D deficiency was defined as below 20 ng/mL, insufficiency between 20 and 32 ng/mL, and sufficiency as above 32 ng/mL. They supported the rationale for these definitions as being multifactorial and supported by studies highlighting improved bone health with vitamin D values above 20 ng/mL and increased calcium absorption in the intestines when vitamin D levels increased between 20 and 32 ng/mL.<sup>15,26</sup> A threshold of 20 ng/mL for vitamin D deficiency was also supported by a 2011 report by the Institute of Medicine.<sup>36</sup>

Statistical analysis was done to evaluate for correlation between player parameters and vitamin D level using Pearson correlation coefficients. Student *t* tests were used to evaluate the relationship between any player parameter and vitamin D status as 2 categories: sufficient or not sufficient. Analysis of variance (ANOVA) and Tukey post hoc tests were used to evaluate the relationship between any player parameter and vitamin D status as 3 categories: deficient, insufficient, or sufficient.

## RESULTS

A total of 279 players were included in the statistical analysis. Among all players, the mean player age ( $\pm$ SD) was  $21.5 \pm 1.3$  years (range, 18.7-27.3 years), mean player height was  $77.7 \pm 3.3$  inches (range, 68.8-85.3 inches), mean player weight was  $216.4 \pm 25.3$  lbs (range, 163.6-302.6 lbs), mean player BMI was  $25.2 \pm 1.9$  kg/m<sup>2</sup> (range, 20.2-32.7 kg/m<sup>2</sup>), and mean vitamin D level was  $25.6 \pm 10.2$  ng/mL (range, 10.5-68.5 ng/mL) (Table 1).

There were 90 players (32.3%) who were vitamin D deficient (<20 ng/mL). Among those players, the mean vitamin D level was  $16.1 \pm 2.1$  ng/mL (range, 10.5-19.8 ng/mL), mean age was  $21.3 \pm 1.3$  years (range, 18.7-24.3 years), mean height was  $76.9 \pm 3.3$  inches (range, 69.5-85.3 inches), mean weight was  $211.2 \pm 25.3$  lbs (range, 163.6-301.8 lbs), and mean BMI was  $25.0 \pm 1.9$  kg/m<sup>2</sup> (range, 20.7-32.7 kg/m<sup>2</sup>) (Table 2).

There were 131 players (47.0%) who were vitamin D insufficient (between 20 and 32 ng/mL). Among those players, the mean vitamin D level was  $25.0 \pm 3.4$  ng/mL, mean age was  $21.6 \pm 1.3$  years (range, 18.8-27.3 years), mean height was  $77.6 \pm 3.3$  inches (range, 68.8-83.8 inches), mean weight was  $216.7 \pm 25.5$  lbs (range, 166.2-302.6 lbs), and mean BMI was  $25.3 \pm 2.1$  kg/m<sup>2</sup> (range, 20.2-32.6 kg/m<sup>2</sup>) (Table 2).

There were 58 players (20.8%) who were vitamin D sufficient (>32 ng/mL). Among those players, the mean

TABLE 1  
Player Parameters (N = 279 Players)<sup>a</sup>

Vitamin D level, ng/mL	25.6 ± 10.2 (10.5-68.5)
Age, y	21.5 ± 1.3 (18.7-27.3)
Height, in	77.7 ± 3.3 (68.8-85.3)
Weight, lbs	216.4 ± 25.3 (163.6-302.6)
BMI, kg/m <sup>2</sup>	25.2 ± 1.9 (20.2-32.7)

<sup>a</sup>Data are provided as mean ± SD (range). BMI, body mass index.

TABLE 2  
Player Parameters for Each Category of Vitamin D Status<sup>a</sup>

	Vitamin D Status			P Value (ANOVA)
	Deficient (<20 ng/mL)	Insufficient (20-32 ng/mL)	Sufficient (>32 ng/mL)	
Players, n (%)	90 (32.3)	131 (47)	58 (20.8)	
Vitamin D level, ng/mL	16.1 ± 2.1	25.0 ± 3.4	41.6 ± 8.6	
Age, y	21.3 ± 1.3	21.6 ± 1.3	21.8 ± 1.3	.136
Height, in	76.9 ± 3.3	77.6 ± 3.3	78.9 ± 2.8	<b>.001</b>
Weight, lbs	211.2 ± 25.3	216.7 ± 25.5	224.1 ± 23.2	<b>.009</b>
BMI, kg/m <sup>2</sup>	25.0 ± 1.9	25.3 ± 2.1	25.2 ± 1.8	.65

<sup>a</sup>Data are provided as mean ± SD unless otherwise indicated. Boldfaced P values indicate statistically significant difference across the 3 groups. ANOVA, analysis of variance; BMI, body mass index.

vitamin D level was 41.6 ± 8.6 ng/mL (range, 32.1-68.5 ng/mL), mean age was 21.8 ± 1.3 years (range, 19.2-25.0 years), mean height was 78.9 ± 2.8 inches (range, 71.3-83.8 inches), mean weight was 224.1 ± 23.2 lbs (range, 175.4-280.0 lbs), and mean BMI was 25.2 ± 1.8 (range, 21.5-30.6) (Table 2).

Pearson correlation coefficients were used to assess for correlations between vitamin D level and each player parameter. Vitamin D level positively but weakly correlated with both height ( $r = 0.19$ ,  $P = .002$ ) and weight ( $r = 0.15$ ,  $P = .012$ ) but not with age ( $r = 0.07$ ,  $P = .26$ ) or BMI ( $r = 0.03$ ,  $P = .61$ ).

When categorizing vitamin D status as either sufficient (n = 58) or not sufficient (n = 221 for both insufficient and deficient), *t* tests showed a significant difference between the 2 groups in terms of height ( $P = .0008$ ) as well as weight ( $P = .009$ ). However, BMI and age did not significantly differ between the 2 groups ( $P = .77$  and  $.15$ , respectively). When categorizing vitamin D status as 3 separate groups (deficient, insufficient, or sufficient), ANOVA similarly showed that a significant difference exists between height ( $P = .001$ ) and weight ( $P = .009$ ) across the 3 groups. BMI and age again did not significantly differ between the 3 groups ( $P = .65$  and  $.136$ , respectively) (Table 2). Tukey post hoc testing with alpha set at 0.05 for height further showed that the sufficient group significantly differed from both the insufficient (95% CI, 0.2-2.5) and deficient (95% CI, 0.7-3.3)

groups. Height did not differ between the insufficient and deficient groups (95% CI, -0.4 to 1.7). In terms of weight, Tukey post hoc testing with alpha set at 0.05 showed the sufficient group significantly differed from the deficient group (95% CI, 3.0-22.8) but not the insufficient group (95% CI, -1.9 to 16.7). Similar to height, weight also did not differ significantly between the insufficient and deficient groups (95% CI, -2.5 to 13.6).

## DISCUSSION

There exists a high prevalence of vitamin D deficiency and insufficiency among participants in the NBA Combines. A total of 79.3% of players in this study fit into either of these 2 categories. While it is difficult to accurately compare with the general population as there is variation in the prevalence of vitamin D deficiency among US adults, the prevalence of our study may indicate a similarly high prevalence of vitamin D deficiency in athletes compared with the US population.<sup>15</sup> The potential for vitamin D deficiency among elite athletes of this caliber should therefore be of consideration in their medical evaluation. Since the participants in this study had not yet entered the NBA, the results of this investigation should particularly alert the physician caring for elite athletes in the high school and collegiate settings.

The results of this study reflect similar findings in a study of players in the NFL by Maroon et al.<sup>26</sup> They found 21 of 80 athletes (26.3%) to be vitamin D deficient and 34 of 80 athletes (42.5%) to be vitamin D insufficient, totaling 55 of 80 athletes (68.8%) who were either deficient or insufficient. While we found a statistical correlation between both height and weight with vitamin D sufficiency, BMI and age did not correlate with vitamin D sufficiency. Maroon et al did not evaluate for player height, weight, or BMI, but they similarly found no correlation between player age and vitamin D status.

There has been prior research on the correlation between a person's height and weight and their vitamin D level. Kremer et al<sup>23</sup> linked decreased height with decreased vitamin D levels, which was similarly found in our work. In terms of the correlation between vitamin D and a person's weight, multiple studies have found that vitamin D deficiency is more prevalent among obese individuals.<sup>23,32</sup> It is thought that this effect is due to the role of vitamin D in limiting adipogenesis.<sup>22</sup> Converse to this finding, our work showed a positive relationship between increased weight and increased vitamin D level. While the mean BMI in our study population was 25.2 kg/m<sup>2</sup>, which would classify them as overweight (overweight defined as BMI 25.0-29.9 kg/m<sup>2</sup>),<sup>21</sup> we did not evaluate for the individual effects of muscle mass or body fat percentage on a player's overall weight in our analysis. If vitamin D has positive effects on muscle,<sup>33</sup> then it is possible that our findings regarding the significant relationship between vitamin D and weight might be attributable to the potential higher muscle mass in our population of elite athletes. Without controlling for the individual components adding up to a player's weight, it is difficult to ascertain the implications of our findings

regarding the correlation between weight and vitamin D level. This requires further investigation.

Many factors play a role in the level of vitamin D in any given population of subjects at any given time.<sup>19</sup> This is due to several reasons. First, there is no single method to measure vitamin D. Different techniques include radioimmunoassay, enzyme-linked assay, and liquid chromatography with mass spectrometry.<sup>4</sup> Also, the effects of seasonal variation and subsequent sunlight exposure play an important role. Sunlight exposure can quickly increase vitamin D levels, and a significant amount of active vitamin D circulating in the body is a result of sunlight exposure.<sup>20</sup> Likely as a result of sunlight exposure, the effect of seasonal variation further makes it difficult to assess one's vitamin D level. Elite ballet dancers had a 9-ng/mL difference in vitamin D level depending on whether the level was measured in summer versus winter.<sup>40</sup> Similarly, vitamin D levels varied significantly among athletes in the English Premier League depending on the season during which the levels were measured.<sup>30</sup> Not only does the NBA Combine typically occur at the end of spring, but basketball at this level of play predominately occurs indoors. It is therefore difficult to say whether the results of our study would reflect the same findings if the combine were to occur at another time of the year or if the NBA played its games outdoors.

The difficulties of measuring vitamin D carry over to the lack of a standard definition of *normal*.<sup>19</sup> The cause for variation mentioned previously, such as a lack of a standard measuring technique and the effect of sunlight exposure and seasonal variation, have led several organizations to adopt different definitions of vitamin D deficiency, insufficiency, and sufficiency. We based our definition of vitamin D categories on that given by Maroon et al<sup>26</sup> because those authors similarly investigated athletes in a professional setting. Maroon et al found 68.8% of NFL athletes from a single team to either be vitamin D deficient or insufficient.<sup>26</sup> This is similar to the results of our study, in which 79.3% fell into 1 of those 2 categories. Although difficult to compare with the normal adult population because of all the factors that influence vitamin D, this number is strikingly high considering there may be structural and performance implications on the athlete. The study by Maroon et al<sup>26</sup> found, although not significant, a trend of increased bone fractures among athletes with lower vitamin D levels. Furthermore, they linked lower vitamin D levels to a risk of off-season termination as well as playing less seasons professionally. While it is difficult to link vitamin D level to athletic performance in this capacity, it does merit consideration.

There are several limitations to this study. First, the lack of a standard definition of normal and the effect on seasonal variation make it difficult to assume that our findings might not differ if measured during a different time of year or using a different definition of abnormal vitamin D levels. Also, we were not able to evaluate for several player factors that might alter the vitamin D levels. For instance, we did not have access to the players' geographic locations of either high school or collegiate play prior to entering the combines or the location in which the player trained immediately prior to the combine. Differences in sunlight exposure

might alter the results of this study. Also, player factors, including prior vitamin supplementation and race, were not evaluated because race was not included in the available deidentified information. Maroon et al<sup>26</sup> cited significant differences in vitamin D levels among different races, and such a correlation may or may not exist in this study's population. Future work is needed to investigate the above factors.

This study, to the best of our knowledge, provides the first report on the prevalence of vitamin D deficiency and insufficiency among athletes of the NBA Combine. In the future, there is a need for continued investigation into the potential effects of vitamin D on clinical factors pertinent to this professional athletic population.

## CONCLUSION

There is a high prevalence of vitamin D deficiency and insufficiency among players in the NBA Combine. Such deficiency and insufficiency should be considered during medical evaluation of elite athletes at the high school, collegiate, and professional levels to improve the overall quality of care for our players. There is a need for continued investigation into the potential clinical effects of vitamin D deficiency and insufficiency among NBA athletes.

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