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Effects of serum 25-hydroxyvitamin D_3 levels on physical fitness in community-dwelling frail women

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Abstract

The aim of this study was to evaluate the effects of a combination of serum 25-hydroxyvitamin D_3 (25(OH)D_3) levels and exercise on physical fitness in community-dwelling frail elderly in Japan. A longitudinal survey was conducted in a town (latitude 36^o north). Eighty women aged 65 years and over attended a 3-month exercise class. A face-to-face interview was conducted based on a questionnaire. The serum levels of 25(OH)D_3, intact parathyroid hormone (iPTH), were measured. Nine physical fitness tests were performed at baseline and at the end of a 3-month follow-up period. Among 80 subjects, 56.3% experienced falls, and 71.3% experienced stumbling more than once during the past year. The prevalence of 25(OH)D_3 < 50 nmol/l or 25(OH)D_3 < 75 nmol/l was 27.5% and 88.8%, respectively. Significantly greater improvements in alternate step, functional reach (FR), "timed up & go" (TUG), and 5-m walk, and superior functional capacity for the subjects with 25(OH)D_3 levels greater than 67.5 nmol/l (highest quartile) was observed at the end of the class. In contrast, the subjects with 25(OH)D_3 levels < 47.5 nmol/l (lowest quartile) did not improve their physical fitness. A serum 25(OH)D_3 level of greater than 47.5 nmol/l may therefore be necessary to maintain walking ability and balance. Greater than 67.5 nmol/l appears to be preferable for lower extremity strength in Japanese frail elderly women.

Keywords: 25-hydroxyvitamin D_3, Physical fitness, Frail elderly women, Exercise

1. Introduction

In April 2000, the 'Long-term Care Insurance System,' i.e., a public nursing care insurance system, was launched in Japan in order to provide nursing care services for the frail elderly. The current problem with this system is that even when nursing care services or supports are offered to frail elderly, their levels of functional capacity are often not improved as expected, and the system users' functional capacity levels have declined in many cases. We therefore need to develop more effective services for this population. Falls and fractures are the main causes of long-term care, accounting for approximately 28% of the disorders leading to long-term care according to the Report on the Comprehensive Survey of Living Condition of the People on Health and Welfare in 2004. The prevalence of hip fracture has increased 2.2-fold in the past 15 years (Yoshimura et al., 2005), and 80% of hip fractures in Japan are caused by falls according to the Committee for Osteoporosis Treatment of The Japanese Orthopaedic Association.

Low levels of serum 25(OH)D_3 and high levels of serum parathyroid hormone (PTH) are considered to represent vitamin D deficiency (Ooms et al., 1995), which is an important risk factor for osteoporosis (van der Wielen et al., 1995) and is associated with body sway and falls in the elderly (Pfeier et al., 2000; Gillespie et al., 2001; Dhesi et al., 2002; Bischoff et al., 2003). Proximal muscle weakness is a prominent feature of the clinical syndrome of vitamin D deficiency (Glerup et al., 2000), and muscle weakness is a major risk factor for falls in the elderly (Moreland et al., 2004). Vitamin D supplementation might prevent falls and fractures (Bischoff-Ferrari et al., 2004a), although contradictory study results exist (Porthouse et al., 2005).

Vitamin D has captured attention as an important determinant of bone health, but there is no common definition of optimal vitamin D status. Opinions regarding the minimum level of serum 25(OH)D_3 that is optimal for fracture prevention have varied between 50 and 80 nmol/l, and a threshold of 75 nmol/l has been proposed as the serum 25(OH)D_3 concentration at which older men and women will be at a lower risk of fracture (Dawson-Hughes et al., 2005). Bischoff-Ferrari (2007) has reported that an optimal dose of vitamin D should raise serum concentrations of 25(OH)D_3 to the desirable range of at least 75 nmol/l.

Although the role of vitamin D in maintaining skeletal health is well known, knowledge about its role in relation to physical fitness is still limited, and it is unknown whether vitamin D status can predict the ability to maintain physical fitness. Many previous studies have been cross-sectional studies (Okuno et al, 2007), with few longitudinal studies examining the relationship between 25(OH)D_3 and physical fitness. Population and case-control studies in older people have shown that low serum 25(OH)D_3 is related to a decrease in lower-extremity muscle strength (Bischoff et al., 1999; Zamboni et al., 2002), a poorer physical performance (Pfeifer et al., 2001; Gerdhem et al., 2005), or a great decline over 3 years in physical performance (Wicherts et al., 2007). However, not all studies support these results (Verreault et al., 2002; Kenny et al., 2003).

With this in mind, the present study was undertaken to evaluate the association of serum 25(OH)D_3 levels with physical fitness in community-dwelling frail elderly.

2. Subjects and methods

2.1. Subjects

This study was a longitudinal survey of community-dwelling Japanese frail elderly, aged 65 years and over, who attended a 3-month exercise class. This study was conducted in a town near Tsukuba City in Ibaraki Prefecture, located 60 km north of Tokyo in Japan (latitude 36° north) from 2006 to 2007 in the form of a nursing care prevention program. Participants were selected from a medical examination in the community. A total of 125 frail elderly who were authorized as “Specified elderly people (tokuteikoureisya)” (Tsutsui and Muramatsu, 2007), who were not certified by the Long-term Care Insurance System, participated in the study. The elderly assessed as “Specified elderly people” met at least 3 of 5 criteria (difficulties in rising from a chair, in ascending and descending the stairs, in walking 15 minutes without rest, an experience of fall in the past 1 year, and fear of fall) by the Japanese Ministry of Health, Labour, and Welfare. If these elderly were not provided any appropriate support programs, they would be expected to become elderly requiring “long-term care supports or services.”

The exclusion criteria included elderly with severe dementia, those being prohibited from exercise by a physician, those taking a vitamin D supplement or an activated form of vitamin D, and men. The Ethics Committee of the University of Tsukuba approved the study, and informed consent for participation was obtained from all participants.

2.2. Measurements

The following assessments were carried out at baseline and at the end of a 3-month follow-up. A face-to-face interview was conducted based on a questionnaire that asked about age, gender, activity of daily living (ADL) based on the Barthel Index (Wade and Collin, 1988), self-rated physical performance (e.g., Can you walk independently? Can you rise from a chair without support?), the Tokyo Metropolitan Institute of Gerontology (TMIG) index of competence as a reflection of high-level functional capacity with scores less than 10 being regarded as having an inferior functional capacity (Koyano et al., 1993), experiences of falls, stumbling or body sway during the past year, frequency of going outside of the home, vitamin D supplementation or activated form of vitamin D, and cognitive impairment as assessed by the mini-mental state examination (MMSE) (Folstein et al., 1975).

2.3. Exercise classes

An exercise class was held in which subjects were taught a comprehensive program with group exercise and a home-based exercise on physical fitness. Subjects participated in a 90-min group exercise session (actual exercise duration was approximately 45 min) each week for 14 weeks and performed a home-based routine exercise every day.

Low-intensity combined exercise programs for nursing care prevention consisted of warming up (stretching exercise and shoulder rotation), main exercise (balance, mobility while sitting on a chair, exercise improving ADL, and recreational activities), and cool-down. Subjects were encouraged to walk at home.

2.4. Laboratory investigation

The serum concentrations of 25(OH)D_3 were used as a measure of vitamin D status (Lips, 2001). Serum 25(OH)D_3 concentrations were assayed with radioimmunoassay kits (RIA kit; DiaSorin). The inter-assay coefficient of variation (CV) was 2.5-5.8%, and the intra-assay CV was 5.2-5.8%. Serum concentrations of iPTH were measured by the electrochemiluminescence immunoassay (Roche

Diagnostics, Mannheim Germany). Intra- and inter-assay CVs were 2.3-4.3% and 2.7-3.8%, respectively. The serum concentrations of calcium, creatinine, and albumin were measured using an auto-analyzer. All blood samples were taken between 10:30 a.m. and 12:30 p.m. after the subject ate a light breakfast.

2.5. Physical fitness tests

Physical performance was assessed by means of nine performance tests: for walking ability, a TUG and a 5-m walk; for balance, FR, a one-legged stance with open eyes, tandem stance, and tandem walk; for muscular strength, hand grip strength, alternate step, and 5 chair sit-to-stands. Two trials of these tests were carried out, and the average values were used in the statistical analysis. TUG consisted of 4 physical performances correlated with falling. Each subject was observed and timed while he or she rose from an armchair, walked 3 m, turned, walked back, and sat down again (better performance at lower time required) (Podsiadlo and Richardson, 1991). Tandem stance: the ability to stand with the heel of one foot directly in front of, and touching the toes of, the other foot for a maximum of 30 sec (Rossiter-Fornoff et al., 1995). Tandem walk: subjects were instructed to place one foot in front of the other, ensuring that with each step, the heel of one foot was directly in front of the toes of the other foot and to walk forward as fast as possible without falling or making a mistake. In addition, the number of mistakes (stepping off the line, touching another object, or taking steps with the heel and toe visibly separated) was also recorded (Nevitt et al., 1989). A composite measure was calculated by summing the time and number of mistakes, with higher scores indicating poorer performance. 5 chair sit-to-stands: subjects were asked to stand up and sit down 5 times as quickly as possible. The time was measured from the initial sitting position to the final fully erect position at the end of the fifth stand (Guralnik et al., 1994). Alternate step: subjects were asked to step alternately 8 times with each leg onto a raised platform (19 cm high). The time taken to alternately place each foot on a 19-cm high step 8 times was measured (Menz and Lord, 2001).

2.6. Statistical analysis

Data are presented as mean ± S.D. The subjects were categorized according to $25(OH)D_3$ quartiles. Differences among the 4 groups according to $25(OH)D_3$ levels were tested by one-way ANOVA and the χ^2-test for categorical variables. Spearman rank tests were used for correlations. To assess the changes in physical fitness between baseline and 3-month follow-up, the paired t-test was used, and for the comparison of physical fitness change (post - pre) among the 4 groups, one-way ANOVA was used for statistical testing. If there was a significant difference among groups on specific variables at the baseline, the variable was used as a covariate in the analysis. A post hoc test was carried out using the Bonferroni correction. The level of significance was set at $p < 0.05$. SPSS for Windows, version 12.0J, was used for the analyses.

3. Results

Among the 125 participants, 17 elderly did not participate in physical fitness tests at the end of the 3-month follow-up or refused biochemical investigation or took an activated form of vitamin D. Baseline data for age and the rate of gender did not differ significantly between the 17 non-participants and the 108 participants. After excluding men, we finally analyzed 80 women out of a total of 108 participants after the baseline examination. The characteristics of the women participants at baseline are shown in Table 1. The mean age (± S.D.) was 76.0 ± 5.4 years (range: 65 - 90). The average score of the Barthel Index was 97.2 ± 5.8, since many of our participants had difficulties, primarily in walking or going up and down stairs. Although 12.5% of women had difficulty in walking at home, 27.5% had difficulty in walking outside of the home. The incidence of having more than one fall during the past year and the prevalence of frequent stumbling were 56.3% and 71.3%, respectively. Thirty-four percent of the elderly were housebound, and 41.3% were assessed as having an inferior functional capacity, which means elderly people have difficulty living in the community independently. The mean $25(OH)D_3$ level of all subjects was

57.5 (±13.4) nmol/l (range: 27.5-92.5), and the intact PTH level was 41.9 ±16.2 pg/ml (range: 15.0-85.0). The prevalences of 25(OH)D_3 < 50 nmol/l and of 25(OH)D_3 < 75 nmol/l were 27.5% and 88.8%, respectively. The mean serum creatinine was 0.7 ± 0.2 mg/dl (range: 0.46-1.05). No subjects with highly impaired renal dysfunction were observed. The mean serum calcium was 9.3 ± 0.4 mg/dl (range: 8.2-10.7). No hypercalcemia was found, since hypercalcemia is defined as a serum calcium level above 12.0 mg/dl (Table 1).

The lowest quartile of 25(OH)D_3 was 47.5 nmol/l, and the highest quartile was 67.5nmol/l. The rates for the subjects with the lowest quartile of 25(OH)D_3, the second, the third, and the highest were 23.8%, 25.0%, 22.5%, and 28.8%, respectively. Baseline data for age, MMSE, serum albumin, 25(OH)D_3 level, the rate of experience of falls, and that of stumbling did not differ significantly among the 4 groups according to 25(OH)D_3 levels (Table 1). The rate of inferior functional capacity (TMIG scores < 10) (21.7%), difficulty in rising from lying (13.0%), and difficulty in walking at home (4.3%) were significantly lower in the highest quartile of 25(OH)D_3 level compared to other groups.

Serum 25(OH)D_3 levels were negatively correlated with age, and lower 25(OH)D was correlated with inferior one-legged stance. After adjusting for age, the relationship was still found to be significant (Table 2).

A comparison of physical fitness among the 4 groups according to 25(OH)D_3 quartile levels is shown in Table 3. Baseline data for physical fitness except for one-legged stance did not differ significantly among the 4 groups. Five of 9 physical fitness tests such as alternate step, 5 chair sit-to-stands, TUG, 5-m walk, and tandem walk were improved in all subjects after attending the 3-month exercise class. We compared changes in physical fitness between baseline and 3-month follow-up in each of the 4 groups (Table 3). There was no significant improvement in physical fitness in the group with 25(OH)D_3< 47.5 nmol/l. One-legged stance and 5 chair sit-to-stand tended to decline, but this trend was not statistically significant. In the group with 47.5 nmol/l < 25(OH)D_3 < 60.0 nmol/l, one-legged stance, 5 chair sit-to-stand, TUG, 5-m walk, and tandem walk were significantly improved. In the group with 60.0 nmol/l <25(OH)D_3 < 67.5 nmol/l, alternate step and tandem walk were significantly improved. The group in the highest quartile of 25(OH)D_3 levels greater than 67.5 nmol/l significantly improved in alternate step, FR, TUG, and 5-m walk.

Changes (post - pre) in alternate step were significantly different among the 4 groups. There was a significant difference in the change in alternate step between the group with 47.5nmol/l < 25(OH)D_3 < 60.0 nmol/l and the group with 25(OH)D_3 greater than 67.5 nmol/l. After adjusting for age, the difference in the change in alternate step between the 2 groups was still significant.

4. Discussion

We investigated the effects of serum 25(OH)D_3 levels on physical fitness in community-dwelling Japanese specified elderly women aged 65 years and over attending an exercise class for nursing care prevention. Five items of physical fitness had improved at the end of the 3-month class. However, there were different patterns of effects in each of the 4 groups. The specified elderly women with 25(OH)D_3 levels below 47.5 nmol/l, which is the lowest quartile of serum 25(OH)D_3 levels, had no significant physical fitness improvements and those with 25(OH)D_3 levels over 67.5 nmol/l, which is the highest quartile, improved in 4 items of physical fitness such as alternate step, FR, TUG, and tandem walk.

Vitamin D deficiency has been classically diagnosed among individuals with little sunlight exposure such as elderly people, housebound individuals, and hospitalized individuals (Gloth et al., 1995). Approximately 33.8% of our subjects certified as specified elderly were housebound, i.e., went outside of the home less than once per week, and the mean level of 25(H)D_3 was 57.5 ± 13.4 nmol/l. The rates of 25(OH)D_3 < 50 nmol/l and < 75 nmol/l were 27.5% and 88.8%, respectively.

The definition of threshold levels of 25(OH)D_3 for vitamin D deficiency remains controversial, and there is no generally accepted criterion for vitamin D deficiency.

Proposals for adequate vitamin D status have frequently been made (Dawson-Hughes et al., 2005; Bischoff-Ferrari, 2007), but they are mainly based on levels of PTH and a few on physical fitness or muscle strength. Among older adults in the National Health and Nutrition Examination Study (NHANES) (Bischoff-Ferrari et al., 2004b), serum 25(OH)D_3 levels < 40 nmol/l were associated with poor physical performance on an 8-foot walk test and a sit-to-stand test measuring lower extremity strength compared to serum 25(OH)D_3 levels < 40 nmol/l in a cross-sectional study. Most of the improvement occurred in subjects with 25(OH)D_3 concentrations between 22.5 and approximately 40 nmol/l. However, further but less dramatic improvement was seen in the range of 40-94 nmol/. The authors concluded that at least 40 nmol/l should be achieved, but most advantageous are levels between 90 and 100 nmol/l. In the Longitudinal Aging Study Amsterdam including Dutch men and women age 65 and older, physical performance (sum score of the walking test, chair stands, and tandem stand) and decline in physical performance were measured, and they confirmed that participants with 25(OH)D_3 less than 10 ng/ml and 25(OH)D_3 between 10 and 20 ng/ml had significantly higher odds ratios (OR) for 3-year decline in physical performance compared with participants with 25(OH)D_3 of at least 30 ng/ml, and they confirmed that for physical performance, serum 25(OH)D_3 should be at least 50 nmol/l (Wicherts et al., 2007). In the Osteoporosis Prospective Risk Assessment study (OPRA, n = 986) of elderly ambulatory women in Sweden, women with low 25(OH)D_3 levels below 30 ng/ml (75 nmol/l) had inferior gait speed, poorer balance, and less activity than women with 25(OH)D_3 levels above this threshold (Gerdhem et al., 2005).

If an optimal level of 25(OH)D_3 is greater than 75 nmol/l, approximately 90% of Japanese specified elderly women in this study were in a state of vitamin D deficiency and insufficiency. We also found that the physical fitness levels of elderly women with 25(OH)D_3 levels less than 47.5 nmol/l at baseline did not improve or actually declined. In contrast, 4 items of physical fitness significantly improved for those with 47.5 nmol/l < 25(OH)D_3 < 60.0 nmol/l, and 2 for those with 60.0 nmol/l < 25(OH)D_3 < 67.5 nmol/l, 4 for those with 25(OH)D_3 < 67.5 nmol/l. It is suggested that serum $25(OH)D_3$ levels greater than 47.5 nmol/l might suggest a need for improvements in physical fitness. In addition, levels of $25(OH)D_3$ of 67.5 nmol/l and over are preferable for improvements in walking ability, balance, and lower extremity strength.

As a tendency for self-reported disability in IADLs (Instrumental Activities of Daily Living) to precede ADLs has been observed by some investigators (Kempen et al, 1995; Jagger et al., 2001), in our study samples, more than 78% of the elderly with $25(OH)D_3$ levels greater than 67.5 nmol/l were in a state of superior functional capacity, which allowed them to live independently in the community. These results suggest that higher levels of $25(OH)D_3$ may be necessary to maintain functional capacity.

Weiss et al. (2007) have attempted to determine whether there is a hierarchy to mobility performance. The odds ratios for prevalent report of walking limitation, versus no limitation, for 10% lower performance walking, dressing, repeating chair stands, and climbing, respectively, were 1.05 (95%CI, 0.97-1.17), 1.08 (1.00-1.16), 1.15 (1.06-1.25), and 1.22 (1.12-1.33). They concluded that their study partially supported the hypothesis that mobility performance tends to follow a hierarchical pattern. From our results, change in alternate step was significantly higher in the greater than 67.5 nmol/l group than in other groups. The alternate step test, which measures lower extremity strength, has been reported to provide the best discrimination between multiple and non-multiple fallers (Tiedemann et al., 2008). The decline in lower extremity strength and balance observed in the state of higher level of $25(OH)D_3$ may precede to the decline in walking ability observed in those with the lower level of $25(OH)D_3$. From this perspective, the optimal level of $25(OH)D_3$ might be over 65.7 nmol/l for the Japanese specified elderly women to live independently in the community (Bischoff-Ferrari, 2007).

A limitation of our study was that the number of participants was small. However, to sustain the Long-term Care Insurance System in Japan, it is crucial to prevent the deterioration of functional capacity and mobility in the frail elderly by considering vitamin D status. Further study is needed to confirm the relationship between vitamin D and physical fitness in frail elderly women.

In conclusion, 27.5% of the Japanese “Specified elderly women” were in the state of 25(OH)D_3 less than 50 nmol/l, and 88.8% were in the state of 25(OH)D_3 less than 75 nmol/l. Our study results suggest that serum 25(OH)D_3 levels at baseline are associated with functional capacity and improvements in physical fitness with regard to walking ability, balance, and lower extremity strength, and at least 47.5 nmol/l may be necessary to maintain walking ability and balance, and greater than 67.5 nmol/l is preferable for lower extremity strength and a functional capacity in Japanese “Specified elderly women.”

Conflict of interest statement:

None.

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Table 1

Baseline characteristics of frail elderly women aged 65 and over according to quartile distribution of 25(OH)D_3, mean ± S.D., or n(%)

		Quartiles according to serum 25(OH)D_3 (nmol/l) levels				
Parameters	Total	1^{st} (<47.5)	2^{nd} (47.5 -60.0)	3^{rd} (60.0 - 67.5)	4^{th} (> 67.5)	p^a
Number	80	19 (23.8)	20 (25.0)	18 (22.5)	23 (28.8)	
Age, years, (range)	76.0±5.4 (65-90)	77.7±4.7	77.6±5.5	74.9±4.4	74.3±6.1	ns
MMSE	25.7±3.4 (17-30)	25.7±3.8	25.4±3.6	25.8±3.4	25.9±3.5	ns
BMI	24.7±3.3	26.2±2.9	24.1±2.9	23.1±1.9	25.3±4.0	< 0.05 (3rd-1st)
Barthel Index	97.2±5.8 (60-100)	95.8±8.0	97.8±4.1	96.9±6.0	98.0±4.7	ns
Difficulties in rising from lying	24 (30.0)	5 (26.3)	11 (55.0)	5 (27.8)	3 (13.0)	< 0.05
Difficulties in walking at home	10 (12.5)	6 (31.6)	2 (10.01)	1 (5.6)	1 (4.3)	< 0.05
Difficulties in walking outside	22 (27.5)	6 (31.6)	8 (40.0)	2 (11.1)	6 (26.1)	ns
A least 1 fall in the past 1year	45 (56.3)	10 (52.6)	10 (50.0)	9 (50.0)	16 (69.6)	ns
Frequent stumbling during the past 1 year	57 (71.3)	14 (73.7)	16 (80.0)	13 (72.2)	14 (60.9)	ns
Going outside less than once/week	27 (33.8)	9 (47.4)	5 (25.0)	6 (33.3)	7 (30.4)	ns
TMIG Index scores≦10	33 (41.3)	10 (52.6)	8 (40.0)	10 (55.6)	5 (21.7)	< 0.05
Data of blood (range)						
Serum albumin (g/dl)	4.2±0.3 (3.5-5.0)	4.2±0.3	4.2±0.3	4.3±0.3	4.3±0.3	ns
Serum calcium (mg/dl)	9.3±0.4 (8.2-10.7)	9.3±0.4	9.2±0.4	9.3±0.4	9.4±0.4	ns
Serum creatinine (mg/dl)	0.7±0.18 (0.5-1.0)	0.7±0.1	0.7±0.1	0.6±0.1	0.6±0.1	ns
Serum iPTH (pg/ml)	41.9±16.2 (15.0-85.0)	45.5±17.9	39.4±16.5	45.1±16.7	38.4±13.8	ns
Serum 25(OH)D_3 (nmol/l)	57.5±13.4 (27.5-92.5)	39.5±5.3	52.6±3.2	61.9±1.8	73.3±6.5	< 0.01
Serum 25(OH)D_3 > 50 nmol/l	22 (27.5)	19 (100.0)	3 (15.0)	0 (0.0)	0 (0.0)	
Serum 25(OH)D_3 < 75 nmol/l	71 (88.8)	19 (100.0)	20 (100.0)	18 (100.0)	14 (60.9)	

Notes: [a]Analysis of variance with p for trend was used for continuous variables, and χ^2 -test for categorical variables; ns = not significant

Table 2.

Correlation between physical fitness and 25(OH)D_3 levels at baseline (women, number = 80)

	r[a]	*p*	r[b]	*p*
Age, year	-0.31	< 0.001		
iPTH (pg/ml)	-0.09	ns	-0.09	ns
Grip strength (kg)	0.17	ns	-0.09	ns
One-legged stance with open eyes (s)	0.33	< 0.01	0.25	< 0.05
Alternate step (s)	0.18	ns	0.08	ns
Functional reach (cm)	-0.08	ns	-0.18	ns
5 chair sit-to-stand (s)	0.04	ns	0.10	ns
TUG (sec)	-0.05	ns	-0.01	ns
Tandem stance (s)	0.12	ns	-0.02	ns
5-m walk (sec)	-0.004	ns	0.02	ns
Tandem walk (s+number)	-0.06	ns	-0.05	ns

[a] Spearman rank correlation.

[b] Partial correlation coefficients adjusted by age, ns = not significant

Table 3.

Comparison of change (pre-post) of physical fitness in each of the 4 groups, and among 4 groups according to the 25(OH)D_3 levels, mean ± S.D.

Functions		Total	Quartiles according to serum 25(OH)D_3 (nmol/l) levels 1st (<47.5)	2nd (47.5-60.0)	3rd (60.0-67.5)	4th (> 67.5)	p[a]
Number (%)		80	19 (23.8)	20 (25.0)	18 (22.5)	23 (28.8)	
Hand grip strength (kg)	Pre	18.7±4.4	17.6±3.4	18.3±4.6	19.5±5.0	19.3±4.6	
	Post	18.8±4.2	17.7±2.9	18.2±4.4	20.1±4.6	19.1±4.4	
	Change[b]	0.0±2.3	0.1±3.0	-0.1±2.1	0.5±2.2	-0.2±2.1	ns
5 Chair sit-to-stand (s)	Pre	10.5±3.8	9.9±4.0	9.9±2.1	10.6±3.2	11.2±5.1	
	Post	9.5±3.5	10.2±5.2	8.8±1.8	9.5±2.6	9.5±3.7	
	Change[b]	-1.0±3.3*	0.3±2.6	-1.1±2.4†	-1.1±3.7	-1.7±4.0	ns
Alternate step (s)	Pre	6.5±2.0	6.5±2.5	5.9±1.2	6.6±1.9	7.0±2.1	
	Post	5.9±1.5	6.0±1.4	5.9±1.4	6.0±1.8	5.7±1.5	
	Change[b]	-0.6±1.5**	-0.4±1.4†	-0.0±1.3	-0.6±0.9*	-1.4±1.9**	$p < 0.05$,
Tandem stance (s)	Pre	21.6±9.7	20.8±9.5	21.2±9.6	22.0±9.2	22.3±11.0	
	Post	24.3±8.0	21.8±10.6	25.1±5.6	25.3±7.0	24.8±8.4	
	Change[b]	2.7±8.2	1.0±7.7	3.9±9.5†	3.2±8.2	2.5±7.6	ns
1-leg stance with open eyes (s)	Pre	10.9±13.7	6.7±5.6	5.1±4.0	13.3±17.7	17.3±17.3	$p<0.05$ (4th vs 2nd)
	Post	12.2±12.9	6.1±4.4	7.2±4.6	14.0±15.3	19.7±16.4	
	Change[b]	1.1±7.5	-1.3±5.4	2.1±3.8*	0.7±5.9	2.4±11.3	ns
Functional reach (cm)	Pre	24.6±6.5	25.3±7.7	25.4±7.7	24.9±4.9	23.2±5.4	
	Post	25.5±7.3	25.9±9.0	24.4±4.8	25.5±5.9	26.9±8.6	
	Change[b]	1.1±6.1	0.6±4.0	-1.1±5.0	0.6±5.8	3.8±7.6*	$p < 0.1$(4th vs 2nd)
TUG (s)	Pre	10.8±3.6	10.7±3.8	11.2±3.0	11.2±5.0	10.3±3.0	
	Post	9.5±2.7	10.1±3.5	9.7±2.2	9.5±2.4	8.8±2.5	
	Change[b]	-1.4±2.4***	-0.6±2.1	-1.6±2.5*	-1.7±3.4†	-1.5±1.4***	ns

5-m walk (s)	Pre	6.0±2.1	5.7±2.1	6.1±1.7	6.3±3.0	5.7±1.8	
	Post	5.3±1.7	5.6±2.5	5.4±1.3	5.0±0.9	5.1±1.8	
	Change[b]	-0.7±1.7**	-0.2±1.6	-0.7±1.1*	-1.3±2.9†	-0.7±1.1*	ns
Tandem walk (s+number)	Pre	18.1±6.5	17.4±7.5	19.9±7.5	18.7±5.4	16.4±5.2	
	Post	15.0±4.9	16.0±6.6	15.8±5.6	14.1±2.9	14.3±4.2	
	Change[b]	-3.0±5.5***	-1.4±5.2	-4.1±6.6*	-4.6±5.4**	-2.0±4.6†	ns

[a] Analysis of variance with p for trend was used for continuous variables

[b] Paired *t*-test (pre vs. post)

* $p<0.05$.

** $p<0.01$.

*** $p<0.001$; ns = not significant