



Prevalence of and Risk Factors for Hypovitaminosis D in Patients with Rotator Cuff Tears

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Background: It has been reported that vitamin D may play an important role in rotator cuff tears. However, there has been limited information about the prevalence of and risk factors for hypovitaminosis D in patients with rotator cuff tears. Therefore, the purpose of current study was to investigate the prevalence of and risk factors for hypovitaminosis D in patients with rotator cuff tears.

Methods: One hundred seventy-six patients (age, 61.9 ± 8.90 years) who underwent arthroscopic rotator cuff repair for a full-thickness tear were enrolled in this retrospective study. Preoperative serum vitamin D levels (25-hydroxyvitamin D) were measured. Hypovitaminosis D was defined as a serum concentration of 25-hydroxyvitamin D < 20 ng/mL. We investigated whether age, sex, height, weight, body mass index, bone mineral density, alcohol consumption, smoking status, and outdoor occupation were associated with hypovitaminosis D.

Results: The prevalence of hypovitaminosis D in patients with rotator cuff tears was 44.3% (78/176). The mean serum concentration of 25-hydroxyvitamin D of total patients was 24.7 ± 13.7 ng/mL. A higher serum level of vitamin D was significantly associated with older age ($p < 0.001$). Young age was an independent risk factor for hypovitaminosis D. The prevalence of hypovitaminosis D was also lower in patients with an outdoor occupation than in those with an indoor occupation (19.0% vs. 31.4%, $p = 0.001$).

Conclusions: The prevalence of hypovitaminosis D in patients with rotator cuff tears was 44.3%. Age had a significant positive correlation with the serum concentration of 25-hydroxyvitamin D. Young age and indoor working were independent risk factors for hypovitaminosis D in patients with rotator cuff tears. Therefore, the possibility of hypovitaminosis D should be considered for young and indoor working patients who have rotator cuff tears.

Keywords: Vitamin D, Vitamin D deficiency, 25-Hydroxyvitamin D, Rotator cuff, Risk factors

Vitamin D deficiency is known to affect more than 1 billion people worldwide.¹⁾ In the USA, its prevalence has been reported to be 40%.²⁾ Recently, vitamin D deficiency in Asian

countries has been the focus of attention because it has been reported to have a prevalence of up to 70%. Vitamin D deficiency in Asian countries seems to be more serious than that in western countries.^{3,4)} Based on the Korea National Health and Nutrition Examination Survey (KNHANES), there has been a gradual increase in the prevalence of vitamin D deficiency in the Korean population over time.⁴⁾

Vitamin D plays an important role in the musculoskeletal system, as it affects the regulation of bone health, fracture healing, and soft-tissue healing and function.⁵⁾ Recent studies have shown that low levels of vitamin D have negative effects on articular cartilage.⁵⁻⁸⁾ Several studies have reported that sufficient vitamin D supplementation can increase upper and lower body muscle strength.⁹⁾ In par-

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ticular, in the elderly, vitamin D supplementation has been shown to reduce the risks of fragile fractures and falls.¹⁰⁾

The pathophysiologic role of vitamin D in the rotator cuff has been investigated in the context of shoulder disease.^{11,12)} In a rat model, low vitamin D levels were associated with healing failure of rotator cuff repair.¹²⁾ Vitamin D seemed to enhance rotator cuff healing, and it also increased bone mineral density (BMD) and strength of skeletal muscles.^{5,12)} Furthermore, a clinical study reported a significant negative correlation between vitamin D levels and fatty degeneration of rotator cuff muscles and a positive correlation between serum vitamin D and shoulder isokinetic muscle torque.¹¹⁾

Several studies have reported risk factors of hypovitaminosis D.^{1,2,4,13-16)} Age, degree of sun exposure, race, and/or body mass index (BMI) have all been reported to affect the prevalence of hypovitaminosis D.^{1,2,13,14)} Little exposure to sunlight is a known risk factor of hypovitaminosis D, but the effect of age has not been firmly established. Furthermore, these known risk factors of hypovitaminosis D have not been thoroughly investigated in patients with a rotator cuff tear. Proper evaluation and supplementation of vitamin D deficiency are clinically important to achieve satisfactory results of rotator cuff repair.

The prevalences of hypovitaminosis D in patients who have undergone orthopedic surgery have been reported. High prevalences of hypovitaminosis D have been demonstrated in patients who underwent foot, ankle, or spine operations or joint arthroplasty. However, information about hypovitaminosis D in patients with rotator cuff tears is limited. Therefore, the purpose of the current study was to investigate the prevalence of and risk factors for hypovitaminosis D in patients with rotator cuff tears.

METHODS

A retrospective review was conducted on all patients with a full-thickness rotator cuff tear, who underwent arthroscopic rotator cuff repair by a single surgeon (JHY) at a single institution between December 1, 2017, and July, 31, 2019. Exclusion criteria were a partial thickness rotator cuff tear, calcific tendinitis without a rotator cuff tear, use of vitamin D supplements, and the presence of hyper- or hypoparathyroidism. We conducted this study in compliance with the principles of the Declaration of Helsinki. The protocol of this study was reviewed and approved by the Institutional Review Board of Dongguk University Ilan Hospital (IRB No. DUIH 2020-03-029). The informed consent was waived.

Patient Demographics

A total of 176 patients (mean age, 61.9 ± 8.9 years) who underwent arthroscopic rotator cuff repair due to a full thickness tear were evaluated. To identify risk factors for hypovitaminosis D, demographic and preoperative variables were recorded through electronic health record review. The variables included age, sex, height, weight, BMI, alcohol consumption, current smoking status, supplementation of vitamin D prior to serum test, outdoor worker, and BMD (Table 1). BMD was measured using dual energy X-ray absorptiometry. Patients were considered to be alcohol consumers if they consumed alcohol more than 3 times a week. Current smokers were defined as being nicotine dependent at 6 months before surgery. Vitamin D supplementation was considered positive if it was documented in medical records during 6 months prior to serum vitamin D testing.

Vitamin D Evaluation

Preoperative serum 25-hydroxyvitamin D levels were collected from our hospital laboratory for all patients who underwent arthroscopic rotator cuff repair. Hypovitaminosis D was defined as a serum concentration of 25-hydroxyvitamin D less than 20 ng/mL.^{1,17)}

Statistical Analysis

Univariate analysis was conducted to identify possible risk factors for hypovitaminosis D. The variables included in the analysis were age, sex, height, weight, BMI, alcohol consumption, current smoking status, outdoor working, and BMD. For univariate analysis, simple regression analy-

Table 1. Patient Demographics

Variable	Value (n =176)
Age (yr)	61.9 ± 8.9 (37 to 82)
Sex	
Male	82 (46.6)
Female	94 (53.4)
Height (cm)	159.9 ± 9.62 (139.9 to 185.5)
Weight (kg)	64.9 ± 10.6 (40.2 to 89.8)
Body mass index (kg/m ²)	40.5 ± 5.2 (26.9 to 51.7)
Alcohol consumer	58 (33.3)
Current smoker	41 (23)
Outdoor worker	48 (27.3)
Bone mineral density	-1.18 ± 1.18 (-4.9 to 1.9)

Values are presented as mean ± standard deviation (range) or number (%).

sis was used for continuous variables and the chi-square test for categorical variables. Multivariate analysis was conducted using a logistic regression model to evaluate the collective influences of covariates. Statistical analyses were performed with IBM SPSS ver. 22.0 (IBM Corp., Armonk, NY, USA). A p -value < 0.05 was considered to be statistically significant.

Table 2. Prevalence of Hypovitaminosis D in Patients with Rotator Cuff Tears

Vitamin D	Value (n = 176)
Sufficient (> 30 ng/mL)	51 (29.0)
Insufficient (20–30 ng/mL)	47 (26.7)
Deficient (< 20 ng/mL)	78 (44.3)

Values are presented as number (%). Hypovitaminosis D was defined as a serum concentration of 25-hydroxyvitamin D less than 20 ng/mL.

Table 4. Effects of Variables on Hypovitaminosis D

Variable	25(OH)D ₃ < 20 ng/mL	25(OH)D ₃ ≥ 20 ng/mL	p -value
Age (yr)			0.006
< 50 (n = 18)	14 (77.8)	4 (22.2)	
50–59 (n = 49)	25 (51.0)	24 (49.0)	
60–69 (n = 70)	26 (37.1)	44 (62.9)	
≥ 70 (n = 39)	13 (33.3)	26 (66.7)	
Sex			0.544
Male (n = 82)	34 (41.5)	48 (58.5)	
Female (n = 94)	44 (46.8)	50 (53.2)	
Alcohol consumption			0.544
Alcohol consumer (n = 58)	28 (68.3)	30 (51.7)	
Non-alcohol consumer (n = 118)	50 (42.4)	68 (57.6)	
Current smoking status			0.858
Smoker (n = 41)	19 (46.3)	22 (53.7)	
Nonsmoker (n = 135)	59 (43.7)	76 (56.3)	
Outdoor working			0.001
Outdoor worker (n = 58)	11 (36.2)	37 (63.8)	
Indoor worker (n = 118)	37 (48.3)	61 (51.7)	

Values are presented as number (%). Hypovitaminosis D was defined as a serum concentration of 25(OH)D₃ less than 20 ng/mL. 25(OH)D₃: 25-hydroxyvitamin D.

RESULTS

Prevalence of Hypovitaminosis D

Among the 176 patients, the mean serum concentration of 25-hydroxyvitamin D was 24.7 ± 13.7 ng/mL: 51 (29.0%) were vitamin D sufficient (> 30 ng/mL), 47 (26.7%) were vitamin D insufficient (20–30 ng/mL), and 78 (44.3%) were deficient (< 20 ng/mL). The prevalence of hypovitaminosis D in all patients with rotator cuff tears was 44.3% (78/176).

Table 3. Serum Concentration of 25(OH)D₃ According to Age

Age	Concentration of 25(OH)D ₃ (ng/mL)	p -value
< 50 yr (n = 18)	18.0 ± 5.8	< 0.001
50–59 yr (n = 49)	21.8 ± 10.0	
60–69 yr (n = 70)	24.2 ± 10.5	
≥ 70 yr (n = 39)	32.5 ± 20.7	

Values are presented as mean \pm standard deviation. Hypovitaminosis D was defined as a serum concentration of 25(OH)D₃ less than 20 ng/mL. 25(OH)D₃: 25-hydroxyvitamin D.

(Table 2). The serum concentration of 25-hydroxyvitamin D was significantly greater in the older group ($p < 0.001$) (Table 3). The prevalence of hypovitaminosis D significantly decreased with age ($p = 0.006$) (Table 4).

Risk Factors for Hypovitaminosis D

For continuous variables such as age, height, weight, BMI, and BMD, simple regression analysis was conducted. Age and BMD were significantly associated with serum concentration of 25-hydroxyvitamin D ($p < 0.001$ and $p = 0.008$, respectively). However, height, weight, and BMI were not significantly associated with serum concentration of 25-hydroxyvitamin D ($p = 0.232$, $p = 0.388$, and $p = 0.556$, respectively). Multivariate linear regression analysis showed that only younger age was an independent risk factor for a lower serum 25-hydroxyvitamin D level (β coefficient = 0.533, $p < 0.001$). Age and 25-hydroxyvitamin D level were found to be positively correlated.

For categorical variables such as age, sex, alcohol consumption, current smoking status, and outdoor working, Chi-square tests were conducted to identify the risk factors for hypovitaminosis D. Sex, alcohol consumption, and current smoking were not significantly associated with the presence of hypovitaminosis D (Table 4). However, older age and indoor working were significantly associated with the higher prevalence of hypovitaminosis D ($p = 0.006$ and $p = 0.001$, respectively). Multivariate analysis using logistic regression model for all risk factors (age, sex, height, weight, BMI, alcohol consumption, current smoking status, outdoor working, and BMD) was performed. The multivariate logistic regression analysis showed that only age and indoor working were independent variables for hypovitaminosis D (odds ratio = 0.939, $p = 0.001$; odds ratio = 3.228, $p = 0.003$, respectively) (Table 5). Therefore, young age and indoor workers were independent risk factors for hypovitaminosis D in patients with rotator cuff tears.

Table 5. Multivariate Analysis: Risk Factors for Hypovitaminosis D

Risk factor	Odds ratio (95% CI)	<i>p</i> -value
Age	0.939	0.001
Indoor worker	3.228	0.003

Hypovitaminosis D was defined as a serum concentration of 25-hydroxyvitamin D less than 20 ng/mL.
CI: confidence interval.

DISCUSSION

In this study, the prevalence of hypovitaminosis D in all patients with rotator cuff tears was 44.3% (78/176). Among 176 patients, 51 (29.0%) were vitamin D sufficient (> 30 ng/mL), 47 (26.7%) were vitamin D insufficient (20–30 ng/mL), and 78 (44.3%) were vitamin D deficient (< 20 ng/mL). Vitamin D deficiency is known to affect more than 1 billion people worldwide.¹⁾ In the United States, the prevalence of hypovitaminosis D has been reported to be 40%.²⁾ Its prevalence in Asian countries has been reported to be up to 70%, and vitamin D deficiency in Asian countries seems to be more serious than that in western countries.^{3,4)} A previous study based on KNHANES has reported that the prevalence of hypovitaminosis D gradually increased over time.⁴⁾

Vitamin D is synthesized in the human body under the influence of ultraviolet B light, which can convert 7-dehydrocholesterol to pre-vitamin D in cutaneous tissue. The pre-vitamin D is then transported to the liver and converted to 25-hydroxyvitamin D. Then, the 25-hydroxyvitamin D is converted to 1,25-dihydroxyvitamin D (active form of vitamin D), predominantly in the kidney.^{5,18-20)} Vitamin D is mostly acquired by cutaneous synthesis with help of ultraviolet B exposure. Dietary absorption of vitamin D is limited.⁴⁾ Lifestyle changes in modern environments, which include indoor lifestyles, have resulted in an increasing prevalence of vitamin D deficiency.

Information about hypovitaminosis D in patients with rotator cuff tears is limited. As far as author's knowledge, there have been only 2 studies regarding the prevalence of hypovitaminosis D and serum concentration of 25-hydroxyvitamin D in patients with rotator cuff tears.^{11,21)} Oh et al.¹¹⁾ reported the prevalence of hypovitaminosis D among patients with full-thickness rotator cuff tears (mean age: 61.3 years) was 51.3% and the mean serum concentration was 44.02 ± 20.26 ng/mL. Ryu et al.²¹⁾ reported the prevalence in patients with full-thickness rotator cuff tears (mean age: 57.5 ± 4.3 years) was 88% and the serum concentration was 13.82 ± 6.61 ng/mL. In the current study, the prevalence of hypovitaminosis D (25-hydroxyvitamin D < 20 ng/mL) in patients with full thickness rotator cuff tears (mean age: 61.9 ± 8.9 years) was 44.3%, and the mean serum concentration was 24.7 ± 13.7 ng/mL. Compared with the prevalence of hypovitaminosis D in the general population of South Korea (male: 75.2%, female: 82.5%), its prevalence in patients with rotator cuff tears as determined in the current study was relatively low (44.3%). However, the percentage of outdoor workers in the present study was 33.0% (58/176), which is higher than in

the general population. Heavy laborers, who mostly have outdoor jobs, are usually susceptible to rotator cuff tears.²²⁾ Therefore, the higher ratio of outdoor workers in the study population might be one of the reasons the prevalence of hypovitaminosis D was lower in the patients with rotator cuff tears than in the normal population.

In addition, our results showed that age was an independent variable for serum 25-hydroxyvitamin D level. Age and 25-hydroxyvitamin D level were positively correlated. Young age and indoor working were independent risk factors for hypovitaminosis D in patients with rotator cuff tears. Physiologically, vitamin D levels are known to decrease with increasing age.¹⁵⁾ Aging is possibly associated with hypovitaminosis D for 2 reasons. One reason is that aging causes decreased synthesis of vitamin D at cutaneous tissue. The other reason is that the elderly are less active and have decreased mobility, hence the possibility of sun exposure decreases.²⁾ Contrary to the physiologic mechanism, however, recent studies have reported that the prevalence of hypovitaminosis D decreases with age.^{2,4)} Parva et al.²⁾ analyzed 4,962 American participants aged ≥ 20 years hospitalized between 2011 and 2012 and found that the prevalence of vitamin D deficiency decreased with age. Park et al.⁴⁾ performed an observational study based on KNHANES data of 39,759 patients collected from 2008 to 2014 and confirmed the prevalence of vitamin D decreased with age, which is also in accord with our results.

There may be several factors associated with the lower prevalence of hypovitaminosis D in elderly patients with rotator cuff tears. One primary factor that causes a decreased prevalence of hypovitaminosis D in the older population is vitamin D supplementation. Usually, elderly patients take vitamin D supplements for the prevention or treatment of osteoporosis. In the USA, the percentage of older adults who take vitamin D supplements has increased over time whereas the percentage of younger patients who use vitamin D supplementation has been relatively stable throughout the years.^{2,23)} The second factor is modern lifestyle and working environments. Lack of sunlight exposure is known as a risk factor for hypovitaminosis D because nearly 90% of vitamin D is synthesized in human body with help of sunlight.²⁴⁾ Our results also showed the same results. In the group of indoor workers, the prevalence of hypovitaminosis D was higher than that

in outdoor workers. Indoor working was an independent risk factor for hypovitaminosis D. The proportion of urban population in South Korea has increased.⁴⁾ At the same time, the proportion of people who have outdoor occupations, such as farmers, is decreasing in South Korea, especially in the relatively younger population.⁴⁾ The prevalence of hypovitaminosis D in the younger population is relatively high because younger patients have usually indoor lifestyle and are more likely to have indoor jobs, compared with the elderly.²⁵⁾ In addition, the aggressive use of sun blocks by young and middle-aged individuals, unlike the elderly, provides another explanation for the increasing incidence of hypovitaminosis D in relatively younger patients.²⁵⁾

The current study has several limitations. First, it is a retrospective study with a relatively small number of participants ($n = 176$). Second, we did not consider the effects of seasonal variations on vitamin D levels. Third, we did not investigate the effect of hypovitaminosis D on rotator cuff disease. Therefore, further study is needed to confirm the role of vitamin D in the pathogenesis of rotator cuff disease or the healing process of rotator cuff repair.

The prevalence of hypovitaminosis D in patients with rotator cuff tears was 44.3%. Age had a significant positive correlation with serum concentration of 25-hydroxyvitamin D. Young age and indoor working were independent risk factors for hypovitaminosis D in patients with rotator cuff tears. Therefore, the possibility of hypovitaminosis D should be considered for young and indoor working patients who have rotator cuff tears.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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