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- Gülsüm DOĞAN[1]
- Naciye Füsun TORAMAN[2]
- Neşe TOKTAŞ[3]
- Meral BİLGİLİSOY FİLİZ[2]
- Tuncay ÇAKIR[4]
- Şebnem KOLDAŞ DOĞAN[2]
- Tülay ERÇALIK[5]

CORRESPONDANCE

Gülsüm DOĞAN
Pamukkale University, Faculty of Medicine, Department of Physical Medicine and Rehabilitation, Division of Rheumatology (formerly), Denizli, Turkey

Phone: 2422372283
e-mail: drgulsum07@gmail.com

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[1] Pamukkale University, Faculty of Medicine, Department of Physical Medicine and Rehabilitation, Division of Rheumatology (formerly), Denizli, Turkey
[2] Health Sciences University, Antalya Training and Research Hospital, Physical Medicine and Rehabilitation Clinic, Antalya, Turkey
[3] Akdeniz University, Faculty of Sport Sciences, Antalya, Turkey
[4] Antalya Likya Hospital, Physical Medicine and Rehabilitation Clinic, Antalya, Turkey
[5] Şişli Etfal Training and Research Hospital, Physical Medicine and Rehabilitation Clinic, Division of Algologia, İstanbul, Turkey

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RESEARCH

DO THE EFFECTS OF VITAMIN D SUPPLEMENTATION ON MUSCLE STRENGTH DIFFER ACCORDING TO AGE?

Abstract

Introduction: Vitamin D plays an important role in musculoskeletal health and its use improves muscle strength. However, the effect of vitamin D use on muscle strength in women of different ages is yet to be investigated. Therefore, in this study, we aimed to evaluate the effect of vitamin D use on muscle strength in women of different age groups and determine the differences of muscle strength gain between age groups.

Materials and Method: Sixty-three women with calcidiol levels<30 ng/mL were randomly assigned and stratified by their age group as follows: Group I (aged 40–49 years), Group II (aged 50–59 years) and Group III (aged 60–69 years). Calcidiol levels, body mass index, fat free mass, percent fat, grip strength, arm curl, chair stand and isokinetic concentric flexor and extensor peak torque and power at 60°•s−1 and 180°•s−1 were assessed at baseline and six months after oral cholecalciferol supplementation.

Results: Vitamin D supplementation caused significant improvement in body mass index, arm curl, grip strength and knee flexor and extensor peak torque and power at 60°•s−1 and 180°•s−1 in all groups ($p<0.05$). Knee flexor power at 60°•s−1 and extensor power at 180°•s−1 were significantly higher in group I than in group III ($p<0.025$).

Conclusion: Muscle strength in response to vitamin D supplementation increased in all age groups, and isokinetic muscle power was the highest in the youngest age group studied.

Keywords: Body composition; Muscle strength; Vitamin D; Women

ARAŞTIRMA

D VİTAMİNİN KULLANIMININ KAS KUVVETİNE ETKİSİ YAŞA GÖRE DEĞİŞİR Mİ?

Öz

Giriş: D vitamininin muskuloskeletal sağlık için önemli olduğu ve D vitamin kullanımının kas kuvvetini arttırdığı bilinmektedir. Ancak, farklı yaşlardaki kadınlarda, D vitamin kullanımının kas kuvvetine etki farklılığını araştıran çalışma yoktur. Bu nedenle bu çalışmada, farklı yaş gruplarındaki kadınlarda D vitamin kullanımının kas kuvvetine etkisini değerlendirmek ve yaş grupları arasındaki kuvvet değişim farkını belirlemek amaçlanmıştır.

Gereç ve Yöntem: Kalsidiol düzeyi <30ng/ml olan altmış üç kadın rasgele olarak yaş gruplarına göre sınıflandırıldı ve tabakalandı: Grup I (40-49 yaş arasında), Grup II (50-59 yaş arasında), ve Group III (60-69 yaş arasında). Kalsidiol düzeyi, beden kütle indeksi, yağsız kütle, yüzde yağ, kavrama kuvveti, kol bükme, otur kalk testleri ile 600.s-1 and 1800.s-1 hızlarda izokinetik konsantrik fleksör ve ekstensör zirve tork ve güç başlangıçta ve oral kolekalsifereol verildikten altı ay sonra değerlendirildi.

Bulgular: D vitamin kullanımı tüm yaş gruplarında beden kütle indeksi, kol bükme, kavrama kuvveti, 600.s-1 and 1800.s-1 hızlarda diz fleksör ve ekstensör zirve tork ve güçte artışa neden oldu ($p<0.05$). Grup I'de, Grup III'e kıyasla 600.s-1 hızda fleksör güç ve 1800.s-1 hızda ekstensör güç daha büyüktü ($p<0.025$).

Sonuç: D vitamin kullanımı sonucu tüm yaş gruplarında kas kuvveti arttı ve izokinetik kas gücü artışının genç yaş grubunda daha fazla olduğu belirlendi.

Anahtar sözcükler: Beden kompozisyonu, Kas kuvveti, Vitamin D, Kadın

INTRODUCTION

Muscle strength declines with age, and its loss is prominent in people over 40 years of age (1). Vitamin D has a small but positive effect on muscle strength (2), and the improvement of muscle strength with vitamin D supplementation can only be achieved in persons with vitamin D deficiency (3). On performing meta-analysis, no significant effect of vitamin D supplementation was noted on grip strength in adults with 25(OH)D levels>10 ng/mL, but a large effect was noted on hip muscle strength in adults with 25(OH)D levels<10ng/mL (4). Most of the improvement in lower extremity functions occurred in 25(OH)D concentrations between 9 and 16 ng/mL, while the change was not as noticeable in the range of 16–37.6 ng/mL in older adults (5). In adults aged 65–102 years, vitamin 25(OH)D levels<10 ng/mL were significantly associated with lower extremity performances, whereas serum 25(OH)D levels<20 ng/mL were significantly associated with grip strength (5,6). To the best of our knowledge, there is no study comparing the effects of serum 25(OH)D levels on muscle strength and that of vitamin D supplementation on muscle strength gain across different age groups of women.

Some studies suggest that vitamin D improves isometric (7-11) or isokinetic muscle strength (7,12,13), while other studies suggest that it has no effect on isometric (12,14-16) and isokinetic muscle strength (17). However, no study has yet investigated the differences in isometric or isokinetic strength gain on vitamin D supplementation in different age groups of women. Therefore, this study was designed to determine the effects of vitamin D supplementation on isometric and isokinetic muscle strength and to assess whether these effects differ according to the ages of women.

MATERIALS AND METHOD

Sixty-three sedentary women (aged 40–69 years) with 25(OH)D levels<30 ng/mL and without a history of vitamin D use within the last six months participated in the study and provided written informed consent. Exclusion criteria included the presence of any of the following comorbidities that may affect vitamin D levels or physical performance: renal and liver diseases, endocrine and neurologic diseases, a history of myocardial disease within the last six months, gastrointestinal malabsorption, the use of medicines which may affect muscles and the history of trauma/surgery of related muscles. The patients were stratified into the following three age groups: Group I (40–49 years of age), Group II (50–59 years of age) and Group III (60–69 years of age).

Vitamin D supplementation with 300.000 IU oral cholecalciferol was administered to patients according to their vitamin D status in March 2013: three doses at 10-day intervals in patients with vitamin D levels ≤ 10 ng/mL, two doses at 15-day intervals in patients with vitamin D levels of 11–20 ng/mL and a single dose in patients with vitamin D levels of 21–30 ng/mL. Oral calcium supplementation was administered to patients with insufficient calcium intake to achieve a total daily calcium intake of 1000 mg. This study was approved by the Institutional Ethics Committee (decision no;date.4/5; 2012).

All the following outcome measures were assessed at baseline and on the sixth month following vitamin D supplementation.

Serum 25(OH)D (calcidiol) assays (DiaSorin, Stillwater, MN, USA) were performed using direct competitive chemiluminescence immunoassay. LIAISON assay is linear up to 125 ng/mL, the limit of detection is 3.5 ng/mL and the coefficient of variation ranges between 4.8% and 11.1%. Blood samples were obtained after overnight fasting. Serum samples were separated via centrifugation at 3000 rpm for 10 minutes, and serum portions were stored at −80°C and later used for analysing 25(OH) D levels.

Height was measured using a tape measure with the participant in standing position. Body Mass Index (BMI), fat free mass (FFM) and percentage

body fat were measured using Tanita Body Composition Analyzer (TANİTA MC-180MA).

The handgrip strength of the dominant limb was measured using a baseline hydraulic hand dynamometer in which the dynamometer was used with participants in seated positions, their elbow by their side and flexed to right angles and their wrists in neutral positions. For the analyses, the maximum force from the three trials was used.

The chair stand test assessed lower body strength. The score was the total number of stands correctly executed within 30 seconds. The dominant side of the arm curl test assessed upper body strength. The score was the total number of hand weight curls through the full range of motion in 30 seconds (18). Isokinetic concentric measurements of knee flexor/extensor muscles at $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$ were evaluated using ISOMED2000 (model code 106-012, Hemau/Germany/2008). The test protocol included five maximal contractions at each speed with 1-minute intervals between each speed. The relative peak torque and power values were used in the analysis.

The study participants were assessed for any adverse reactions of vitamin D supplementation during and at the end of the study.

Statistical analysis

Data were analysed using the SPSS software (version 18.0). One-way ANOVA test was used for comparing baseline values and the post-hoc Tukey test was used. The level of significance was set at 0.05. Multiple 3×2 (group×time) repeated measures ANOVA were performed for identifying significant changes over time. When significant differences were observed between groups at the start of the study, analysis of covariance was performed on the outcome variables at the end of the study. The covariate was the baseline value of each participant for the particular outcome variable being analysed. Post-hoc analyses were conducted using the Bonferroni test for examining time and group effects. The level of significance was set at 0.025; that is, 0.05 divided by 2.

RESULTS

In the present study, we included 20 patients in the group I, 24 patients in the group II and 19 patients in the group III. One patient was excluded after stratification because of a haemorrhagic stroke. Vitamin D treatment was not associated with any clinically adverse reactions. Laboratory results revealed that serum 25(OH)D levels were <10ng/mL in 95% of participants in groups I and III and in 92% of participants in the group II. At baseline, no significant difference was noted in serum vitamin D levels among the groups ($p>0.05$) (Table 1).

Baseline BMI, FFM and percent fat measurements did not significantly differ among the study groups, and no significant differences were noted between groups I and II regarding isokinetic measurements ($p>.05$). Chair stand and grip strength test scores were higher in group I than in groups II and III and arm curl test scores were higher in the group I when compared with those in group the III and in group the II when compared with those in the group III ($p<.05$). No significant differences were noted between groups II and III for the chair stand and grip strength tests or between groups I and II for the arm curl test ($p>.05$). Furthermore, extension torque and power at $60°\cdot s^{-1}$ and $180°\cdot s^{-1}$ and flexion torque at $60°\cdot s^{-1}$ were higher in the group I than in the group III ($p<.05$). The flexion torque and power at $60°\cdot s^{-1}$ and extension torque at $60°\cdot s^{-1}$ were higher in the group II than in the group III ($p<.05$) (Table 1).

According to the 25(OH)D blood concentrations at the end of the study, 70% and 71% of women in groups I and II, respectively, reached levels >30ng/mL, whereas only 37% of the women in group III reached these levels. Repeated measures of ANOVA revealed a significant time effect for 25(OH)D levels ($p<.025$), while no group effect was noted ($p>.025$) (Table 1).

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Table 1. Outcome measures at baseline and six months.

			Group I, N=20 mean±sd		Group II, N=24 mean±sd		Group III, N=19 mean±sd		Baseline difference	Time	Group
			Pre-	Post-	Pre	Post-	Pre-	Post-			
25 (OH)D,ng/mL			7.2±2	39.9±17.5	7.8±2.3	36.5±11.1	7.1±2.6	28.8±7.0	*p=.580	**p<.001	**p=.027
Body Mass Index, kg/m²			31.4±5.3	30.9±5.1	30.9±3.4	30.2±3.8	34.2±6.2	33.4±5.8	*p=.086	**p<.001	**p=.091
Fat free mass,kg			24.5±3.1	24.4±2.5	24.6±3.2	24.1±2.1	22.9±2.9	23.4±3.4	*p=.171	**p=.725	**p=.248
% fat			43.9±7	43.1±5.9	43.3±6.2	43.8±4.6	47.1±6.4	46±7.2	*p=.140	**p=.456	**p=.177
Chair stand,rep/30 s			8.9±1.6†‡	11.1 ±2.1	7.5±1.4	9.7±2.6	6.8±1.2	8.1±2.2	*p< .001	††p=.470	††p=.301
Arm curl,rep/30s			11.1±2.3‡§	13.8±2.2	10.5±1.9	12.3±2.6	8.4±2.4	10.6±2	*p=.001	††p<.001	††p=.046
Grip strength,kg			24.4±5.3†‡	27.9±4.8	20.4±4.8	26.7±9.6	17.7±5.4	19.9±5.9	*p=.001	††p=.003	††p=.072
60⁰/s	**Flex**	**Peak Torque,Nm/kg**	0.47±0.17‡§	0.62±0.20	0.46±0.21	0.58±0.17	0.28±0.16	0.38±0.19	*p=.002	††p<.001	††p=.106
		Peak Power,W	21.6±10.1†§	29.3±10.8‡‡	22.3±11.7	26.5±9.8	13.6±8.9	16.6±9.1	*p=.018	††p<.001	††p=.015
	Ext	**Peak Torque, Nm/kg**	0.89±0.30‡	1.10±0.33	0.83±0.32	0.97±0.31	0.55±0.32	0.66±0.28	*p=.003	††p<.001	††p=.029
		Peak Power W	38±15.5‡	44.8±15	35.9±16.7	40.1±12.7	25.2±14.5	29.2±13.7	*p=.030	††p<.001	††p=.067
180⁰/s	**Flex**	**Peak Torque, Nm/kg**	0.29±0.14	0.45±0.15	0.30±0.16	0.46±0.19	0.19±0.11	0.27±0.16	*p=.021	††p<.001	††p=.036
		Peak Power,W	25.4±15.5	39.5±15.5	27.7±17.3	37±15.4	13.8±10.4	21.1±15	*p=.010	††p<.001	††p=.029
	Ext	**Peak Torque, Nm/kg**	0.52±0.23‡§	0.70±0.23	0.46±0.21	0.61±0.23	0.33±0.16	0.42±0.20	*p=.012	††p<.001	††p=.029
		Peak Power,W	46.7±25.1†‡	65.1±20.3‡‡	41.6±23.8	50.3±21.8	26.3±16.6	35.4±18.4	*p=.016	††p<.001	††p=.004

* One-way ANOVA; †Tukey difference between Group I and II; ‡Tukey, difference between Group I and III; §Tukey, difference between Group II and III , p<.05
**Repeated measures of ANOVA; ††Repeated measures of ANCOVA; ‡‡Bonferroni, difference between Group I and III, p <.025

There were no significant time effect for the FFM and percent fat values (p>.025) but did so for BMI (p<.025). No significant group effects were noted for BMI, FFM and percent fat values (p>.025) (Table 1).

There was no significant time effect for the chair stand test (p>.025), whereas significant time effects were noted for grip strength, arm curl, flexor and extensor torque and power at 60°·s^{-1} and 180°·s^{-1} for all groups (p<.025). The performance of flexor power at 60°·s^{-1} and that for extensor power at 180°·s^{-1} were higher in group I than in group III (p<.025) (Table 1).

DISCUSSION

The results in this study demonstrated that vitamin D supplementation improved BMI, arm curl, grip strength as well as flexor, extensor torque, and power at 60°·s^{-1} and 180°·s^{-1} in all age groups. The effect sizes for flexion power at 60°·s^{-1} and extension power at 180°·s^{-1} were greater in group 1 than in the group 3.

At baseline, 25(OH)D levels were <15 ng/mL (range 4–14 ng/mL) in all groups without any significant differences. Chair stand and grip strength were higher in group I than in groups II and III, while arm curl was lower in group III than in groups I and II. Flexor and extensor torque at 60°·s^{-1} were significantly lower in group III than in groups I and II. Extensor power at 60°·s^{-1} and 180°·s^{-1} and extensor torque at 180°·s^{-1} were significantly lower in group III than in group I, while flexion power at 60°·s^{-1} and 180°·s^{-1} and also flexion torque at 180°·s^{-1} were significantly lower in group III than in group II. These findings suggested that muscle strength and power correlated with age rather than with vitamin D levels.

Grip strength was lower than normative values in all groups at baseline (19). Conflicting results have been reported regarding the relation between vitamin D and grip strength, with some studies proposing the presence of such a relation (6,7,11) while others proposing the lack of a relation (12). A study reported that women with serum vitamin D levels <30ng/mL had lower grip strength (11), while another study reported that grip strength was lower when serum vitamin D levels were <20ng/mL in both sexes (6). In addition, various cut-off levels were defined for serum vitamin 25(OH)D levels in studies investigating the relation between the physical performance of lower extremities. In some studies, physical performance was reportedly lower at vitamin 25(OH)D levels <10ng/mL (6), while other studies proposed different levels such as <32 ng/mL (20) and <30ng/mL (11,13). In a study on individuals older than 60 years of age (51 women, 75% physically active), lower extremity performances were suggested to be worse when serum 25(OH)D concentrations were between 9 and 16ng/mL (5). In the present study, we could not determine whether group differences in muscle strength, muscle power and physical performances were associated with age or serum vitamin D levels because none of the participants had normal vitamin D levels.

Although it has been reported that there was no significant effect of vitamin D on muscle power (2,11,14), Bischoof et al.(20) stated that there was a significant, positive correlation between muscle power and 25(OH)D only in male participants between 65 and 95 years of age. In another study, vitamin D was positively associated with isometric flexion and extension average torque at the knee and isokinetic flexion strength at 60°·s^{-1} and 180°·s^{-1}; there was no correlation between vitamin D and knee isokinetic extension strength at 60°·s^{-1} and 180°·s^{-1} (12). Previous studies have suggested that vitamin D affected isometric muscle strength (7-11) and isokinetic muscle strength (7,12,13), but other reports have proposed no effect (12,14-17). In this study, improvement was observed in the knee flexor as well as extensor torque and power at 60°·s^{-1} and 180°·s^{-1} in all assessed age groups, and the between-group effect sizes for flexion power at 60°·s^{-1} and extension power at 180°·s^{-1} after vitamin D supplementation suggested that vitamin D was more effective for muscle power in younger age groups than in older ones. This outcome suggested that the effect of vitamin D supplementation depends on age and also on increased 25(OH)D levels because 25(OH)D levels were >30 ng/mL in 70% of participants in the group I and in 37% of participants in group III. Serum 25(OH)

D level increment was 481% in group I, 404% in group II and 360% in group III. Grip strength increased from 15% at baseline to 50% in group I, from 13% to 35% in group II and from 11% to 21% in group III. The increase in grip strength was consistent with the increase in serum vitamin D levels. It has been demonstrated that the greatest improvement of muscle strength occurred from very low concentrations of serum 25(OH)D up to 16–20 ng/mL (5).

Even though vitamin D supplementation resulted in increased grip strength and isokinetic strength in our study, it had no effect on chair stand test performance. However, McCarthy et al.(21) stated that isokinetic knee extensor strength was an important but moderate predictor of chair stand test performance and additional independent variables such as leg power, leg endurance, posture, and psychological variables may have contributed to the variance in chair stand test performance.

Obesity is a major risk factor for vitamin D deficiency because of body fat absorption of vitamin D (11,22). BMI and higher body fat percentage are significantly associated with lower serum 25(OH) D levels, especially in older persons, and there is a relation between vitamin D levels and adipose tissue (23). On the basis of this evidence, obese individuals are expected to require higher doses of vitamin D supplementation (22). The smaller increment of serum 25(OH)D levels in the group III depended on the percentage of obese participants in this age group. BMI was >30 kg/m^2 in 54% of the group I, 60% of the group II and 79% of the group III in this study.

Although high doses of vitamin D were used in this study, there were no adverse reactions. In a previous review, it was suggested that doses <300.000 IU do not provide an adequate amount of vitamin D for restoring vitamin D status in most populations, and the increases in 25(OH)D concentration safely occur in a majority of individuals (24). Moreover, this review highlighted previous works wherein there were no adverse events when participants received up to 500.000 IU of vitamin D (24).

One of the limitations of the present study was its small sample size. In addition, there was a significant difference in muscle strength, especially for isokinetic muscle strength, between groups at baseline. Furthermore, the lack of a control group with different serum vitamin D levels is another study limitation. In addition, we did not have specific information regarding sunlight exposure. Lastly, we were unable to evaluate the response of muscle strength of different body regions to vitamin D supplementation. Randomised, controlled studies using a large sample of participants with different serum 25(OH)D levels are required for defining optimal treatment modalities, including the dose and mode of administration and duration. Future research may also identify factors such as age, sex, physical activity level, the number of concomitant medications and endogenous gonadal hormone levels that affect responses to vitamin D supplementation.

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