Low Serum Vitamin D Is Not Correlated With the Severity of a Rotator Cuff Tear or Retear After Arthroscopic Repair

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Low Serum Vitamin D Is Not Correlated With the Severity of a Rotator Cuff Tear or Retear After Arthroscopic Repair

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Background: Despite the essential role of vitamin D in muscle function, the prevalence of vitamin D deficiency has been reported to be very high. Recently, low vitamin D level was found to correlate with fatty degeneration of the rotator cuff tendon in humans and to negatively affect early healing at the rotator cuff repair site in an animal study. However, the effects of vitamin D level on severity of rotator cuff tear and healing after surgical repair have not been documented.

Purpose: To evaluate (1) the prevalence of vitamin D deficiency among patients who underwent arthroscopic repair for a full-thickness rotator cuff tear, (2) the relationship of vitamin D level with severity of the rotator cuff tear, and (3) surgical outcomes after repair.

Study Design: Cohort study; Level of evidence, 2.

Methods: A consecutive series of 91 patients (age, 50-65 years) who underwent arthroscopic rotator cuff repair for full-thickness, small-sized to massive tears were evaluated. Preoperative serum vitamin D levels (25-hydroxyvitamin) were analyzed to detect correlations with the features of a preoperative rotator cuff tear as well as postoperative structural and functional outcomes. All patients were followed clinically for a minimum of 1 year.

Results: Preoperative vitamin D levels were deficient (<20 ng/mL) in 80 subjects (88%), insufficient (20-30 ng/mL) in 8 subjects (9%), and normal (>30 ng/mL) in 3 subjects (3%). No correlation was found between preoperative tear size ($P = .23$), extent of retraction ($P = .60$), degree of fatty infiltration of each cuff muscle ($P > .50$ each), or the global fatty infiltration index ($P = .32$). Similarly, no correlations were detected between vitamin D level and postoperative Sugaya type ($P = .66$) or any of the functional outcome scores ($P > .50$ each).

Conclusion: Low serum vitamin D level was not related to tear size, extent of retraction, or the degree of fatty infiltration in cuff muscles. It also had no significant relationships with postoperative structural integrity and functional outcomes after arthroscopic repair. The results suggest that low serum vitamin D level is not a significant risk factor for the severity of rotator cuff tear or poor healing after repair.

Keywords: vitamin D; 25-hydroxyvitamin; calcifediol; rotator cuff; retear

A rotator cuff tear is a common shoulder lesion that causes pain and disability. Features of a rotator cuff tear, such as tear size, tear shape, extent of retraction, degree of fatty infiltration, and muscle atrophy, have been well documented in the literature.[11,15,16,21] Additionally, structural and functional outcomes after arthroscopic repair have been correlated with patient demographic information and preoperative cuff conditions.[10,30,33] However, these factors have not been considered in relation to serum vitamin D level.

Vitamin D plays a crucial role maintaining calcium and phosphate homeostasis.[2,3,5,18,31] It is mainly synthesized from the skin, where 7-dehydrocholesterol is converted to pre–vitamin D under ultraviolet radiation. This inactive product is converted to 25-hydroxyvitamin D (25(OH)D, calcifediol) in the liver, which is then converted to 1,25-dihydroxyvitamin D ($1,25(OH)_2D$) in the kidney.[18]

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Although 1,25-hydroxyvitamin D is the biologically active form, 25-hydroxyvitamin D is the major circulating form of vitamin D and is a barometer for vitamin D status in the body.[18,31] Serum 25-hydroxyvitamin D level has 4 categories: deficiency (<20 ng/mL), insufficiency (20-30 ng/mL), sufficiency (>30-<150 ng/mL), and intoxication (>150 ng/mL).[5,18,31] One billion people worldwide are vitamin D insufficient or deficient.[‖]

One of the target organs of vitamin D is skeletal muscle.[2,8,12,18,40,41] 25-Hydroxyvitamin D regulates intracellular accumulation of phosphate within muscle cells, which helps to maintain muscle function and metabolism.[2] 1,25-Hydroxyvitamin D binds to the vitamin D receptor (VDR),[12,40,41] which promotes gene transcription, leading to increased cell protein synthesis and growth of skeletal muscles.[8] Serum vitamin D deficiency is associated with degenerative change in type II muscle fibers, including the rotator cuff.[2,42] These muscles have enlarged interfibrillar spaces, fatty infiltration, fibrosis, and increased glycogen[2,42] and are prone to tear with poor healing after repair. Serum vitamin D level is negatively correlated with fatty degeneration of the rotator cuff muscle in human subjects[31] and may have a negative effect on early healing at rotator cuff repair sites in a rat model.[3] Despite the high prevalence of serum vitamin D deficiency and the possible negative effects on the rotator cuff muscle, few studies have considered vitamin D level in relation to a rotator cuff tear and healing after the repair.

The purpose of this study was to evaluate (1) the prevalence of vitamin D deficiency among patients who underwent arthroscopic repair for a full-thickness rotator cuff tear; (2) the relationships between serum vitamin D level and features of a rotator cuff tear, such as tear size, amount of retraction, and the degree of fatty infiltration; and (3) the relationships between serum vitamin D level and structural and functional outcomes after arthroscopic repair of torn tendons.

METHODS

Patient Selection

This study was approved by the institutional review board at the authors' institution. All patients who underwent arthroscopic repair for a full-thickness rotator cuff tear involving the supraspinatus and/or infraspinatus tendons from December 2011 to June 2013 with the following inclusion/exclusion criteria were included in this study. The inclusion criteria were (1) patients with rotator cuff tears with full-thickness, small-sized to massive tears preoperatively diagnosed by magnetic resonance imaging (MRI), (2) patients whose preoperative serum vitamin D level (25-hydroxyvitamin D, ng/mL) was known, (3) patients age 50 to 65 years, (4) patients who underwent an assessment of structural integrity by MRI at a minimum of 3 months postoperatively, and (5) patients who underwent an assessment of functional status 1 year after the surgery. The exclusion criteria were (1) patients without preoperative data on serum vitamin D level, (2) patients who had undergone partial repair of a torn rotator cuff, (3) patients who refused to undergo postoperative MRI, (4) patients who were lost to follow-up, and (5) patients who had additional trauma or other shoulder disease not related to the index surgery postoperatively. Initially, 109 patients met the inclusion criteria, and 18 were excluded (6 had no preoperative vitamin D level data, 4 had a partial repair, 4 refused the postoperative MRI, and 4 were lost to follow-up). Therefore, 91 patients were evaluated for this study.

The mean ± SD age of the patients was 57.5 ± 4.3 years, and the female to male ratio was 44:47. All patients were preoperatively diagnosed with a full-thickness rotator cuff tear by a standardized MRI examination with 1.5-T (Magnetom Vision and Sonata; Siemens Medical Systems) or 3.0-T (Signa HDxt 3.0T; General Electronic Healthcare) superconducting magnets. Rotator cuff tear size, the extent of retraction of the torn tendon, and the degree of fatty infiltration into each cuff muscle were assessed. Rotator cuff tear size was measured as the maximum anterior-to-posterior distance of the tear on an oblique sagittal view.[10] The amount of retraction of the torn tendon was measured as the maximum medial-to-lateral distance of the torn area on an oblique coronal view.[11] Fatty infiltration of the cuff was assessed for each muscle using Goutallier staging.[15,16] Demographic variables and features of the preoperative rotator cuff tears, including tear size, extent of retraction of the torn tendon, and the degree of fatty infiltration of cuff muscles from MRI, are summarized in Table 1.

Surgical Procedure

All surgeries were performed by a single surgeon with the patient in the lateral decubitus position. Routine arthroscopic surgical procedures were as follows. After the subacromial space was accessed, a partial bursectomy and debridement were performed to obtain a clear torn margin on the rotator cuff tendons. After adequate visualization of the torn cuff, features of the rotator cuff tear including tear size, shape, and the extent of retraction were identified. Mobility of the torn and retracted rotator cuff tendons was also evaluated for complete repairs. The cortical bone was debrided at the footprint to expose underlying cancellous bone. Care was taken to prevent excess bone loss at the greater tuberosity.

Arthroscopic rotator cuff repair was based on tear size. A single-row repair technique with 1 or 2 suture anchors (4.5-mm Bio-corkscrew FT suture anchor; Arthrex) was used for small-sized tears. A modified suture bridge technique was used for medium-sized to massive tears, as described in our earlier report, and was similar to the one described originally[22,23] but modified to prevent dog ear deformities, which frequently develop at the cuff margins. Additional suture anchors were used for complete repair in a few cases, such as with the 3 × 3 double-row suture bridge repair technique. The lateral row was fixed at the pilot hole created 2 cm distal to the lateral edge of the footprint using a push-lock device (3.5-mm Bio-PushLock; Arthrex) while maintaining adequate tension.

[‖]References 4, 5, 7, 9, 14, 17, 19, 25, 26, 28, 29, 36.

TABLE 1
Demographic and Preoperative MRI Features of the Patients[a]

Demographics (N = 91)		Preoperative MRI (N = 91)	
Age, y	57.5 ± 4.3	Tear size, cm	1.8 ± 1.1
Sex, female:male, n	44:47	Small, n	23
Time to operation, mo	7.0 ± 2.4	Medium, n	53
Acute:chronic:acute on chronic, n[b]	3:62:26	Large, n	13
Involved side, dominant:nondominant, n	65:26	Massive, n	2
Medical history, n		Extent of retraction, cm	1.7 ± 1.4
Diabetes mellitus	17	Degree of fatty infiltration[c]	
Hypertension	25	Supraspinatus	1.1 ± 1.0
Cerebrovascular accident	1	Infraspinatus	0.2 ± 0.5
Injury mechanism, n		Subscapularis	0.3 ± 0.6
Overuse	44	GFII[d]	0.5 ± 0.5
Trauma	40		
Sports	8		

[a]Values are mean ± SD for continuous variables. GFII, global fat infiltration index; MRI, magnetic resonance imaging.
[b]Acute, shoulder pain developed within 3 months. Chronic, shoulder pain for >3 months. Acute on chronic, recently aggravated shoulder pain within 3 months with chronic pain.
[c]Goutallier classification.
[d]The average of the Goutallier stages of the 3 tendons.

Concomitant procedures included acromioplasty (7 cases), distal clavicle resection (14 cases), and biceps procedure (tenotomy or tenodesis, 12 cases).

Evaluation of the Rotator Cuff in Relation to Serum Vitamin D Level

Serum vitamin D level (25-hydroxyvitamin D) was measured in all enrolled patients within 10 days before the surgery. Patients were grouped into 1 of the following categories: intoxication (>150 ng/mL), sufficiency (>30-<150 ng/mL), insufficiency (20-30 ng/mL), or deficiency (<20 ng/mL). The relationships between serum vitamin D level and patient age and bone mineral density (BMD, kg/cm^2) were analyzed. Differences were assessed by sex (female vs male).

We were interested in any significant relationships between serum vitamin D level and preoperative rotator cuff tear, the extent of retraction of the torn tendon, and the degree of fatty infiltration of the cuff muscles. Rotator cuff tear size was plotted with serum vitamin D level in a 2-dimensional plane to detect any significant correlation between the 2 variables. After the rotator cuff tear size was categorized (from small to massive tears), serum vitamin D levels were tested for differences between any of the 4 tear size groups. Similarly, the extent of retraction of the torn tendon was tested to identify any significant correlation with serum vitamin D level. The degree of fatty infiltration of each cuff muscle was assessed by the Goutallier stage and was tested to detect any significant difference with serum vitamin D level. Global fatty infiltration index (GFII), which was defined as the average of the Goutallier stages of the 3 tendons (supraspinatus, infraspinatus, and subscapularis), was calculated and tested to detect any significant correlation with serum vitamin D level.

All patients were evaluated for the structural integrity of the repaired tendon via MRI at a minimum of 3 months postoperatively. Postoperative rotator cuff integrity was categorized as types I through IV according to Sugaya et al[35]: type I, sufficient thickness compared with normal cuff with homogeneously low intensity on MRI; type II, sufficient thickness compared with normal cuff associated with partial high-intensity area on MRI; type III, insufficient thickness with less than half the thickness when compared with a normal cuff, but without discontinuity, suggesting a partial-thickness delaminated tear; type IV, presence of a minor discontinuity in only 1 or 2 slices on oblique coronal and sagittal images, suggesting a small full-thickness tear; and type V, presence of a major discontinuity observed in more than 2 slices on both oblique coronal and sagittal images, suggesting a medium or large full-thickness tear. The MRIs were interpreted by a single radiologist using a Picture Archiving and Communication System (PACS; Marosis; Infinitti) workstation. The radiologist was blinded to the serum vitamin D level of each patient. Serum vitamin D level was tested to detect any significant difference between the 5 Sugaya types. The mean ± SD time to undergo the postoperative MRI was 4.4 ± 1.4 months. The University of California, Los Angeles (UCLA) Shoulder Rating Scale,[10] Constant scores,[8,9] and the American Shoulder and Elbow Surgeons (ASES) Shoulder Score[36] were also evaluated for the functional assessment. All functional assessments were performed at a minimum 1 year postoperatively. The functional scores at 1 year postoperatively were tested for a correlation with serum vitamin D level. All patients were followed up clinically at a minimum of 2 years postoperatively (mean, 26.7 ± 4.3 months).

Postoperative Rehabilitation

All patients underwent a routine rehabilitation protocol under the guidance of the operating surgeon and the assistance of a shoulder physical therapist, both of whom were blinded to the serum vitamin D level of each patient. Sling

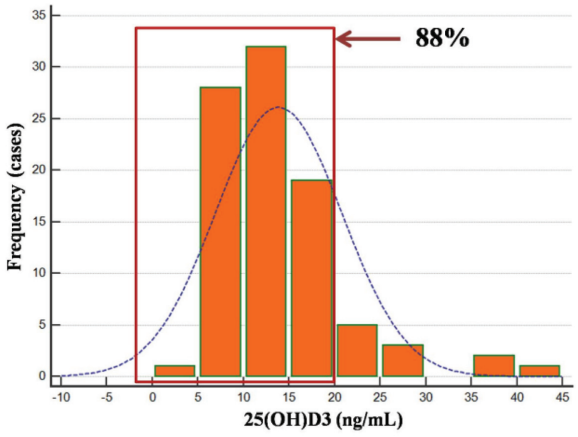

Figure 1. Levels of serum vitamin D (25-hydroxyvitamin D [25(OH)D]) in patients who underwent arthroscopic repair for a full-thickness rotator cuff tear showing that 88% of patients were vitamin deficient (arrow).

immobilization with a supporting abduction pillow was worn at all times for the first 6 weeks except during a shower or during rehabilitation exercise. The rehabilitation protocol consisted of 5 phases. Gentle range of motion (ROM) of the shoulder joint was allowed in phase I, including shrugging and pendulum exercises. The full ROM of the elbow and wrist and strengthening of the hand and grip of the affected side were allowed in this phase. Passive assisted ROM of the shoulder joint via pulley or bar exercise was started at the beginning of phase II (bar exercise was not allowed for patients with subscapularis repair for the first 6 weeks). These exercises were permitted only when tolerable. Active assisted ROM exercise was started gradually at the end of this phase. Scapular strengthening exercise was started with isometrics in phase III and advanced to Thera-Band exercises as tolerated while continuing the phase II exercises. Patients were allowed to lift light weight (up to 10 lb) and return to light sports activities during phase IV. Full sports activities were permitted as tolerated in phase V.

The rehabilitation schedule was dependent on each patient's rotator cuff tear size. For small to medium-sized tears, phase I was performed for the first 3 weeks postoperatively, phase II from 3 to 6 weeks, phase III from 6 weeks to 3 months, phase IV after 3 months, and phase V after 6 months. For large-sized to massive tears, phase I was performed for the first 6 weeks postoperatively followed by phase II from 6 to 8 weeks, phase III from 8 weeks to 3 months, phase IV after 3 months, and phase V after 6 months. However, the rehabilitation pace was adjusted individually by the senior surgeon depending on the patient's subjective feeling of pain and functional capability.

Statistical Analysis

All continuous variables were expressed as mean ± standard deviation, tested for normality using the Shapiro-Wilk test, and confirmed to be normally distributed. Correlation analyses of serum vitamin D level with other variables, such as age, bone mineral density (BMD), preoperative tear size, the extent of retraction, GFII, and postoperative functional scores, were conducted using the Pearson method. Differences in serum vitamin D levels between the sexes were tested with Student *t* test. Differences in serum vitamin D levels between the 4 tear size groups (categorized from small to massive), degree of fatty infiltration (Goutallier stage 0-4), and postoperative structural integrity (Sugaya type I-V) were tested with the Kruskal-Wallis test because of the insufficient number of cases for subgroups of each variable. MedCalc (version 11.6; MedCalc Software) and R (version 3.1.0, Comprehensive R Archive Network, GNU General Public License) were used for all statistical analyses.

TABLE 2
Distribution of Serum Vitamin D Levels in Patients (N = 91) Who Underwent Arthroscopic Rotator Cuff Repair

25-Hydroxyvitamin D	n (%)
Intoxication (>150 ng/mL)	0 (0)
Sufficiency (>30 ng/mL)	3 (3)
Insufficiency (20-30 ng/mL)	8 (9)
Deficiency (<20 ng/mL)	80 (88)

TABLE 3
Relationships Between Serum Vitamin D Levels and Patient Age, BMD, and Sex[a]

Correlation With 25-Hydroxyvitamin D	*P* Value
Age	.28
BMD, femur neck[b]	.48
BMD, L-spine[b]	.28
Sex Differences	**25-Hydroxyvitamin D, ng/mL**
Female	13.0 ± 8.4
Male	14.6 ± 5.2
P value[c]	.31

[a]Values are mean ± SD for continuous variables. BMD, bone mineral density.
[b]Correlation via Pearson correlation analysis.
[c]*P* value via Student *t* test.

RESULTS

The serum vitamin D levels in patients who underwent arthroscopic repair for a full-thickness rotator cuff tear were 13.82 ± 6.61 ng/mL (range, 4.0-41.0 ng/mL). Analysis showed that 80 patients (88%) were deficient and 8 (9%) were insufficient (Figure 1). Only 3 patients (3%) were in a vitamin D–sufficient state (Table 2). Serum vitamin D level was not correlated with patient age or BMD. No significant difference was found between women and men, although vitamin D levels tended to be higher in men (Table 3).

Serum vitamin D level was not correlated with rotator cuff tear size ($P = .23$) (Figure 2A). Serum vitamin D levels

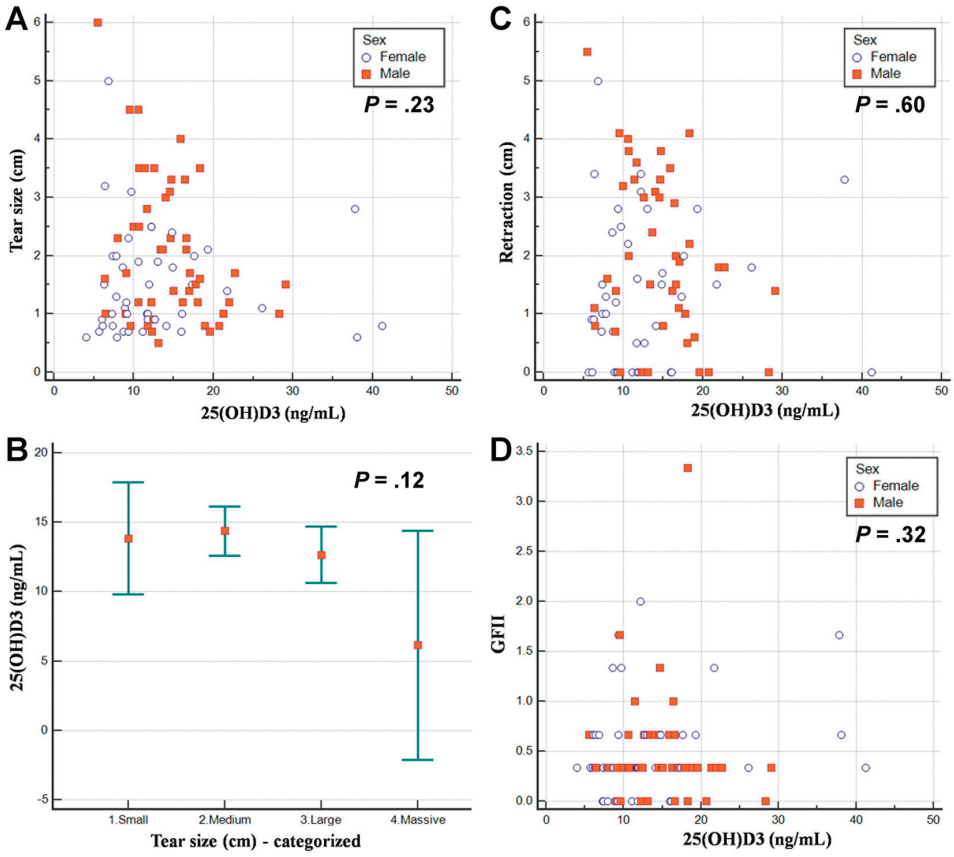

Figure 2. Plots showing the relationships between serum level of vitamin D (25-hydroxyvitamin D [25(OH)D3]) and tear size, extent of retraction, and degree of fatty infiltration of the rotator cuff muscles. (A) Scatter plot shows no correlation between 25(OH)D3 level and rotator cuff tear size. (B) Plot showing means with 95% confidence intervals of 25(OH)D3 levels depending on the tear size group. A decreasing tendency was observed without a significant difference. (Correlation analyses were done via Pearson method, and group comparisons were made via Kruskal-Wallis test.) (C) Scatter plot shows no correlation between 25(OH)D3 level and the extent of retraction of the torn tendon. (D) Scatter plot shows no correlation between 25(OH)D3 level and the global fat infiltration index (GFII), which is the average of the Goutallier stages of the 3 tendons.

were not different among the different tear size groups (P = .12). However, a decreasing trend was detected from medium-sized to massive tears (Figure 2B), which was not significant. Serum vitamin D level was not correlated with the extent of retraction of the torn tendon (P = .60) (Figure 2C). Vitamin D level showed no significant differences (P = .53 for supraspinatus, P = .92 for infraspinatus, and P = .87 for subscapularis) on the degree of fatty infiltration of each rotator cuff muscle classified by the Goutallier stage (Table 4). No correlation was found between vitamin D level and GFII (Figure 2D).

The relationships between serum vitamin D level and postoperative structural and functional outcomes were assessed and summarized (Table 5). Serum vitamin D level was not different between the postoperative Sugaya types (P = .66), although a lower vitamin D level tended to be observed in Sugaya types IV and V (Figure 3). The UCLA score, Constant score, and ASES score were not correlated with serum vitamin D level (P = .53, P = .70, and P = .68, respectively).

DISCUSSION

Our results show that low serum vitamin D level was not related to tear size, extent of retraction, or the degree of fatty infiltration of the rotator cuff. In addition, vitamin D level was not related to postoperative structural integrity and functional outcomes after arthroscopic repair of the torn tendons. However, low serum vitamin D level tended to be negatively associated with preoperative tear size (decreasing trend from medium-sized to massive tear) and postoperative structural integrity (lower vitamin D levels in Sugaya type IV and V), although these differences were not significant. Our study is the first to describe features of preoperative rotator cuff tears and structural and functional outcomes after arthroscopic repair in relation to serum vitamin D level.

The prevalence of deficiencies in serum vitamin D has been extensively investigated.[¶] Serum vitamin D level depends on several demographic factors, such as amount

[¶]References 4, 5-7, 9, 14, 17-19, 25-29, 36, 37.

TABLE 4
Relationships Between Serum Vitamin D Level and Degree of Fatty Infiltration of the Rotator Cuff Muscles[a]

Degree of Fatty Infiltration[b]	No. of Cases	25-Hydroxyvitamin D, mean ± SD, ng/mL	*P* Value[c]
Supraspinatus			.53
Grade 0	27	12.3 ± 5.6	
Grade 1	39	13.6 ± 7.1	
Grade 2	20	14.5 ± 7.0	
Grade 3	2	9.5 ± 0.3	
Grade 4	3	19.5 ± 15.9	
Infraspinatus			.92
Grade 0	81	13.7 ± 6.7	
Grade 1	8	14.3 ± 9.9	
Grade 2	1	14.7	
Grade 3	0	N/A	
Grade 4	1	13.8	
Subscapularis			.87
Grade 0	72	13.9 ± 7.4	
Grade 1	16	13.1 ± 4.9	
Grade 2	2	15.6 ± 8.6	
Grade 3	0	N/A	
Grade 4	1	18.3	

[a]N/A, not applicable.
[b]Goutallier classification.
[c]*P* value via Kruskal-Wallis test.

of sunlight exposure, geographic location of the subject, season when the level is measured, and patient age.[2,5,9,27] About 1 billion people worldwide are vitamin D insufficient or deficient,[#] and 40% to 100% of the US and European elderly population are vitamin D deficienct.[37] In addition, 42% of adolescent patients and 40% of preoperative orthopaedic surgery patients are vitamin D deficient.[6,18] In our study, 88% of the patients with shoulder pain and a full-thickness rotator cuff tear were vitamin D deficient, which was relatively high compared with results of other studies,[1,6,18,37] suggesting a positive relationship between low serum vitamin D level and rotator cuff tear. However, we have no evidence to show such a relationship because our study did not include subjects with an intact rotator cuff. We only showed a relatively high prevalence of serum vitamin D deficiency among patients with full-thickness rotator cuff tears. We also showed that serum vitamin D level was not correlated with patient age, BMD, or sex. These results may be due to the age limit of 50 to 65 years for our study subjects, which we used so we could exclude other possible factors influencing surgical outcome, such as poor bone quality, age-related degeneration and delamination of cuff tissues, and low rehabilitation compliance, which are more likely to occur in elderly patients.

Patients with a low serum vitamin D level may have more severe rotator cuff tear features. Vitamin D signaling via the VDR plays a role in regulating myoblast proliferation and differentiation,[12,39-41] and vitamin D deficiencies are associated with changes in muscle morphologic characteristics, such as opaque, ghostlike necrotic muscle fibers with enlarged interfibrillar spaces; infiltration of fat, fibrosis, and glycogen granules; and atrophy of type II muscle fibers.[2,24] Oh et al[31] reported that serum vitamin D level was negatively correlated with fatty degeneration of cuff muscle after they compared patients with full-thickness rotator cuff tears (228 cases) versus patients with other shoulder lesions without a tear (138 cases). However, the effects of the vitamin D remain inconclusive particularly in patients with a torn rotator cuff. Muscle biopsy specimens obtained from patients with low vitamin D levels in the study by Angeline et al[2] did not represent the rotator cuff muscle itself. Additionally, the correlation coefficients in the study

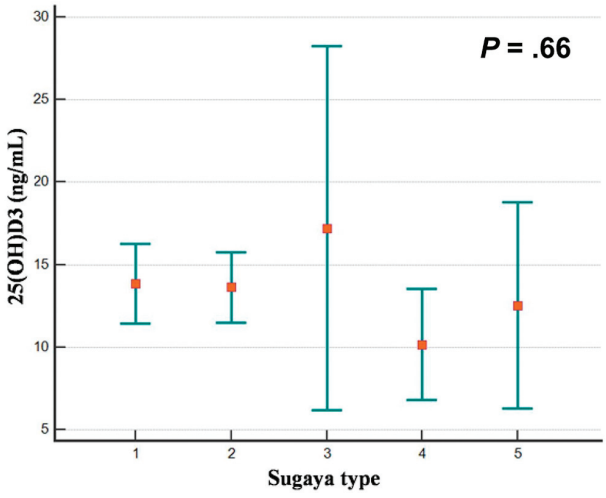

Figure 3. Plot showing means with 95% confidence intervals for level of vitamin D (25-hydroxyvitamin D [25(OH)D3]) and no significant differences (in group comparison via Kruskal-Wallis test) depending on Sugaya type.

[#]References 4, 5, 7, 9, 14, 17, 19, 25, 26, 28, 29, 36.

TABLE 5
Relationships Between Serum Vitamin D Level and Postoperative Structural and Functional Outcomes[a]

Structural Integrity	No. of Cases	25-Hydroxyvitamin D, mean ± SD, ng/mL	*P* Value
Sugaya type[b]			.66[c]
Type I	33	13.9 ± 6.9	
Type II	43	13.6 ± 7.0	
Type III	6	17.2 ± 10.5	
Type IV	3	10.2 ± 1.4	
Type V	5	12.5 ± 5.0	
Functional Outcome			
Correlation with 25-hydroxyvitamin D[c]			
UCLA score at 1 year			.53[d]
Constant score at 1 year			.70[d]
ASES score at 1 year			.68[d]

[a]ASES, American Shoulder and Elbow Society; UCLA, University of California, Los Angeles.
[b]Magnetic resonance imaging was conducted at a mean ± SD of 4.4 ± 1.4 months.
[c]*P* value via Kruskal-Wallis test.
[d]Correlation via Pearson correlation analysis.

by Oh et al[31] were too low (<0.3) to suggest clinical significance between low vitamin D level and fatty degeneration of cuff muscles. In our study, low serum vitamin D level was not related to tear size, extent of retraction of torn tendons, or the degree of fatty infiltration of each cuff muscle. We suggest that low serum vitamin D level is not a significant risk factor for rotator cuff tear severity.

Several studies have been conducted on the relationships between serum vitamin D level and muscle strength and function.[2,8,12,20,32] They reported that subjects with low serum vitamin D levels were more prone to have decreased quadriceps and grip strength, decreased physical performance (in athletes), changes in gait, inability to ascend stairs, diffuse muscle pain, leg heaviness, tiring easily, and difficulty in mounting stairs and rising from a chair.[2,3,8,13,34,38] Angeline et al[3] reported that low vitamin D levels may negatively affect early healing at the rotator cuff repair site after comparing rats with diet-induced vitamin D deficiency (28 cases) and rats with normal vitamin D levels (32 cases). However, no evidence has been provided on the relationship between serum vitamin D level and structural and functional outcomes after arthroscopic repair of a rotator cuff tear in humans. Vitamin D metabolism differs between rats and humans, and no clear correlation can be made with levels defined as insufficient or deficient in humans.[3] Our study was based on the acute repair model of a cut rotator cuff. We showed that low serum vitamin D level had no effects on postoperative structural integrity or functional outcomes after arthroscopic repair.

Several limitations should be mentioned. First, we analyzed only preoperative serum vitamin D levels, without considering several variables known to influence rotator cuff tears. Various factors influence the severity of rotator cuff tear preoperatively, such as patient age, underlying medical status, degree of overuse, trauma, and sports activities. Other factors influence postoperative structural and functional outcomes after repair, such as preoperative tear size, retraction, degree of fatty infiltration, surgical repair method, and postoperative rehabilitation. However, to exclude the effects of these factors, we enrolled only patients aged 50 to 60 years and those undergoing complete repair of torn tendons. This was done to eliminate other possible factors that could influence preoperative rotator cuff tear severity and the structural and functional outcomes after repair, such as poor bone quality, which may cause failure of the fixation construct; degeneration and delamination of cuff tissues, which occur in varying degrees; and low rehabilitation compliance, which is more likely to occur in elderly patients. We believe that our data are homogeneous and elicited the true effect of serum vitamin D level. Second, a small sample size results in inadequate statistical power and a large type II error. We enrolled 91 patients, but only 11 (12%) were not in a serum vitamin D–deficient state (88% of patients were vitamin D deficient). To determine the relationships between serum vitamin D level (sufficiency vs deficiency) and features of rotator cuff tears as well as healing status after repair, a certain number of patients with sufficient vitamin D level are required. Third, this study had a selection bias. Eighteen patients were excluded for several reasons. If they produced results different from those of the patients evaluated, it could bias our conclusion significantly. However, this study was based on surgery by a single surgeon, an identical laboratory evaluation of serum vitamin D levels, a uniform postoperative evaluation scheme for structural integrity, and functional assessment at the same time point postoperatively (1 year), which all may provide more authentic results. Fourth, only preoperative serum vitamin D level was measured. It may sound questionable to correlate preoperative vitamin D level with postoperative structural and functional outcomes. However, it is very likely that the patients maintained similar levels of serum vitamin D if any medical interventions were made postoperatively. Also, preoperative vitamin D level can influence postoperative healing by its effect on preoperative rotator cuff tear severity.

CONCLUSION

Low serum vitamin D level was not related to rotator cuff tear size, extent of retraction of the torn tendons, or the

degree of fatty infiltration of the cuff muscles. Serum vitamin D level was not related to postoperative structural integrity and functional outcomes after arthroscopic repair of torn tendons. Our result suggests that low serum vitamin D level is not a significant risk factor for rotator cuff tear severity or poor healing after arthroscopic repair. However, a larger scale, longer term follow-up study is required to confirm our results.

REFERENCES

1. Allison RJ, Farooq A, Hamilton B, Close GL, Wilson MG. No association between vitamin D deficiency and markers of bone health in athletes [published online July 23, 2014]. *Med Sci Sports Exerc*. doi:10.1249/MSS.0000000000000457.
2. Angeline ME, Gee AO, Shindle M, Warren RF, Rodeo SC. The effects of vitamin D deficiency in athletes. *Am J Sports Med*. 2013;41:461-464.
3. Angeline ME, Ma R, Pascual-Garrido C, et al. Effect of diet-induced vitamin D deficiency on rotator cuff healing in a rat model. *Am J Sports Med*. 2014;42:27-34.
4. Bakhtiyarova S, Lesnyak O, Kyznesova N, Blankenstein MA, Lips P. Vitamin D status among patients with hip fracture and elderly control subjects in Yekaterinburg, Russia. *Osteoporos Int*. 2006;17:441-446.
5. Bischoff-Ferrari HA, Giovannucci E, Willett WC, Dietrich T, Dawson-Hughes E. Estimation of optimal serum concentrations of 25-hydroxyvitamin D for multiple health outcomes. *Am J Clin Nutr*. 2006;84:18-28.
6. Bogunovic L, Kim AD, Beamer BS, Nguyen J, Lane JM. Hypovitaminosis D in patients scheduled to undergo orthopaedic surgery: a single-center analysis. *J Bone Joint Surg Am*. 2010;92:2300-2304.
7. Boonen S, Bischoff-Ferrari HA, Cooper C, et al. Addressing the musculoskeletal components of fracture risk with calcium and vitamin D: a review of the evidence. *Calcif Tissue Int*. 2006;78:257-270.
8. Cannell JJ, Hollis BW, Sorenson MB, Taft TN, Anderson JJ. Athletic performance and vitamin D. *Med Sci Sports Exerc*. 2009;41:1102-1110.
9. Chapuy MC, Preziosi P, Maamer M, et al. Prevalence of vitamin D insufficiency in an adult normal population. *Osteoporos Int*. 1997;7:439-443.
10. Choi S, Kim MK, Kim GM, Roh YH, Hwang IK, Kang H. Factors associated with clinical and structural outcomes after arthroscopic rotator cuff repair with a suture bridge technique in medium, large, and massive tears. *J Shoulder Elbow Surg*. 2014;23:1675-1681.
11. Davidson JF, Burkhart SS, Richards DP, Campbell SE. Use of preoperative magnetic resonance imaging to predict rotator cuff tear pattern and method of repair. *Arthroscopy*. 2005;21:1428-1429.
12. Geusens P, Vandevyver C, Vanhoof J, Cassiman JJ, Boonen S, Raus J. Quadriceps and grip strength are related to vitamin D receptor genotype in elderly nonobese women. *J Bone Miner Res*. 1997;12:2082-2088.
13. Girgis CM, Clifton-Bligh RJ, Turner N, Lau SL, Gunton JE. Effects of vitamin D in skeletal muscle: falls, strength, athletic performance and insulin sensitivity. *Clin Endocrinol (Oxf)*. 2014;80:169-181.
14. Glerup H, Mikkelsen K, Poulsen L, et al. Commonly recommended daily intake of vitamin D is not sufficient if sunlight exposure is limited. *J Intern Med*. 2000;247:260-268.
15. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures: pre- and postoperative evaluation by CT scan. *Clin Orthop Relat Res*. 1994;304:78-83.
16. Goutallier D, Postel JM, Gleyze P, Leguilloux P, Van Driessche S. Influence of cuff muscle fatty degeneration on anatomic and functional outcomes after simple suture of full-thickness tears. *J Shoulder Elbow Surg*. 2003;12(6):550-554.
17. Holick MF. High prevalence of vitamin D inadequacy and implications for health. *Mayo Clin Proc*. 2006;81:353-373.
18. Holick MF. Vitamin D deficiency. *N Engl J Med*. 2007;357:266-281.
19. Holick MF, Siris ES, Binkley N, et al. Prevalence of vitamin D inadequacy among postmenopausal North American women receiving osteoporosis therapy. *J Clin Endocrinol Metab*. 2005;90:3215-3224.
20. Janssen H, Samson MM, Verhaar H. Vitamin D deficiency, muscle function, and falls in elderly people. *Am J Clin Nutr*. 2002;75:611-615.
21. Kim JR, Cho YS, Ryu KJ, Kim JH. Clinical and radiographic outcomes after arthroscopic repair of massive rotator cuff tears using a suture bridge technique: assessment of repair integrity on magnetic resonance imaging. *Am J Sports Med*. 2012;40(4):786-793.
22. Kim KC, Rhee KJ, Shin HD. Deformities associated with the suture-bridge technique for full-thickness rotator cuff tears. *Arthroscopy*. 2008;24(11):1251-1257.
23. Kim KC, Rhee KJ, Shin HD, Kim YM. A modified suture-bridge technique for a marginal dog-ear deformity caused during rotator cuff repair. *Arthroscopy*. 2007;23(5):562-565.
24. Kim MK, Baek KH, Song KH, et al. Vitamin D deficiency is associated with sarcopenia in older Koreans, regardless of obesity: the Fourth Korea National Health and Nutrition Examination Surveys (KNHANES IV) 2009. *J Clin Endocrinol Metab*. 2011;96:3250-3256.
25. Larsen ER, Mosekilde L, Foldspang A. Vitamin D and calcium supplementation prevents osteoporotic fractures in elderly community dwelling residents: a pragmatic population-based 3-year intervention study. *J Bone Miner Res*. 2004;19:370-378.
26. Lips P. Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. *Endocr Rev*. 2001;22:477-501.
27. MacLaughlin L, Holick MF. Aging decreases the capacity of human skin to produce vitamin D3. *J Clin Invest*. 1985;76:1536-1538.
28. Malabanan A, Veronikis IE, Holick MF. Redefining vitamin D insufficiency. *Lancet*. 1998;351:805-806.
29. McKenna MJ. Differences in vitamin D status between countries in young adults and the elderly. *Am J Med*. 1992;93:69-77.
30. Millett PJ, Warth RJ, Dornan GJ, Lee JT, Spiegl UJ. Clinical and structural outcomes after arthroscopic single-row versus double-row rotator cuff repair: a systematic review and meta-analysis of level I randomized clinical trials. *J Shoulder Elbow Surg*. 2014;23(4):586-597.
31. Oh JH, Kin SH, Kim JH, Shin YH, Yoon JP, Oh CH. The level of vitamin D in the serum correlates with fatty degeneration of the muscles of the rotator cuff. *J Bone Joint Surg Br*. 2009;91:1587-1593.
32. Pfeifer M, Begerow B, Minne HW. Vitamin D and muscle function. *Osteoporos Int*. 2002;13:187-197.
33. Saridakis P, Jones G. Outcomes of single-row and double-row arthroscopic rotator cuff repair: a systematic review. *J Bone Joint Surg Am*. 2010;92(3):732-742.
34. Shuler FD, Wingate MK, Moore GH, Giangarra C. Sports health benefits of vitamin D. *Sports Health*. 2012;4:496-501.
35. Sugaya H, Maeda K, Matsuki K, Moriishi J. Functional and structural outcome after arthroscopic full-thickness rotator cuff repair: single-row versus dual-row fixation. *Arthroscopy*. 2005;21(11):1307-1316.
36. Thomas KK, Lloyd-Jones DM, Thadhani RI, et al. Hypovitaminosis D in medical inpatients. *N Engl J Med*. 1998;338:777-783.
37. van derWielen RP, Lowik MR, van den Berg H, et al. Serum vitamin D concentrations among elderly people in Europe. *Lancet*. 1995;346:207-210.
38. von Hurst PR, Beck KL. Vitamin D and skeletal muscle function in athletes. *Curr Opin Clin Nutr Metab Care*. 2014;17:539-545.
39. Wagatsuma A, Sakuma K. Vitamin D signaling in myogenesis: potential for treatment of sarcopenia. *Biomed Res Int*. 2014:121254. doi:10.1155/2014/121254.
40. Wang Y, DeLuca HF. Is the vitamin D receptor found in muscle? *Endocrinology*. 2011;152:354-363.
41. Wang Y, Zhu J, DeLuca HF. Where is the vitamin D receptor? *Arch Biochem Biophys*. 2012;523:123-133.
42. Yoshikawa S, Nakamura T, Tanabe H, Imamura T. Osteomalacic myopathy. *Endocrinal Jpn*. 1979;26:65-72.