Vitamin D and physical performance in older men and women visiting the Emergency Department due to a fall

Nicole D.A. Boyé[1,2], Christian Oudshoorn[1], Nathalie van der Velde[1, 5], Esther M.M. van Lieshout[2], Oscar J. de Vries[6], Paul Lips[6], Ed F. van Beeck[3], Peter Patka [4], Tischa J.M. van der Cammen[1]

[1]Section of Geriatric Medicine, Department of Internal Medicine, [2]Department of Surgery-Traumatology, [3]Department of Public Health, and [4]Department of Emergency Medicine, Erasmus MC, University Medical Center Rotterdam, Rotterdam, The Netherlands. [5] Section of Geriatric Medicine, Department of Internal Medicine, Academic Medical Center, Amsterdam, The Netherlands. [6]Department of Endocrinology, VU University Medical Center, Amsterdam, The Netherlands.

Corresponding author

Dr. T.J.M. Van der Cammen

Erasmus MC, University Medical Center Rotterdam

PO Box 2040, 3000 CA Rotterdam

The Netherlands

Phone: +31 107035979

Fax: +31 107034768

E-mail: t.vandercammen@erasmusmc.nl

Alternate Corresponding Author

Nicole D.A. Boyé

E-mail: n.boye@erasmusmc.nl

Funding

This work was supported by a research grant from the Netherlands Organization for Health Research and Development (ZonMw) [grant number 170.885.607].

Vitamin D and physical performance

ABSTRACT

Background: Vitamin D deficiency is considered a key contributor to impaired physical performance. However, many studies demonstrating this relationship were conducted in female-only populations, and recent studies investigating men specifically found no association. Nevertheless, evidence regarding an underlying gender-specific mechanism is lacking.

Objectives: To investigate whether serum 25-hydroxy vitamin D [25(OH)D] is associated with physical performance in both men and women.

Design: Cross-sectional.

Setting: Community.

Participants: 616 older adults who visited the Emergency Department due to a fall.

Measurements: Physical performance was assessed with the Timed "Up & Go" test, the "Five Time Sit to Stand" test, handgrip strength, and the tandem stand test. Multivariate linear regression was used to assess the association between physical performance, and (log transformed) serum 25 (OH)D concentration, and adjust for potential confounders.

Results: In men, the serum 25(OH)D concentration was significantly associated with better handgrip strength, with a regression coefficient (B) and [95% CI] of 3.86 [2.04; 5.69], faster TUG times -2.82 [-4.91; -0.73], and faster FTSS times -3.39 [-5.67; -1.11]. In women, a higher serum 25(OH)D concentration was significantly associated with faster TUG times -2.68 [-4.87; -0.49].

Conclusion: In the present study, we found a positive association between vitamin D and physical performance in both men and women. Intervention studies are needed which include vitamin D deficient, older, community-dwelling men and women, to further investigate the effect of vitamin D supplementation in this particular group.

Key words: older adults, physical performance, vitamin D, falls, strength

INTRODUCTION

A decrease in physical performance, such as impaired mobility, reduced muscle strength or poor balance, predisposes to falls and related injuries (1-3). Furthermore, it results in loss of quality of life (4), threatens functional independence (5-7), and increases the risk of morbidity and mortality (8, 9). Therefore, identification of modifiable causes of physical impairment can aid in the prevention of decline of functional-independence, future falls, associated morbidity, and loss of quality of life (10).

Muscle tissue is an important target tissue of vitamin D (11). Furthermore, vitamin D deficiency has been shown to be a key contributor to a decline in physical performance and increase in fall incidence (12-19). However, most studies demonstrating the relationship between vitamin D levels and physical performance were conducted in female-only populations (12, 15-18). In addition, recent studies investigating the relationship between serum 25(OH)D levels and physical performance in men found no significant associations (20, 21). However, these studies were conducted in a population of highly functional, younger men with a low prevalence of vitamin D deficiency. Furthermore, evidence regarding an underlying gender-specific mechanism is lacking.

Therefore, we assessed whether serum 25(OH)D was associated with physical performance in community-dwelling older men and women who visited the emergency department (ED) after experiencing a fall. We hypothesized that this association is as strong in men as previously demonstrated in women.

METHODS

Data collection

For this study, baseline data of the IMPROveFALL study were used, a detailed description of the methods can be found elsewhere (22). In short, patients meeting the following inclusion criteria were eligible for enrolment: aged 65 years or older, visited the ED due to a fall, use of one or more fall-risk increasing drugs (22-26); Mini-Mental State Examination (MMSE) score of at least 21 out of 30 points (27), ability to walk independently, community dwelling, and provision of written informed consent by patient. Enrolment started in October 2008 and was completed in October 2011. The local Medical Research Ethics Committee approved the study protocol.

Covariates

A fall was defined as coming to rest unintentionally on the ground or a lower level with or without losing consciousness, but not induced by acute medical conditions, *e.g.* stroke, or exogenous factors such as a traffic accident (28). At the baseline assessment, a geriatric assessment was performed. Medical history, prescription medication, supplements and lifestyle factors (*e.g.*, education, smoking, and alcohol intake) were documented. The number of comorbidities was derived from the following chronic comorbidities: any malignancy, diabetes mellitus, cardiac disease (*i.e.* hypertension, myocardial infarction, cardiomyopathy, congestive heart failure, arrhythmia, and valve disease), chronic obstructive pulmonary disease, stroke, neurological disorders (*i.e.* Parkinson's disease, epilepsy, neuropathy, myopathy, spinal disc herniation, and multiple sclerosis), peripheral vascular disease, renal insufficiency, and arthritis. Collected data were verified with records from the patient's general physician and local pharmacist. Height and weight were measured using standardized equipment and procedure. Body mass index (BMI) was calculated as body weight (in kilograms) divided by height^2 (in meters).

Biochemistry

Non-fasting blood samples were collected at the baseline assessment. Serum 25(OH)D_3 levels (in nmol/l) were measured using a radio-immuno-assay (DiaSorin, Saluggia (Vercelli) - Italy). Intra-assay and inter-assay coefficients of variation were <10%. Serum 25(OH)D groups were chosen based on levels of vitamin D deficiency as described in the literature (11, 29); i.e. severe vitamin D deficiency < 25 nmol/l, moderate vitamin D deficiency 25 – 49.9 nmol/L, and sufficient vitamin D levels, of 50-74.9 nmol/L, and ≥ 75 nmol/L.

Physical performance

Physical performance was assessed with handgrip strength measurements, the Timed "Up & Go" (TUG) test, the Five Time Sit to Stand (FTSS) test, and the tandem stand test. Handgrip strength (30), was measured in kilograms using a digital strain-gauged dynamometer (Takei TKK 5401, Takei Scientific Instruments Co, Ltd., Tokyo, Japan). The participant was asked to stand upright with arms hanging beside his or her body. Subsequently, grip strength was measured with the left and right hand. In the TUG test (32), time was measured while the participant stood up from a sitting position, walked three meters along a line, performed a 180 degree turn, walked back to the chair and sat down, as fast as safely possible. In the FTSS test (3, 31), time was measured while the participant stood up and sat down five consecutive times, as fast as safely possible. The participant was not permitted to use their hands or the chair's arm supports during standing up or sitting down. In the tandem stand test, the participant had to stand fully independent for 10 seconds with one foot in front of the other.

The test was scored as completed (1) or failed (0) (31). All tests were performed twice and the best score was recorded.

Statistical analysis

All analyses were performed using the Statistical Package of the Social Sciences (SPSS version 17.0, Chicago, Ill.). Baseline characteristics were compared using Student t-test analyses for continuous variables and chi-square analyses for dichotomous variables. Linear regression and binary logistic regression models were constructed to adjust for potential confounders. The crude model was solely age-adjusted. Potential confounders that were considered for inclusion in the multivariate model besides age, were number of comorbidities, degree of urbanization, marital status, level of education, current or past smoker, alcohol units p/day, MMSE, and BMI. Confounders that led to a change in the regression coefficient (B) of 10% or more were retained in the multivariate-adjusted regression model. Participants with incomplete or missing performance test measures were excluded from related analyses, handgrip strength (n=7), TUG test (n=55), FTSS test (n=95), and the tandem stand test (n=4). Missing measures were mostly due to injuries following fall (e.g. upper or lower extremity fractures), or pre-existing conditions. Due to a right-skewed distribution, serum 25-(OH)D levels were log transformed (natural log) for the regression models. Furthermore, a general linear model (GLM) was used to multivariately compare all continuous outcomes, and chi-square analyses to compare the tandem stand outcomes. All analyses were stratified by gender, and a p-value < 0.05 was considered statistically significant.

RESULTS

In total, 616 participants were enrolled in the IMPROveFALL study. Serum 25(OH)D concentration was obtained from 600 participants, 230 (38%) men and 370 (62%) women respectively. The gender-specific baseline characteristics are shown in Table 1; the mean age was 76 years with a standard deviation (SD) of 7. The mean ± SD serum 25(OH)D concentration was 59 ± 29 nmol/L. Stratification according to vitamin D status is shown in Table 2. Of the participants, 55 (9%) had severe vitamin D deficiency (25(OH)D < 25 nmol/L), 209 participants (35%) had moderate vitamin D deficiency (25(OH)D 25-49.9 nmol/L), 172 participants (29%) were vitamin D-sufficient and had 25(OH)D levels of 50-74.9 nmol/L, and 164 participants (27%) had 25(OH)D levels ≥ 75 nmol/L.

Regression models of the physical performance according to log-transformed serum 25(OH)D concentration were constructed (Table 3). The results for the men were as follows, in the fully adjusted model a higher serum 25(OH)D concentration was significantly associated with better handgrip strength, with a regression coefficient (B) and [95% CI] of 3.86 [2.04; 5.69], faster TUG times -2.82 [-4.91; -0.73], and faster FTSS times -3.39 [-5.67; -1.11]. In women, a higher serum 25(OH)D concentration was significantly associated with faster TUG times -2.68 [-4.87; -0.49].

A general linear model was used in order to compare the means of the handgrip strength, TUG, and FTSS (Figure 1 A, B and C) according to gender and vitamin D group. The percentage of completed tandem stands according to vitamin D group in men was 68%, 59%, 64% and 86% respectively, $p = 0.009$. The percentage of completed tandem stands according to vitamin D group in women was 44%, 61%, 66% and 63% respectively, $p = 0.153$.

DISCUSSION

As was hypothesized, serum 25(OH)D levels were significantly associated with physical performance, not only in community-dwelling older women, but also in men.

As mentioned in the introduction, there are several studies which have demonstrated the relationship between vitamin D and physical performance (15-21, 33, 34). Although most of these were conducted with female-only populations (15-18), some studies including both men and women had similar results (12, 33).This includes a 3-year follow-up study which reported poorer physical performance and a greater decline in physical performance in older vitamin D deficient men and women (19). However, recent studies investigating men specifically did not find an association between vitamin D levels and physical performance (20, 21, 34). Lack of an association in the previously mentioned populations may be due to the target population; young, healthy men, and the low prevalence of vitamin D deficiency (20, 21, 34). Our population consisted of older men with a mean age of 76 years, of which a large proportion was vitamin D deficient, 44% had 25(OH)D levels <50 nmol/L. Making it a particularly adequate population to investigate the relationship between vitamin D and physical performance. Furthermore, community-dwelling elderly who have recently experienced a fall are certainly part of the target group, which have the greatest need for fall prevention strategies. A recent meta-analysis assessing the effects of interventions designed to reduce the incidence of falls in older people living in the community observed that only trials recruiting participants with lower vitamin D levels at enrolment had a reduction in rate of falls and risk of falling (35).

The following limitations should be taken into account when interpreting our results. First, the cross-sectional design of the study limits the ability to infer a causal relationship between serum 25(OH)D levels and physical performance, and does not dismiss the possibility of reverse causality. Nevertheless, the comparable population characteristics argue against this, all participants had experienced a recent fall and were community-dwelling (similar frailty). Furthermore, similar to previous studies, the analyses were multivariately adjusted for a wide range of confounders including comorbidities and BMI (with the exception of nutrition and physical activity). Second, serum parathyroid hormone (PTH) levels were not determined. Vitamin D deficiency leads to an increase of serum PTH which increases bone turnover and bone loss, and is related to a decrease in muscle strength (36). Third, the use of the MMSE as an exclusion criterion could have resulted in the exclusion of the frailest persons. A major strength of this study is the substantial proportion of the participants deficient in vitamin D included in the study, which enabled analysis of the physical performance in both vitamin D deficient and sufficient men and women.

In addition, it was striking to note how few of the older fallers in our study were prescribed vitamin D supplements, especially in the male population; though 44% of the men and women were deficient in vitamin D, only 6% of the men and 17% of the women used vitamin D supplements. The under-prescribing of vitamin D in this age group has previously been reported (37). Yet, despite evidence that vitamin D supplementation has been shown to increase muscle strength and reduce the risk of falls (38), vitamin D deficiency is still common in community-dwelling elderly, with a prevalence of 40-100% in U.S. and European older men and women (11). Furthermore, while we set the levels ≥50 nmol/L as vitamin D sufficient, another opinion is that optimal vitamin D levels should be ≥75 nmol/L (39). This is interesting to note when considering figure 1, where it seems levels closer to 75 nmol/L result in continued physical performance benefits, especially in men.

In conclusion, in the present study higher serum 25(OH)D concentrations were associated with better strength and physical performance in community-dwelling older men and women.

Intervention studies are needed to further investigate the effect of vitamin D supplementation in this particular group.

ACKNOWLEDGEMENTS

Conflict of Interest Disclosure

Elements of Conflicts	NB	CO	NvdV	EvL	OdV	PL	EvB	PP	TvdC
Employment or Affiliation	No	No	No	No	No	No	No	No	No
Grants/Funds	No	No	No	No	No	Yes*	No	No	No
Honoraria	No	No	No	No	No	No	No	No	No
Speaker Forum	No	No	No	No	No	No	No	No	No
Consultant	No	No	No	No	No	No	No	No	No
Stocks	No	No	No	No	No	No	No	No	No
Royalties	No	No	No	No	No	No	No	No	No
Expert Testimony	No	No	No	No	No	No	No	No	No
Board Member	No	No	No	No	No	No	No	No	No
Patents	No	No	No	No	No	No	No	No	No
Personal Relationship	No	No	No	No	No	No	No	No	No

* Merck & Co. Grant for the LASA trial; used for the serum vitamin D laboratory measurements. Not a conflict of interest, grant was allotted to other trial.

Author Contributions

N.D.A. Boyé: study design, enrolment of participants, acquisition, analysis, and interpretation of data, and preparation of manuscript.

C. Oudshoorn: analysis and interpretation of data, and preparation of manuscript.

N. Van der Velde: study design, enrolment of participants, analysis and interpretation of data, and preparation of manuscript.

E.M.M. Van Lieshout: study design, interpretation of data, and preparation of manuscript.

O.J. De Vries: enrolment of participants, acquisition of data, and revision of manuscript.

P. Lips: enrolment of participants, acquisition of data, and revision of manuscript.

E.F. Van Beeck: study design, interpretation of data, and revision of manuscript.

P. Patka: study design, interpretation of data, and revision of manuscript.

T.J.M. Van der Cammen: study design, enrolment of participants, interpretation of data, and revision of manuscript.

All authors approved the final version of the manuscript.

We thank Eunice Comvalius, medical student, for her assistance with data collection and manuscript preparation.

Sponsor's Role

None.

REFERENCES

1. Tinetti ME, Baker DI, McAvay G, et al. A multifactorial intervention to reduce the risk of falling among elderly people living in the community. N Engl J Med 1994;331(13):821-7.
2. Toraman A, Yildirim NU. The falling risk and physical fitness in older people. Arch Gerontol Geriatr 2009;51(2):222-6.
3. Whitney SL, Wrisley DM, Marchetti GF, et al. Clinical measurement of sit-to-stand performance in people with balance disorders: validity of data for the Five-Times-Sit-to-Stand Test. Phys Ther 2005;85(10):1034-45.
4. Takata Y, Ansai T, Soh I, et al. Quality of life and physical fitness in an 85-year-old population. Arch Gerontol Geriatr 2009;50(3):272-6.
5. Giampaoli S, Ferrucci L, Cecchi F, et al. Hand-grip strength predicts incident disability in non-disabled older men. Age Ageing 1999;28(3):283-8.
6. Guralnik JM, Ferrucci L, Simonsick EM, et al. Lower-extremity function in persons over the age of 70 years as a predictor of subsequent disability. N Engl J Med 1995;332(9):556-61.
7. Hairi NN, Cumming RG, Naganathan V, et al. Loss of muscle strength, mass (sarcopenia), and quality (specific force) and its relationship with functional limitation and physical disability: the Concord Health and Ageing in Men Project. J Am Geriatr Soc 2010;58(11):2055-62.
8. Al Snih S, Markides KS, Ray L, et al. Handgrip strength and mortality in older Mexican Americans. J Am Geriatr Soc 2002;50(7):1250-6.
9. Bohannon RW. Hand-grip dynamometry predicts future outcomes in aging adults. J Geriatr Phys Ther 2008;31(1):3-10.

10. Hartholt KA, van Beeck EF, Polinder S, et al. Societal consequences of falls in the older population: injuries, healthcare costs, and long-term reduced quality of life. J Trauma 2010;71(3):748-53.

11. Holick MF. Vitamin D deficiency. N Engl J Med 2007;357(3):266-81.

12. Bischoff-Ferrari HA, Dietrich T, Orav EJ, et al. Higher 25-hydroxyvitamin D concentrations are associated with better lower-extremity function in both active and inactive persons aged > or =60 y. Am J Clin Nutr 2004;80(3):752-8.

13. Dukas L, Bischoff HA, Lindpaintner LS, et al. Alfacalcidol reduces the number of fallers in a community-dwelling elderly population with a minimum calcium intake of more than 500 mg daily. J Am Geriatr Soc 2004;52(2):230-6.

14. Gallagher JC, Fowler SE, Detter JR, et al.Combination treatment with estrogen and calcitriol in the prevention of age-related bone loss. J Clin Endocrinol Metab 2001;86(8):3618-28.

15. Gerdhem P, Ringsberg KA, Obrant KJ, et al. Association between 25-hydroxy vitamin D levels, physical activity, muscle strength and fractures in the prospective population-based OPRA Study of Elderly Women. Osteoporos Int 2005;16(11):1425-31.

16. Okuno J, Tomura S, Yabushita N, et al. Effects of serum 25-hydroxyvitamin D(3) levels on physical fitness in community-dwelling frail women. Arch Gerontol Geriatr 2010;50(2):121-6.

17. Pfeifer M, Begerow B, Minne HW, et al. Vitamin D status, trunk muscle strength, body sway, falls, and fractures among 237 postmenopausal women with osteoporosis. Exp Clin Endocrinol Diabetes 2001;109(2):87-92.

18. Stewart JW, Alekel DL, Ritland LM, et al. Serum 25-hydroxyvitamin D is related to indicators of overall physical fitness in healthy postmenopausal women. Menopause 2009;16(6):1093-101.

19. Wicherts IS, van Schoor NM, Boeke AJ, et al. Vitamin D status predicts physical performance and its decline in older persons. J Clin Endocrinol Metab 2007;92(6):2058-65.

20. Ceglia L, Chiu GR, Harris SS, et al. Serum 25-hydroxyvitamin D concentration and physical function in adult men. Clin Endocrinol (Oxf) 2011;74(3):370-6.

21. Dam TT, von Muhlen D, Barrett-Connor EL. Sex-specific association of serum vitamin D levels with physical function in older adults. Osteoporos Int 2009;20(5):751-60.

22. Hartholt KA, Boyé NDA, Van der Velde N, et al. [Cost]effectiveness of withdrawal of fall-risk increasing drugs versus conservative treatment in older fallers: design of a multicenter randomized controlled trial (IMPROveFALL-study). BMC Geriatr 2011;11:48.

23. Leipzig RM, Cumming RG, Tinetti ME. Drugs and falls in older people: a systematic review and meta-analysis: II. Cardiac and analgesic drugs. J Am Geriatr Soc 1999;47(1):40-50.

24. Leipzig RM, Cumming RG, Tinetti ME. Drugs and falls in older people: a systematic review and meta-analysis: I. Psychotropic drugs. J Am Geriatr Soc 1999;47(1):30-9.

25. van der Velde N, Stricker BH, Pols HA, et al. Risk of falls after withdrawal of fall-risk-increasing drugs: a prospective cohort study. Br J Clin Pharmacol 2007;63(2):232-7.

26. Woolcott JC, Richardson KJ, Wiens MO, et al. Meta-analysis of the impact of 9 medication classes on falls in elderly persons. Arch Intern Med 2009;169(21):1952-60.
27. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12(3):189-98.
28. The prevention of falls in later life. A report of the Kellogg International Work Group on the Prevention of Falls by the Elderly. Dan Med Bull 1987;34 Suppl 4:1-24.
29. Lips P. Vitamin D deficiency and secondary hyperparathyroidism in the elderly: consequences for bone loss and fractures and therapeutic implications. Endocr Rev 2001;22(4):477-501.
30. Campbell AJ, Borrie MJ, Spears GF. Risk factors for falls in a community-based prospective study of people 70 years and older. J Gerontol 1989;44(4):M112-7.
31. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49(2):M85-94.
32. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39(2):142-8.
33. Dhesi JK, Jackson SH, Bearne LM, et al. Vitamin D supplementation improves neuromuscular function in older people who fall. Age Ageing 2004;33(6):589-95.
34. Kenny AM, Biskup B, Robbins B, et al. Effects of vitamin D supplementation on strength, physical function, and health perception in older, community-dwelling men. J Am Geriatr Soc 2003;51(12):1762-7.

35. Gillespie LD, Robertson MC, Gillespie WJ, et al. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012 Sep 12;9:CD007146. doi: 10.1002/14651858.CD007146.pub3.

36. Oudshoorn C, van der Cammen TJ, McMurdo ME, et al. Ageing and vitamin D deficiency: effects on calcium homeostasis and considerations for vitamin D supplementation. Br J Nutr 2009;101(11):1597-606.

37. Lang PO, Hasso Y, Drame M, et al. Potentially inappropriate prescribing including under-use amongst older patients with cognitive or psychiatric co-morbidities. Age Ageing 2012;39(3):373-81.

38. Bischoff-Ferrari HA, Dawson-Hughes B, Willett WC, et al. Effect of Vitamin D on falls: a meta-analysis. Jama 2004;291(16):1999-2006.

39. Dawson-Hughes B, Heaney RP, Holick MF, et al. Estimates of optimal vitamin D status. Osteoporos Int 2005;16: 713-716.

TABLES

Table 1. Baseline characteristics according to gender

		Men (n=230)	Women (n=370)	***p*-value**
Age (years)		76.4 ± 6.7	76.5 ± 7.0	0.820
Serum 25(OH)D		58.9 ± 30.9	58.7 ± 27.8	0.939
Mini Mental State Examination score		27.0 ± 2.3	26.9 ± 2.4	0.716
Body mass index (kg/m^2)		27.1 ± 3.9	27.9 ± 4.9	0.027
Level of education (secondary)		185 (80)	250 (68)	<0.001
Degree of urbanization (urban)		190 (83)	323 (87)	0.142
Smoking				
	Current	28 (12)	40 (11)	0.609
	Past	152 (66)	122 (33)	<0.001
	Never	76 (33)	245 (66)	<0.001
Alcohol units p/day				<0.001
	0	92 (40)	212 (57)	
	<1	24 (10)	63 (17)	
	1-3	66 (29)	78 (21)	
	>3	48 (21)	17 (5)	
Vitamin D supplements		14 (6)	61 (17)	<0.001
Number of comorbidities		2.1 ± 1.2	2.1 ± 1.2	0.654
Number of medications		5.9 ± 2.9	6.5 ± 3.5	0.027
Number of FRIDs		2.5 ± 1.5	2.7 ± 1.6	0.378

Data are given as mean values ± standard deviation, or as number (percentages). FRID: fall-risk increasing drugs.

Table 2. Serum 25 (OH)D groups stratified by gender

	Men (n=230)		**Women** (n=370)	
25(OH)D < 25 nmol/L	19	(8)	36	(10)
25(OH)D 25 – 49.9 nmol/L	83	(36)	126	(34)
25(OH)D 50 – 74.9 nmol/L	72	(31)	100	(27)
25(OH)D ≥ 75 nmol/L	56	(24)	108	(29)

Data are shown as number (percentage)

Table 3. Results of regression analysis of strength and physical performance according to log transformed serum 25 (OH)D concentration and gender

	Model 1		Model 2	
Men (n* = 230*)				
Handgrip strength (n=228)	4.02	[2.30; 5.75]***	3.86	[2.04; 5.69]***
Timed “Up & Go” (n=211)	-3.02	[-5.03; -1.02]**	-2.82	[-4.91; -0.73]**
Five Time Sit to Stand (n=197)	-3.11	[-5.27; -0.94]**	-3.39	[-5.67; -1.11]**
Tandem stand (n=230)	0.59	[1.05; 3.11]*	0.55	[0.93; 3.19]
Women (n* = 370*)				
Handgrip strength (n=365)	0.80	[-0.13; 1.72]	0.67	[-0.26; 1.61]
Timed “Up & Go” (n=334)	-3.19	[-5.34; -1.04]**	-2.68	[-4.87; -0.49]*
Five Time Sit to Stand (n=308)	-2.69	[-4.90; -0.49]*	-2.13	[-4.30; 0.04]
Tandem stand (n=366)	0.15	[0.77; 1.76]	0.04	[0.68; 1.59]

Data are shown as B with the 95% confidence interval between square brackets.

Model 1: adjusted for age. Model 2: adjusted for age, number of comorbidities, smoking, degree of urbanization, body mass index, and Mini Mental State Examination score. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

FIGURE LEGENDS

Figure 1. Strength and physical performance according to serum 25 (OH) D group and gender

General linear model analysis of the handgrip strength (A), Timed "Up & Go" test (B), and Five Time Sit to Stand test (C) with mean ± standard error. Adjusted for age, number of comorbidities, smoking, degree of urbanization, body mass index, and Mini Mental State Examination score.