

ORIGINAL

Association between Vitamin D nutrition status and physical functions in latter stage elderly at nursing home

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Abstract : Vitamin D nutritional status was assessed in very elderly people living in a nursing home to determine its association with nutritional status, and a supplement intervention was provided to those with vitamin D deficiency. In 36 (3 male and 33 female) nursing homes residents aged 91 (IQR 85-94) years, their serum 25-hydroxyvitamin D (25(OH)D) levels were 17.3 (IQR 12.9-23.4) ng/ml distributing 8.3% (3/36) of <10 ng/ml, 47.2% (17/36) of 10-<20 ng/ml and 44.4% (16/36) of 20-<30 ng/ml, respectively. Serum 25(OH)D levels were significantly associated with parathyroid hormone (PTH) level, Barthel Index, diaper wearing rate, nursing care level and swallowing function, but not with nutritional intake. By daily 1000 IU vitamin D supplementation for 6 months in 7 residents (male 2/female 5), serum 25(OH)D levels increased from 14.1 (13.0-21.8) ng/ml to 35.9 (34.0-47.1) ng/ml but physical functions did not improve. These data suggest that other factors such as insufficient protein and energy intake, chronic comorbidities and limited physical activity in addition of vitamin D status might be involved in the manifestations of nursing homes residents. *J. Med. Invest.* 73:21-25, February, 2026

Keywords : vitamin D nutrition, serum 25-hydroxyvitamin D level, physical function, nursing home residents

INTRODUCTION

Vitamin D has an important role in mineralization of bone, skeletal maturation, regulating calcium and phosphate metabolism. Recently identified roles of vitamin D in health include protection from bacterial and viral infections, better lung function, benefits to the cardiovascular and nervous systems and cancer prevention (1). Overall, vitamin D deficiency is associated with a loss of muscle mass and strength in elderly people and with a decline in physical performance. Vitamin D can be obtained from limited foods and few foods contain sufficient amounts, making it difficult to achieve requirements through diet alone (2). Advancing age, poor dietary intake of vitamin D and reduced time spent outdoors can lead to low circulating concentrations of 25(OH)D and thus vitamin D deficiency. There is a consensus that a serum 25(OH)D concentration of <20 ng/ml, 20 to <30 ng/mL and ≥ 30 ng/mL indicates vitamin D deficiency (VDD), insufficiency (VDI), and sufficiency (VDS), respectively (3).

Several international studies have shown that vitamin D insufficiency was quite common in the elderly population (4, 5), and institutionalized elderly are at even higher risk for vitamin D insufficiency (6, 7). Median 25(OH)D level was 17.5 nmol/l (7 ng/ml) in Austrian nursing home residents (8) and 93% of the residents had 25(OH)D below 50 nmol/l (20 ng/ml) (9). A limited number of observational studies have assessed general nutrition and vitamin D status of older adults in nursing homes in Japan (10-13). Most of the current guidelines generally advise that institutionalized older individuals should receive a supplementation of at least 1,000 IU of vitamin D per day to achieve the

optimal vitamin D status (14). Therefore, this study was conducted (1) to investigate the association between serum 25(OH)D levels and physical and nutritional parameters in nursing home residents (Study 1), and (2) to examine the effect of 6-month vitamin D supplementation on physical function (Study 2).

MATERIALS AND METHODS

Subjects

Participants were recruited in one nursing home, housing a total of 100 residents. Of the residents, 36 (3 male and 33 female) agreed to participate in this assessment (Table 1). Medians of their age and body mass index (BMI) were 91 (IQR 85-94) years and 20.8 (IQR 17.2-23.1) kg/m², respectively. Most of the present subjects were required wheelchair for transportation. Among the residents, dementia, cardiovascular diseases, bone-joint diseases, diabetes mellitus, cerebrovascular diseases, chronic kidney disease, and Parkinson's disease showed in 55.6% (20/36), 55.6% (20/36), 55.6% (20/36), 33.3% (12/36), 19.4% (7/36), 8.3% (3/36), 5.6% (2/36) and 5.6% (2/36), respectively. Among them, 15 residents were participated in intervention study and divided into 7 (2 male/5 female) daily 1000 IU vitamin D supplementation group and 8 (male 1/7 female 7) control group. Allocation was based on voluntary participation and consent. Among eligible residents with vitamin D deficiency, those who consented to supplementation were included in the intervention group, and those who declined were included as controls. Participants in the intervention group received a daily dose of 1000 IU of vitamin D in tablet form. The supplement was administered once daily after breakfast, under the supervision of nursing staff to ensure compliance. BMI, daily intake of energy and water, diaper-wearing status, nursing care level, physical activity and vitamin D status were assessed. Height and weight measurements were performed with the participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as weight (kg)

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Table 1. Characteristics of the subjects

	All		Male		Female	
	N	median IQR (25th-75th percentile)	N	median IQR (25th-75th percentile)	N	median IQR (25th-75th percentile)
Age (years)	36	91 (85-94)	3	79 (71-83)	33	91 (87-94)
Height (cm)	36	145 (140-149.8)	3	162.5 (148.5-170)	33	145 (139.5-149)
Weight (kg)	36	43.7 (36.1-48.4)	3	62.7 (48.3-80.4)	33	40 (35.7-48.1)
BMI (kg/m ²)	36	20.8 (17.2-23.1)	3	21.9 (21.7-30.5)	33	20.5 (17.1-23.1)
Energy intake (kcal)	36	1022 (821-1310)	3	1545 (1225-1648)	33	997 (812-1266)
Protein intake (g)	36	45 (34-55)	3	62 (57-67)	33	44 (33-55)
Water intake (ml)	36	2282 (1784-2573)	3	3030 (1931-3379)	33	2271 (1637-2550)
Fat mass (kg)	33	18.9 (12.9-27.4)	2	20.3 (19.1-21.4)	31	17.9 (12.6-27.4)
SMM (kg)	33	12.6 (9.8-15.3)	2	19.8 (15.5-24)	31	12.1 (9.6-14.4)
SMI (kg/m ²)	33	5.7 (4.7-7.6)	2	7.3 (6.2-8.4)	31	5.5 (4.7-7.2)
PTH (pg/ml)	36	32 (21.3-48.5)	3	38 (20-50)	33	32 (21.5-48)
25(OH)D (ng/ml)	36	17.3 (12.9-23.4)	3	16.5 (11.2-29.8)	33	17.6 (13-23.3)
Ca (mg/dl)	36	9.1 (8.4-9.3)	3	9.1 (7.9-9.5)	33	9 (8.4-9.3)
P (mg/dl)	36	3.2 (3-3.4)	3	2.9 (2.4-3)	33	3.2 (3-3.5)
Zn (µg/dl)	36	61.5 (52.3-70.8)	3	81 (38-95)	33	61 (52.5-69.5)
Fe (µg/dl)	36	56.5 (45.3-78.3)	3	73 (55-111)	33	56 (44-77.5)
Barthel Index (score)	36	45 (5-63)	3	50 (30-75)	33	40 (3-60)
Diaper wearing (%)	34	0 (0-93)	2	0 (0-0)	32	0 (0-98)

IQR : Interquartile range

PTH : Parathyroid hormone

SMM : Skeletal muscle mass

SMI : SMM index

25(OH)D : 25-hydroxyvitamin D

divided by the square of height (m).

Blood samples

Fasting venous blood was sampled and serum was stored at -20 °C for serum 25(OH)D, parathyroid hormone (PTH), calcium (Ca), phosphorus (P), Zinc (Zn), and Iron (Fe) determination. Serum 25(OH)D levels, as an indicator of the vitamin D status, were measured by electro-chemiluminescent immunoassay (ECLIA) as previously reported (14).

Nutritional analysis

Since the subjects were institutionalized and their diet was supplied from the institution, their nutrients and energy intake were calculated by multiplying the supplied nutrients on the basis of the Standard Tables of Food Composition in Japan, 8th ed (15), with the average percentage intake in a preceding month by the staff. Nutrient and energy intake values were calculated based on institutional meal plans and intake records averaged over 2 consecutive days. The actual consumption was recorded by trained staff and adjusted using estimated consumption percentages from the prior month. Total water intake corresponds to the sum of beverages (including tea, coffee, milk, and soup), water in food taken from the dietary record, and 200 ml of metabolic water on the day of data collection. Dietary data were converted into water using the Standard Tables of Food Composition in Japan (15).

Assessment of physical performance

Physical performance evaluated by Barthel Index (BI) is a 10-item measurement tool of basic activities of daily living (ADL) (16). Diaper wearing rate, evaluated by research staff, was expressed as daily percentage. Screening tool for sarcopenia

(SARC-F) and The European Quality of Life-5 Dimensions (EQ-5D) were also assessed.

Statistical analysis

Statistical analysis was performed by SPSS for Windows v.13 (SPSS Corp, Chicago, IL). All numerical data were presented as median (interquartile range [IQR]) and categorical data are presented as counts (%). Spearman's rho was used to assess correlations between serum 25(OH)D levels and other variables. The Wilcoxon signed rank test was performed to test for differences in each item before and after vitamin D supplementation. All tests were two-sided, with a level of significance at $p < 0.05$.

Ethical considerations

Ethics approval was obtained from the clinical research ethics committee at Tokushima University Hospital (approval number 384). Informed consent to participate in the study was also obtained from participants or from an authorized surrogate. This trial was registered as UMIN000038105.

RESULTS

Prevalence of Vitamin D deficiency/insufficiency in nursing home residents

The medians (IQR) of serum 25(OH)D levels for 36 residents were 17.3 ng/ml (IQR 12.9 - 23.4) (Table 1). The numbers of subjects with serum 25(OH)D levels of <10 ng/ml, 10 - <20 ng/ml, 20 - <30 ng/ml were 8.3% (3/36), 47.2% (17/36) and 44.4% (16/36), respectively. These subjects showed a significant inverse correlation between individual 25(OH)D and PTH levels ($p < 0.05$) (Table 2). Such correlations were not observed between

serum 25(OH)D concentrations and serum Ca, P, Zn or Fe concentrations.

Correlation between 25(OH)D levels and nutritional intake and motor performance in nursing home residents

Serum 25(OH)D concentration was not correlated with nutritional intake such as energy, protein, or water. In contrast, it was significantly correlated with handgrip strength (p<0.05), BI (p<0.001), diaper wearing rate (p<0.01), nursing care level (p<0.05) and swallowing function (p<0.01) (Table 2).

Effects of vitamin D supplementation in nursing home residents

Serum 25(OH) level in 7 subjects (male 2/female 5) was 14.1 (13.0-21.8) ng/ml before vitamin D supplementation and increased to 35.9 (34.0-47.1) ng/ml at 6 months after vitamin D supplementation. The levels of control group did not change. Physical functions such as handgrip strength, calf circumference, BI, SARC-F, diaper wearing status, EQ5D, nursing care level and frail levels did not show any improvement in both groups.

DISCUSSION

The observation of low serum 25(OH)D concentrations in this study was in line with previous findings among institutionalized elderly people (7, 9, 17-20). Serum 25(OH)D concentrations in Japanese individuals aged 83.8 ± 7.6 and 85.4 ± 8.5 years were

Table 2. Correlation coefficients between serum 25-hydroxyvitamin D and other variables

	Spearman's rank correlation (p)	P-value
Age (years)	-0.837	0.0001
Body weight (kg)	0.612	0.0152
Food intake		
Energy (kcal/kg/day)	-0.1171	0.4963
Protein (g/kg/day)	-0.0685	0.6915
Water (ml/day)	0.1585	0.3557
Blood chemistry		
Ca (mg/dl)	0.3036	0.0719
P (mg/dl)	-0.01	0.9541
Zn (mg/dl)	0.0383	0.8244
Fe (mg/dl)	0.0973	0.5724
PTH (pg/dl)	-0.4135	0.0122
Physical function		
Handgrip strength (kg)	0.5268	0.0436
Barthel index (score)	0.5504	0.0005
Diaper wearing (%)	-0.472	0.0047
Nursing care level	0.5937	0.0283
Swallowing function	-0.575	0.0026

PTH : parathyroid hormone

Table 3. Effects of vitamin D supplementation in nursing home residents

	Control group		Vitamin D supplementation group	
	before	after	before	after
n (M/F)	8 (1/7)		7 (2/5)	
Age (years)	92 (89-94)		86 (82-89)	
Body weight (kg)	43.0 (34.4-60.3)	47.3 (37.9-55.8)	47.3 (45.5-53.1)	48.6 (39.4-56.0)
BMI (kg/m ²)	20.1 (17.3-25.8)	21.4 (18.2-24.9)	23.0 (21.4-23.4)	24.0 (19.8-24.4)
Handgrip strength (kg)	11.2 (0-13)	7.6 (0-10.1)	0 (0-6.3)	8.7 (0-10.8)
Calf circumference (cm)	29.2 (26.5-33.8)	30.8 (24.1-32.1)	29.6 (23.8-32.5)	29.3 (26.8-32.5)
Barthel index	65 (35-75)	50 (30-66)	53 (31-70)	65 (35-80)
SARC-F	7 (5-8)	7 (5-8)	7 (4-8)	6 (2-7)
Diaper wearing status	0 (0-0)	0 (0-0)	0 (0-31)	0 (0-0)
EQ5D	9 (8-11)	10 (8-11)	10 (8-11)	9 (8-9)
Nursing care level	3 (2-4)	3 (2-4)	3 (2-4)	3 (2-4)
Frailty scale	0 (0)	2 (25)	2 (29)	3 (43)
Serum concentration				
PTH (pg/ml)	53 (32-58)	41 (28-55)	32 (21-46)	48 (41-52)
25(OH)D (ng/ml)	23.2 (18.0-26.5)	13.0 (9.3-20.5)	14.1 (13.0-21.8)	35.9 (34.0-47.1)*
Ca (mg/dl)	9.0 (8.6-9.2)	9.3 (8.8-9.6)	9.1 (8.7-9.3)	8.9 (8.6-9.3)
P (mg/dl)	3.4 (3.2-3.8)	3.9 (3.4-4.1)*	3.1 (3.0-3.5)	3.4 (3.2-3.7)
Zn (µg/dl)	63 (50-76)	62 (45-73)	67 (60-74)	55 (49-71)
Fe (µg/dl)	56 (51-92)	51 (39-83)	60 (49-102)	51 (36-67)

BMI : body mass index Difference between before and after (* : p<0.05, The Wilcoxon signed rank test)
 SARC-F : Screening tool for sarcopenia
 EQ5D : The European Quality of Life-5 Dimensions Questionnaire

reported to be 9.7 ± 1.8 ng/ml and 9.7 ± 3.7 ng/mL, respectively (21). In a study of 1585 osteoporotic Japanese women aged 70-95 years, their mean serum 25(OH)D level was 23.7 ng/mL (22). The numbers of those subject with serum 25(OH)D levels of < 20 ng/ml (VDD), 20 to 30 ng/ml (VDI), and ≥ 30 ng/ml (VDS) were 376 (23.7%), 982 (63.0%), and 227 (14.3%), respectively. In another study that examined institutionalized elderly from Buenos Aires, 40.5% of nursing home residents had a serum 25(OH)D level of less than 25 nmol/l (10 ng/ml) (23).

The average dietary intake of vitamin D in institutionalized elderly was around 300 IU/day, which is approximately 88% of the adequate intake (AI) by the Japan Dietary Reference Intake (DRI) 2020 (12). Their mean plasma 25(OH)D level increased from 12 ng/ml at baseline to 14.7 ng/ml after daily 200 IU vitamin D supplementation for 30 days. Cashman *et al.* reported dose-dependent increase in serum 25(OH)D concentration after incremental supplementation with vitamin D3 in free-living adults over 64 years of age (24). Most subjects in the present study had VDD/VDI in spite of adequate intake (AI) of dietary vitamin D in nursing home. Although AI by the Japan RDS 2025 for vitamin D slightly increased to 9.0 μ g/day (360 IU/day) (25), the elderly are likely to require much more vitamin D intake to avoid VDD/VDI.

Serum 25(OH)D levels were significantly correlated with various physical performances such as BI, diaper wearing rate, nursing care level and swallowing function in this study. Previously reported surveys revealed that vitamin D levels are positively correlated with muscle mass, strength and physical performance in elderly (14, 26, 27). Other evidence support that vitamin D can reduce bone turnover, incidence of falls, risk of bone fractures, and improve balance and muscle strength (28-32). It was also defined that the concentration of 75.0 nmol/L (30 ng/ml) as the cut-off value for which serum 25(OH)D concentrations did not correlate with PTH levels (33). Lower serum 25(OH)D levels were associated with a lower QOL score, and this relationship was clearly observed in patients with levels < 20 ng/ml. Previous study suggested that the majority of institutionalized female patients are vitamin D deficient and that there was an inverse association of 25(OH)D and mortality (9). Considering a meta-analysis that documented a nonlinear relationship between 25(OH)D and mortality with the lowest mortality risk at 25(OH)D levels ranging from 75–87.5 nmol/liter (19, 34). Thus, VDD/VDI could have a significant impact on poor health and welfare of elderly in nursing homes. The increase in phosphorus levels in the control group is an interesting finding. While the mechanism remains unclear, we speculate that changes in dietary intake or renal function could have contributed. However, due to the small sample size and lack of detailed intake data for phosphorus, we cannot draw firm conclusions.

In our previous study of high school athletes showed different effect of vitamin D on physical functions from present study, daily 1000 IU vitamin D supplementation for 6 months increased serum vitamin D levels from 27.0 (22.9-32.1) ng/ml to 37.9 (28.9-40.9) ng/ml and improved muscle functions (35). It was suggested that the study subjects in nursing home consumed insufficient protein and energy and was at risk for not meeting the requirements. A healthy diet associated with a physically active lifestyle and possibly with aerobic exercise are the basis of healthy aging, although only a small percentage of older people do exercise regularly and continuously. Combination program of Vitamin D3 supplementation and Nordic Walking training on muscle strength and postural control might be important to improve physical functions in elderly people (36). The right

kind of diet and a physically active lifestyle are two important factors to counterbalance the development of malnutrition and accessory complications such as reduced QOL and increased risk for chronic comorbidities (e.g., cardiovascular disease, cerebrovascular disease, and sarcopenia), and limited physical activity in nursing home residents.

Limitations of the current study included the relatively small sample size and a lack of data regarding elderly mobility and dietary intake or supplemental vitamin D intake in the nursing home. When measuring food intake, it is well known that most assessment techniques lead to underestimating intake, which results in higher prevalence rates of residents at risk for low protein and energy intake. However, these data underscore the urgent need for effective strategies for the prevention and treatment of vitamin D deficiency, in particular in the setting of nursing homes. Weight gain observed in the control group suggests possible variation in nutritional intake during the study period. Then, the assumption of uniform low protein/energy intake should be interpreted with caution. Therefore, it was suggested from present study that appropriate nutritional support in addition to daily 1000 IU vitamin D supplement and exercise were required to keep high QOL in nursing home residents.

CONFLICT OF INTEREST AND ACKNOWLEDGEMENT

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