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Relation Between Vitamin D, Physical Performance, and Disability in Elderly Persons

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Background. The aim of this study was to evaluate the relationships between vitamin D, functional status, and disability in a sample of elderly, community-dwelling subjects.

Methods. Serum values of 25-hydroxyvitamin D (25[OH] D) and albumin were determined in all participants. Anthropometric measures were obtained, and body composition was assessed using dual-energy x-ray absorptiometry. Arm and leg isometric strength was tested. Reported disability was evaluated using a modified version of the Activities of Daily Living Scale and physical performance with the 6-minute walking test and two items of the Short Form 36 Health Survey Questionnaire (SF-36).

Results. A significantly higher prevalence of hypovitaminosis D, defined as level of 25(OH)D < 37.5 nmol/l, was observed in women than in men (55.4% and 35.1%, respectively; $p < .001$). In women, 25(OH)D was significantly associated with muscular strength and levels of physical function as assessed by SF-36. After adjusting for body mass index, albumin, appendicular fat-free mass, and season, muscle strength was still significantly lower in women with hypovitaminosis D than in those without. Women with reported disability showed significantly lower 25(OH)D values than those without. No relationship between muscular strength, physical function, or reported disability and 25(OH)D was found in men.

Conclusions. In community-dwelling elderly women, 25(OH)D is related to muscular function and reported disability. Because of the high prevalence of hypovitaminosis D in the elderly population, this association seems to be clinically relevant.

MUSCLE mass and muscle strength decline with age in both sexes (1–3). The reduction of muscle strength and muscle mass has been shown to be related to functional impairment and risk of disability in the elderly population (1–3). Several risk factors have been recognized for functional impairment and disability (4–6).

Vitamin D deficiency is a highly prevalent condition in the elderly population (7,8). Vitamin D receptors have been identified in most tissues, including skeletal muscular tissue (9). Low vitamin D levels in patients with osteomalacia and uremia are associated with a reversible proximal myopathy, characterized by a type II fiber atrophy (10).

We hypothesized that hypovitaminosis D through an impaired muscular function may be associated with physical disability in elderly persons. This report examines the relationships between levels of vitamin D, muscle strength, and reported disability in a sample of community-dwelling elderly people.

Methods

Subjects

Subjects were recruited from the lists of 11 general practitioners in Verona and were eligible if they were able to walk for at least 1/2 mile without difficulty and if they were free of cognitive impairment (Mini-Mental Status Examination score >24). Exclusion criteria included a history of hypercalcemia, renal insufficiency, primary hyperparathyroidism, disabling knee osteoarthritis, congestive heart disease, and lung disease. A total of 175 women and 94 men ranging in age from 68 to 75 years were included in the study. None of the participants received treatment with calcium, vitamin D, hormone replacement therapy, calcitonin, or bisphosphonates during the 6 months before the evaluation, and none engaged in regular physical exercise. The evaluations were conducted at different times throughout the year.

All the participants gave their informed consent, and the experimental protocol was approved by our Ethical Committee.

Anthropometry

With the subjects wearing light indoor clothes and no shoes, body weight was measured to the nearest 0.1 kg (Salus scale, Milan, Italy) and height to the nearest 0.5 cm using a stadiometer (Salus, Milan, Italy). Body mass index (BMI) was calculated as body weight adjusted by stature (kg/m^2). Waist circumference was obtained with a measuring tape at the level of the narrowest part of the torso as viewed anteriorly.

Dual-Energy X-Ray Absorptiometry

Total body fat, total fat-free mass (FFM) tissue, and percent total fat were determined using dual-energy x-ray absorptiometry (DXA) (QDR 2000; Hologic, Waltham, MA) array beam with software version 7.2. The characteristics and physics concepts of DXA measurement have been described elsewhere (11,12). Total body fat was expressed in percent of body weight as well as in kg; FFM was expressed in kg. Coefficient of variation (CV) for double determination in 11 subjects (men and women ranging in age from 68–75 years) was 1% for total body fat, 1.3% for FFM, and 2.3% for percent body fat. Using the subregion option of the software, appendicular FFM was measured as the sum of the lean soft-tissue masses for the arms and the legs, as described by Heymsfield and colleagues (13).

Physical Performance Evaluation

A 6-minute walking test (14) was performed, and the distance walked by each subject at normal speed was determined. The Short Form 36 Health Survey Questionnaire (SF-36) (15) was administered to all subjects. In this study, we considered only two items of the questionnaire evaluating the subjective level of limitation in physical function as an indirect measure of the level of physical function and exercise.

Strength

Isometric strength of the dominant knee and arm extensors was tested with a handheld dynamometer (Model 160; Spark, Iowa City, IA). Strength was recorded in kg and was calculated as the highest peak torque obtained in three trials. The CV for double determination in 20 subjects was 6.9% for the dominant arm and 7.7% for the dominant leg.

Reported Disability

Physical function was assessed, according to Langlois and colleagues (16), using a combination of three scales: the ADL scale (17), three Rosow-Breslau physical function items (18), and the instrumental activities of daily living (IADL) scale (19). Two groups were identified according to the following criteria: (i) "no physical function's limitations" if subjects reported "easy" for all ADL and "no difficulty" for the physical function items and for all IADL; and (ii) "physical function's limitations" if subjects reported any level of physical disability in any of the three scales.

A strong association has been previously observed in a large community-based study between this combined scale and well established predictors of physical performance (18).

Biochemical Measures

Fasting early morning venous blood samples were collected from resting supine patients to measure albumin levels and 25(OH)D values. 25(OH)D is considered to be the most reliable index of vitamin D status (20). 25(OH)D was measured by a radioimmunoassay procedure after acetonitrile extraction (25-OH-assay; DiaSorin, Stillwater, MN). The sensitivity of this assay has been shown to be at or below 3.75 nmol/l, and the specificity is very high; the intraassay CVs were 8% to 11%. The normal range in our laboratory for circulating 25(OH)D, expressed as 2 *SD* from the mean concentration of the general population, was 37.5 to 175 nmol/l; values of 25(OH)D below 37.5 nmol/l are negatively related to circulating parathyroid hormone (7,21). Values of 25(OH)D below 37.5 nmol/l were chosen to define the presence of hypovitaminosis D. Albumin was determined using a colorimetric test (Vitros 950 ALB slides; J&J Health, Cone Systems, Piscataway, NJ); the color complex formed was measured by reflectance spectrophotometry. The sensitivity of this assay has been shown to be 10 g/l; intraassay CVs were 1.3% to 1.5%.

Statistical Methods

Data are shown as mean $\pm SD$. Subjects were stratified by the season in which they were examined: summer was defined as June through August, autumn as September through November, winter as December through February, and spring as March through May. Comparisons between women and men, as well as between subjects with low and normal levels of vitamin D and subjects with and without disability, were made using Student's t test for unpaired data. Seasonal effect on vitamin D levels was evaluated using ANOVA. The prevalence of hypovitaminosis D in men and women was compared using Pearson chi-square. Simple correlations were used to test the association between vitamin D and other variables. Covariance analysis was used to adjust for BMI, albumin, appendicular FFM and season, and arm and leg muscle strength between subjects with and without hypovitaminosis D (22). Differences of $p < .05$ were considered statistically significant. All statistical analyses were performed using SPSS statistical package (23).

Results

Table 1 shows the comparison of anthropometric variables, body composition, and physical performance between men and women: no significant differences were found in age and BMI between the groups. Waist circumference, FFM, appendicular muscle mass, arm and leg strength, and 6-minute walking test results were significantly higher in men than in women, whereas fat mass and percent of body fat were significantly lower in men than in women. 25(OH)D levels were significantly higher in men than in women (56.5 ± 37.5 nmol/l and 39.4 ± 24.1 nmol/l, respectively; $p < .001$).

Table 1. Comparison of Anthropometry, Body Composition, Physical Performance, and Levels of 25-hydroxyvitamin D Between Women and Men

Parameter	Women (n = 175)	Men (n = 94)
Age, y	71.9 ± 2.4	71.8 ± 2.1
Body weight, kg	65.1 ± 11.5	78.9 ± 11.6*
BMI, kg/m^2	26.6 ± 4.6	27.3 ± 3.6
Waist circumference, cm	83.7 ± 10.8	95.9 ± 9.3*
FFM, kg†	35.31 ± 4.39	52.42 ± 5.61*
Fat mass, kg†	26.58 ± 8.20	22.37 ± 7.37*
Body fat, %†	41.07 ± 6.4	28.4 ± 6.9*
Appendicular muscle mass, kg†	13.55 ± 2.00	21.39 ± 2.73*
Arm strength, kg	6.5 ± 2.6	11.1 ± 3.8*
Leg strength, kg	10.4 ± 4.5	18.0 ± 5.8*
6-min walking test, m	340.9 ± 64.2	391.2 ± 69.4*
25-hydroxyvitamin D, nmol/l	39.4 ± 24.1	56.5 ± 37.5*

Notes: Values are means ± standard deviation. BMI = body mass index; FFM = fat-free mass.

†Measured by dual-energy x-ray absorptiometry.

*$p < .001$.

Table 2. Relationship Between Levels of 25-hydroxyvitamin D and Muscular Strength, Physical Performance, and Body Composition in Women and Men

Parameter	Women (n = 175) r Value	Men (n = 94) r Value
Age, y	−.03	.03
Body weight, kg	−.09	−.07
BMI, kg/m^2	−.11	−.13
Waist circumference, cm	−.09	−.13
FFM, kg†	−.04	−.01
Fat mass, kg†	−.10	−.11
Body fat, %†	−.09	−.11
Appendicular muscle mass, kg†	−.05	−.01
Arm strength, kg	.19*	−.06
Leg strength, kg	.17*	−.01
6-min walking test, m	.13	.04
Physical functioning‡	.19*	−.12
Physical problems‡	.22**	.03

Notes: BMI = body mass index; FFM = fat-free mass.
†Measured by dual-energy x-ray absorptiometry.
‡Evaluated by two items of the Short Form 36 Health Survey Questionnaire.
*$p < .05$; **$p < .01$.

Vitamin D values were significantly lower in winter than in summer and autumn in women as well as in men (F trend 6.72 and 5.43, respectively, $p < .01$).

The prevalence of hypovitaminosis D, defined as levels of 25(OH)D < 37.5 nmol/l, was significantly higher in women than in men (55.4% and 35.1%, respectively; χ^2 10.1, $p < .001$).

In women, 25(OH)D was significantly associated with strength of the dominant arm and leg and with levels of physical function, as evaluated by two items of SF-36 (Table 2). In men, no significant relation was found between 25(OH)D and anthropometric and body composition variables and measures of strength and physical function (Table 2).

Women with hypovitaminosis D had significantly lower arm and leg strength than women with normal levels of vitamin D (Table 3). After adjusting for BMI, albumin, appendicular FFM, and season, muscular strength was still significantly lower in women with hypovitaminosis D than in those without (data not shown). No significant differences were found in men between subjects with and without hypovitaminosis D except for BMI and waist circumference (Table 4).

In women but not in men, levels of 25(OH)D were significantly lower in subjects with reported disability than in those without (in women: 33.8 ± 21.0 vs 43.5 ± 25.0 nmol/l, respectively, $p < .05$; in men: 54.5 ± 38.6 vs 64.6 ± 33.6 nmol/l, not significant) (data not shown).

Discussion

Our study indicates that in elderly women, 25(OH)D is significantly related to impaired muscular function and disability, independent of nutritional status.

Several studies have shown a high prevalence of hypovitaminosis D in the elderly population (7,8,21,24), especially in European countries (24) where food is not supplemented with vitamin D. Our study, in line with other European data (24), confirms a higher prevalence of hypovitaminosis D in elderly women than in age-matched men.

Table 3. Comparison Between Women With Low and Normal Levels of 25-hydroxyvitamin D

Parameter	≤37.5 nmol/l (n = 97)	>37.5 nmol/l (n = 94)	p Value
Age, y	71.91 ± 2.39	71.99 ± 2.51	.830
Weight, kg	66.14 ± 11.75	64.07 ± 11.00	.235
BMI, kg/m^2	27.06 ± 4.75	26.21 ± 4.43	.228
Waist circumference, cm	84.57 ± 11.69	82.94 ± 9.50	.319
Appendicular muscle mass, kg†	13.71 ± 19.77	13.31 ± 20.37	.160
Arm strength, kg	6.03 ± 2.65	7.04 ± 2.49	.011*
Leg strength, kg	9.77 ± 3.94	11.20 ± 5.08	.037*
6-min walking test, m	334.17 ± 70.29	348.17 ± 55.69	.156
Physical functioning‡	70.59 ± 22.60	71.88 ± 20.25	.706
Physical problems‡	36.31 ± 41.97	44.10 ± 41.22	.235

Notes: Values are means ± standard deviation. BMI = body mass index.
†Measured by dual-energy x-ray absorptiometry.
‡Evaluated by two items of the Short Form 36 Health Survey Questionnaire.
*$p < .05$.

Few papers have evaluated the relationships between vitamin D, muscular strength, and disability as well as the effects of vitamin D supplementation on physical performance (25–34), and their results, even if suggestive, do not appear conclusive. Few cross-sectional studies have shown a significant relation between vitamin D and muscular strength (25–28), disability, or physical performance (28) or falls (25); the variance of physical performance explained by vitamin D in these studies was generally small (35). Moreover, Mowé and colleagues (25) did not evaluate the relationships between vitamin D and functional status separately by gender; because men and women with different levels of vitamin D, muscle strength, and physical function are pooled together, the analyses of Mowé's study are difficult to interpret and need to be confirmed. Interventional studies generally support the results of cross-sectional reports (30–34). However, the only published controlled clinical trial (29) presents negative findings probably due in part to the selection of subjects with a normal functional and vitamin D status and in part to an inadequate supplementation that did not lead to significant increases in vitamin D levels in the study population.

Table 4. Comparison Between Men With Low and Normal Levels of 25-hydroxyvitamin D

Parameter	≤37.5 nmol/l (n = 33)	>37.5 nmol/l (n = 61)	p Value
Age, y	72.27 ± 2.27	71.54 ± 2.00	.110
Weight, kg	81.60 ± 12.38	77.46 ± 11.20	.103
BMI, kg/m^2	28.36 ± 3.72	26.67 ± 3.39	.028*
Waist circumference, cm	98.98 ± 8.83	94.25 ± 9.17	.017*
Appendicular muscle mass, kg†	21.89 ± 2.54	21.12 ± 2.81	.195
Arm strength, kg	11.24 ± 2.81	11.07 ± 4.23	.842
Leg strength, kg	17.81 ± 6.38	18.15 ± 5.50	.786
6-min walking test, m	379.12 ± 82.99	397.88 ± 60.32	.214
Physical functioning‡	85.91 ± 10.57	86.21 ± 15.48	.922
Physical problems‡	63.64 ± 34.28	64.66 ± 40.56	.903

Notes: Values are means ± standard deviation. BMI = body mass index.
†Measured by dual-energy x-ray absorptiometry.
‡Evaluated by two items of the Short Form 36 Health Survey Questionnaire.
*$p < .05$.

In our study, a significant association between vitamin D and muscle strength was found in elderly women, even after adjusting for BMI, albumin, appendicular FFM, and season, showing an effect of vitamin D on muscle independent of nutritional status.

Several mechanisms could support a relation between vitamin D and muscle strength. Biopsies taken before and after treatment with vitamin D revealed an increase in the relative number and cross-sectional area of fast-twitch fibers with treatment (31). In our population, no association was found between FFM measured by DXA (in particular between appendicular FFM) and 25(OH)D. Therefore, the relation between muscle strength and vitamin D could possibly be explained by quality modifications of skeletal muscle rather than by quantitative changes. 1,25-dihydroxyvitamin D_3 in skeletal muscle cells seems to promote calcium release from inner stores (36,37) and to modulate muscle cell metabolism and growth (38,39); an indirect effect of vitamin D on skeletal muscle through the secretion of insulin has also been suggested (40).

Our study failed to observe any relation between 25(OH)D, muscle strength, and reported disability in men. Several factors may explain this negative result. The smaller number of men enrolled in our study, compared with the number of women, and the fact that only 18 men reported disability could be at least partially responsible. Moreover, it is possible to hypothesize that a nonlinear function describes the relationship between 25(OH)D and strength and that the vitamin D values of our men may be higher than a hypothetical threshold associated with impaired muscle function.

Few studies (30,31) have considered the effects of vitamin D on functional status, and these studies examined only subjects with manifest physical impairment. Our significantly lower values of 25(OH)D in women with mild disability than in women without disability confirm and complement the data of a recent report (28), which studied a healthy, community-dwelling population.

It is possible to hypothesize that the relation between vitamin D and muscle strength observed in our subjects might be an epiphenomenon (i.e., that less active people may be weaker and may have reduced sun exposure and consequently lower values of vitamin D). Actually, our findings have been observed in an independent, healthy, community-dwelling population of elderly individuals with only mild levels of physical impairment. It seems unlikely, therefore, that in this population, physical function could be so compromised as to account for differences in sun exposure and explain the finding of lower vitamin D levels in subjects with lower levels of strength.

Cross-sectional studies such as ours can only show associations; it is not possible to indicate cause/effect relationships. Controlled clinical trials will be necessary to confirm the role of vitamin D in influencing muscle function and physical performance.

In conclusion, this report shows that vitamin D is significantly related to impaired muscular function and reported disability in elderly community-dwelling women, independent of nutritional status. The possible relation between vitamin D, impaired muscular function, and reported disability merits great consideration because of the high prevalence of vitamin D deficiency in the elderly population and because of the possibility that the correction of hypovitaminosis D may improve functional status.

Acknowledgments

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