

Original Article

Does vitamin D affect muscle strength and architecture? An isokinetic and ultrasonographic study

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Background and Objectives: The objective of this study was to explore the association between 25-hydroxyvitamin D (25(OH)D) and muscle strength/architecture. **Methods and study Design:** Thirty patients (27 women, 3 men) were allocated into Group I (n=15, mean age; 44.4±9.4 years) and Group II (n=15, mean age; 39.0±9.9 years) according to the median of 25(OH)D (<13.7 ng/mL vs >13.7 ng/mL, respectively). Peak torque/body weight of the knee flexor/extensor muscles at 60°/sec and 180°/sec and those of ankle flexor/extensor muscles at 30°/sec and 90°/sec were evaluated by using a Biodex System 3 Pro Multijoint System isokinetic dynamometer. A 7-12 MHz linear array probe was used to evaluate thickness (MT), pennation angle (PA) and fascicle length (FL) of medial gastrocnemius and vastus lateralis muscles. **Results:** Mean of 25(OH)D was 9.4±2.5 ng/mL and 20.7±8.3 ng/mL in Groups I and II, respectively. Although all isokinetic strength parameters were lower in Group I, significant differences were found in knee flexion at 180°/sec ($p=0.007$), knee extension at 30°/sec ($p=0.038$) and 180°/sec ($p=0.001$), and ankle extension at 30°/sec ($p=0.002$) and 90°/sec ($p=0.007$). On the other hand, no significant difference was found between the groups regarding MT, PA and FL values (all $p>0.05$). **Conclusion:** In light of our results, we can argue that 25(OH)D is associated with muscle strength but not with muscle architecture. Further studies concerning the long-term follow-up effects of 25(OH)D treatment on muscle strength are awaited.

Key Words: muscle strength, isokinetic, 25-hydroxyvitamin D, muscle architecture, ultrasound

INTRODUCTION

Vitamin D (25-hydroxyvitamin D (25(OH)D) deficiency is a widespread and emerging public health problem.¹ Previous studies have established that 25(OH)D deficiency is associated with muscle weakness in different populations.²⁻⁷ Although knee muscles' isokinetic measurements were carried out in these studies, ankle muscles' measurements were not explored. By and large, previous studies focused on the geriatric population.^{2,3,6-8} Tieland et al⁸ have reported reduced muscle mass and impaired physical performance in frail elderly people with low 25(OH)D. As age-related muscle problems, such as sarcopenia, can be seen in older adults,⁹ it is essential to show the impact of vitamin D in young adults. However, there are few studies regarding the impact of vitamin D on muscle strength in young population.^{4,5} On the other hand, microstructure of the muscle in vitamin D deficiency has been studied whereby myopathic and degenerative changes have been shown.¹⁰ To the best of our knowledge, macrostructural analysis of the muscles, such as fascicle length (FL), pennation angle (PA), and muscle thickness (MT), has not been studied in patients with low 25(OH)D. Therefore, the objective of this study was to find out whether low 25(OH)D was associated with muscle strength and muscle architecture in young adults by using ultrasound (US).

MATERIALS AND METHODS

Study design and participants

This was a cross-sectional study where 30 healthy volunteers from the hospital staff (27 women, 3 men; aged between 18 and 50 years), without a history of vitamin D use, were included. Presence of any of the following comorbidities that can affect vitamin D levels or isokinetic muscle strength was accepted as the exclusion criteria; renal/liver diseases, endocrine disorders, use of drugs which can affect muscles (corticosteroids, statins, etc.), and history of trauma/surgery of the related muscles. Demographic features and laboratory parameters were noted. Subjects were allocated into Group I and Group II according to the median of 25(OH)D. Informed consent was obtained from the patients and the study protocol was approved by the Ethics Committee of Ankara Physical Medicine and Rehabilitation Training and Research Hospital (Date: 16.05.2012; No: B.10.4.ISM.4.06.23.34.904).

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Isokinetic measurements

Peak torque/body weight of knee flexor/extensor muscles at 60°/sec and 180°/sec and that of ankle flexor/extensor muscles at 30°/sec and 90°/sec were evaluated by using a Biodex System 3 Pro Multijoint System isokinetic dynamometer (Biodex® Medical Inc, Shirley/New York, USA).

Knee test protocol included:

- 3 maximal reciprocal contractions at 60°/sec
- 15 sec rest period
- 10 maximal reciprocal contractions at 180°/sec

Ankle test protocol:

- 3 maximal reciprocal contractions at 30°/sec
- 15 sec rest period
- 10 repetitions at 90°/sec AV

Ultrasonographic evaluations

Gastrocnemius (GC) and quadriceps muscles are pennate muscles. Fascicles of the relaxed vastus lateralis (VL) and GC muscles have relatively straight alignment. However, vastus medialis muscle has a more complex architecture and its measurement has low reliability.¹¹⁻¹³ Therefore, US measurements were performed from the VL and medial GC muscles. A 7-12 MHz linear probe (Logiq P5, GE Medical Systems, USA) was used for the US measurements by the same physiatrist (rehabilitation physician) (FUM). She performed a pilot study to validate the intrarater reliability of the muscle architecture measurements in a previous study.¹¹

As for the VL measurements, images were obtained from the midhigh level (50% of the distance from the central palpable point of the greater trochanter to the lateral condyle of the femur) while subjects were lying in supine position with their legs extended and their muscles relaxed. As for the medial GC muscle, measurements were obtained from the most bulky area of the muscle. Distance between the two aponeurosis was accepted as the MT (Figure 1A and B). Angle of insertion of muscle fascicles into the deep aponeurosis was accepted as the FL, and length of the fascicular path between the superfi-

cial and deep aponeurosis was accepted the PA (Figure 1C).

25-OH vitamin D measurements

Chemiluminescence microparticle immunoassay method (ARCHITECT®, Biokit S.A., Barcelona, Spain) was used for the serum 25(OH)D measurements. Venous blood samples were obtained after a 12-hour overnight fast. The ARCHITECT assay has been designed to have an imprecision of <10% within laboratory coefficient of variation.

Statistical analysis

SPSS version 16.0 was used for the statistical analysis (SPSS Inc., Chicago, IL, USA). Data were expressed as mean±SD. Normal distribution has been checked with Kolmogorov-Smirnov test. Student's *t*-test or Fisher's exact test was used, where appropriate. Correlations between patients' characteristics and clinical parameters were analyzed using Pearson coefficients. Statistical significance was set at $p < 0.05$.

RESULTS

Demographic features of the subjects are shown in Table 1. Thirty patients were allocated into Group I (n=15, mean age; 44.4±9.4 years) and Group II (n=15, mean age; 39.0±9.9 years) according to the median of 25(OH)D (<13.7 ng/mL vs >13.7 ng/mL, respectively). Mean 25(OH)D in Group I was 9.4±2.5 ng/mL (4.9-12.5 ng/mL) and that of Group II was 20.7±8.3 ng/mL (13.6-41.5 ng/mL). Body mass index (BMI) was significantly higher in Group I ($p=0.008$). No significant difference was found between the groups regarding age, gender, and plasma calcium, phosphorus, alkaline phosphatase and parathormone levels (all $p > 0.05$).

Isokinetic parameters of the groups are shown in Table 2. Although all isokinetic strength parameters were lower in Group I, significant differences were found in knee flexion at 180°/sec ($p=0.007$), knee extension at 30°/sec ($p=0.038$) and 180°/sec ($p=0.001$), and ankle extension at 30°/sec ($p=0.002$) and 90°/sec ($p=0.007$).

Ultrasonographic measurements of the subjects are shown in Table 3. No significant difference was found between the groups regarding MT, PA, and FL values (all

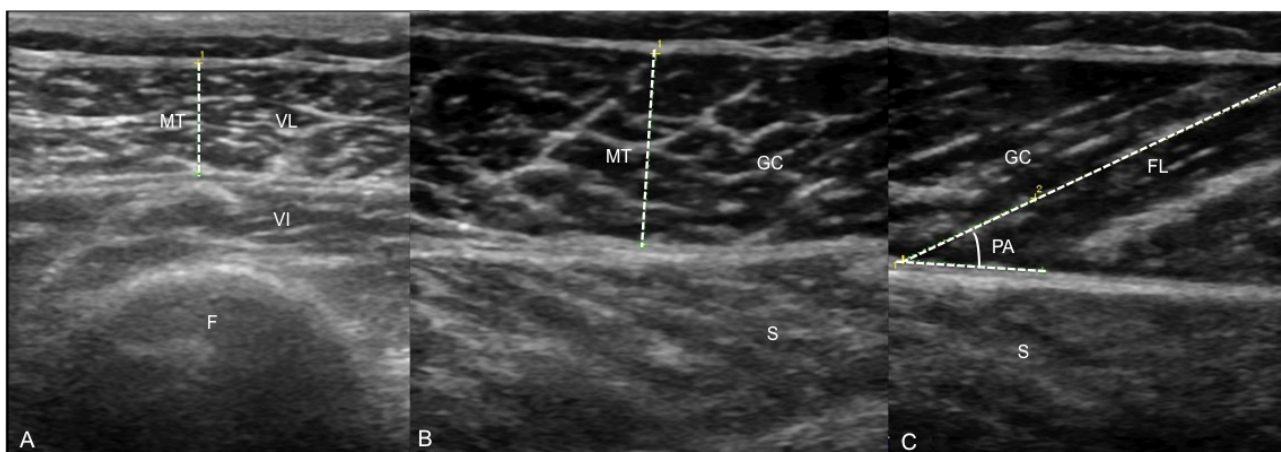


Figure 1. Ultrasound images (axial views) show the muscle thickness (MT) of vastus lateralis (VL) (A) and medial gastrocnemius (GC) muscles (B). Longitudinal view of the medial GC muscle illustrates the pennation angle (PA) and fascicle length (FL) (C). F: femur; VI: vastus intermedius muscle; S: soleus muscle.

Table 1. Demographic and clinical characteristics of the patients

	Group I (25(OH)D <13.7 ng/mL (n=15))	Group II 25(OH)D >13.7 ng/mL (n=15)	<i>p</i> value
Age (years)	44.4±9.4	39.0±9.9	0.142
Gender: women	93.3	86.6	0.543
BMI (kg/m ²)	28.9±4.8	24.3±4.1	0.008
Doing exercise	20.0	20.0	1.000
Ca (mg/dL)	9.5±0.4	9.6±0.5	0.775
P (mg/dL)	3.6±0.5	3.7±0.5	0.573
ALP (U/L)	72.3±17.6	65.8±24.1	0.432
25(OH)D (ng/mL)	9.4±2.5	20.7±8.3	<0.001
PTH (pg/mL)	47.1±17.5	49.7±32.9	0.801

BMI: body mass index; Ca: calcium; P: Phosphorus; ALP: alkaline phosphatase; 25OHD: 25-hydroxy vitamin D; PTH: parathormone. Values are given as mean±SD or %.

Table 2. Isokinetic hip and ankle muscle strength measurements of the groups (mean±SD)

Variable	Velocity (°/sec)	Peak torque/body weight (N.m/kg)		<i>p</i> value
		Group I (n=15)	Group II (n=15)	
Knee flexion	60	63.9±10.2	77.8±27.0	0.079
	180	41.5±9.3	52.4±11.3	0.007
Knee extension	60	137±17.8	153±22.0	0.038
	180	81.9±13.1	99.6±13.5	0.001
Ankle flexion	30	67.3±32.1	70.8±26.6	0.747
	90	39.1±15.6	50.4±18.2	0.080
Ankle extension	30	29.5±12.8	46.4±14.7	0.002
	90	21.6±8.4	33.7±13.9	0.007

Table 3. Muscle ultrasound measurements of the subjects (mean±SD)

	Group I (n=15)	Group II (n=15)	<i>p</i> value
Vastus lateralis			
Muscle thickness (mm)	8.07±1.58	7.60±1.68	0.450
Pennation angle (deg)	16.1±3.13	15.2±3.11	0.457
Fascicle length (mm)	55.6±13.0	48.0±13.7	0.144
Gastrocnemius			
Muscle thickness (mm)	12.8±2.1	12.8±1.2	0.990
Pennation angle (deg)	26.6±5.9	27.8±4.1	0.515
Fascicle length (mm)	37.4±7.9	36.1±5.0	0.593

$p > 0.05$).

DISCUSSION

In this cross-sectional study, we found that low 25(OH)D was associated with decreased muscle strengths (especially in knee and ankle extensors at both slow and fast contractions), but not with muscle architecture.

Vitamin D has essential effects on muscle weakness and morphology. Different molecular mechanisms have shown these effects. Intracellular calcium handling and genomic activity have been reported for muscle contraction and weakness. Muscle metabolism and muscle cell differentiations have been shown as well.¹⁴ Moreover, myopathic and degenerative changes (i.e., opaque, necrotic or regenerating fibers, fat tissue infiltration, fibrotic changes, and atrophy of muscle fibers) were illustrated.¹⁰

Muscle fibers are categorized into type I (slow twitch oxidative) and type II (fast twitch oxidative or glycolytic) fibers.¹⁵ While type I fibers mainly contract at higher velocities (i.e. 180-300°/sec), both type I and II fibers contract at lower velocities (i.e. 30-60°/sec).^{13,15} 25(OH)D affects both fibers, yet more prominently type II fibers.¹⁰ Likewise, we found reduced isokinetic muscle strength

for both slow and fast contractions.

Since PA and FL affect force production and velocity of the muscle shortening, these structures serve an important function in force generation. Previous studies suggested that the more increased PA and longer FL, the greater force generation the muscles can provide. Furthermore, MT shows muscle atrophy or hypertrophy.^{11,16} Previous studies showed muscle atrophy (reduced muscle mass) in association with low 25(OH)D. Tieland et al⁸ found reduced muscle mass in older adults. By contrast, we could not find decreased MT, FL or PA. We can attribute this difference to three facts. First, among our participants, no one had osteomalacia symptoms such as waddling gait or bone pain. If we had included patients with severe deficiency of 25(OH)D, there could have been difference with respect to the morphology. Second, previous studies suggest that atrophic changes due to 25(OH)D deficiency are the late-term result particularly in the elderly population. Finally, neurogenic mechanisms could be the earlier changes, and trophic changes could develop later.^{17,18} Since US illustrates macroarchitecture, microarchitectural changes (might have occurred in the early period) could not be detected by US.

There are some limitations in our cross-sectional study. First, the study could have been designed as a cohort with a larger sample size. Second, BMI was significantly higher in Group I. Therefore, we used adjusted data for the isokinetic measurements.

Conclusion

This study highlight that low 25(OH)D was associated with reduced isokinetic strengths (especially for both knee and ankle extensors at slow and fast contractions). By contrast, muscle architecture did not differ according to 25(OH)D. Further prospective studies also taking into account the possible impact of 25(OH)D supplementation on muscle strength are awaited.

AUTHOR DISCLOSURES

No competing interests are reported.

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