



Original Article

The relation between vitamin D and postural balance according to clinical tests and tetrax posturography

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Abstract. [Purpose] To evaluate the association between Vitamin D and risk of falling, balance, and lower extremity neuromuscular function in women aged 60 and above by using Tetrax posturography. [Subjects and Methods] A total 200 women were classified based on their 25-OH-vitamin D (25(OH)D) values: hypo-vitaminosis group (less than 50.0 nmol/l) and normal group (50.0 more). Balance was measured using a Tetrax[®] posturography device (Sunlight Medical Ltd, Israel). Falling risk, stability index (SI), and weight distribution index (WDI) were calculated. Short Physical Performance Battery (SPPB) and International Physical Activity Questionnaire (IPAQ) were used as the clinical tests. [Results] Standing balance, gait, chair stand performance and total SPPB scores were significantly better in the patients with serum 25(OH)D levels higher than 50.0 nmol/l. Similarly, falling risk and SI values in the most of the postures were significantly higher in the hypovitaminosis group. There were significant associations between serum 25(OH)D levels with SPPB total score and Tetrax-measured falling risk. [Conclusion] This study showed better balance control, lower extremity function, and reduced falling risk in patients with serum 25(OH)D levels higher than 50.0 nmol/l in women aged 60 and above.

Key words: Vitamin D, Balance, Posturography

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INTRODUCTION

The importance of Vitamin D for bone health is well known. However, Vitamin D deficiency is not only a risk factor for osteoporosis; there is also evidence that it is responsible for decreased muscle functions and falls¹⁻⁵⁾. Recently, there has been a growing field of research concerned with the association between vitamin D deficiency and a wide range of diseases other than osteoporosis in the elderly. It has been found that the capacity for synthesizing Vitamin D decreases with age due to the changes in the skin seen with aging²⁾. Decreases in oral intake and absorption of Vitamin D in the intestines as well as low 1 alpha hydroxylase enzyme activity in the kidneys, frequently lead to the development of Vitamin D deficiency in the elderly²⁾.

Considering the theory that vitamin D regulates skeletal muscle physiology, as suggested by various clinical observations and experimental studies, the muscular weakness seen in older patients with low-serum 25-OH-vitamin D (25(OH)D) concentrations may lead to falls^{6, 7)}. Indeed, cholecalciferol-calcium supplementation reduces falls by 46% to 65% in community-dwelling older women⁵⁾. On the other hand, there are many factors affecting fall-risk in the older population. In an overview of the literature by Annweiler et al.⁸⁾, it was asserted that age-related changes in postural reactions may be related to vitamin D status, mediated through either central nervous system integration or antigravity muscles as the effectors in postural responses. Some studies showed that people with vision and balance disorders had lower levels of vitamin D compared to those without. Although no evidence has reported that lower levels of vitamin D result in neurobehavioral impairment, it seems that vitamin D plays an important role in neurobehavioral functions⁹⁾. This suggests that muscular weakness cannot be

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considered as the only mechanism of fall-risk related to vitamin D deficiency.

On the other hand, there is no clear consensus regarding the relationship between falls and Vitamin D. Karlsson et al.¹⁰ in their review reported that Vitamin D supplementation, with or without calcium, in the community-living elderly did not reduce the number of falls or number of fallers. In that study, the authors recommended the administration of Vitamin D supplements in those with low levels of vitamin D. There has been confusion about which form of Vitamin D is effective in reducing the risk of falls. No fall-reductive effect in community-dwellers has been reported with alfacalcidol, whereas those with calcitriol had a 36% reduction in the number of falls¹¹.

According to previous data showing that impaired balance is an established risk factor for falls in older persons^{12, 13}, the evaluation of postural balance is extremely important to prevent falls. Although clinical studies indicated a significant impairment of postural balance in Vitamin D deficiency, there are few studies in which the effect of Vitamin D on falls and balance were assessed by the posturographic method^{14–16}.

For this reason, our study intends to explore whether there is an association between Vitamin D and risk of falling, balance, and lower extremity neuromuscular function in women aged 60 and above by using Tetrax posturography.

SUBJECTS AND METHODS

A total 200 women aged 60 and above who applied to our outpatient clinic were enrolled into the study between December 2010 and June 2012. A history of intake of medications that affect the central nervous system and/or bone metabolism; the presence of a disease that affects postural stability and gait such as Parkinson's disease, stroke, dementia and Vitamin B12 deficiency; the presence of any neurological motor deficit such as paresis or orthopedic problems such as previous arthroplasty, amputation or severe osteoarthritis in the lower extremities, were exclusion criteria. In addition, patients who had severe liver disease, cardiac failure, other severe metabolic diseases, and mental disorders were also excluded. The patients' cognitive status was measured by the Mini Mental State Test (MMST)¹⁷. If the patient had had a score <24 in the MMST, they were excluded.

The study was approved by the institutional review board, and all participants provided written informed consent.

After the socio-demographic characteristics were recorded, a detailed medical history was taken. For osteoporosis and Vitamin D, duration of exposure to sun, number of births, duration of nursing, diet, and history of falls were recorded. Vitamin D supplement use was coded as "yes" if participants reported currently taking supplements. The medical history related to other diseases such as diabetes mellitus, hypertension, use of loop and/or thiazide diuretics, and the taking of psychotropic medications were also recorded.

In the assessment of balance, a Tetrax[®] posturography device (Sunlight Medical Ltd., Israel) was used, taking into consideration the oscillation rates from the posturographic software. This device is comprised of four independent platforms which measure the vertical pressure changes from both toe tips and from both soles, and a computer which collects and processes the digital data from the platform. The system can digitally save the data from the four different measurement platforms simultaneously and document them as visual and numerical values. Pressure detectors placed on a platform on which the person stands straight detect the patterns of displacement at the center of pressure. The subject's risk of falling was calculated by the device from the oscillation angle between the center of pressure and the center of gravity. The measurements were repeated in eight different positions. The patients were asked to look forward with eyes open and closed (NO and NC). Next, they were asked to turn their head to the left and right (HL and HR) more than 45°. Next, they were asked to extend their head upward and downward (HF and HB). Finally, the patients were asked to stand on a foam-rubber pillow with their eyes open and closed (PO and PC). Falling risk, stability index (SI), and weight distribution index (WDI) were calculated for each patient, with high values indicating a worse postural performance.

As a clinical balance test, the Short Physical Performance Battery (SPPB)¹⁸ was applied to the patients. The SPPB is a valid and reliable test which is comprised of three tasks: standing balance, usual gait, and chair stand performance. Scores of 1–4 for each task were computed according to the time spent for the activity. Summing the three individual categorical scores, a summary performance score was created for each participant (range: 0–12), with higher scores indicating better lower body function.

In addition, physical activity levels were evaluated by a short form of the International Physical Activity Questionnaire (IPAQ)¹⁹. This self-reported questionnaire is based on estimations of time spent per week on different physical activities, in order to classify individuals as sedentary, irregularly active (A or B), active, or very active. Total weekly physical activity was estimated by converting the activity items into multiples of the basal resting energy expenditure (Metabolic Equivalent of Task, MET) for each domain alone (walking activity, moderate physical activity, and vigorous physical activity) and in combination (sum of all physical activity).

Grip strength was measured in the dominant hand using a JAMAR[®] Plus digital handheld dynamometer. Three attempts at maximal squeeze were recorded, and the best of the three measurements was used.

Blood and urine samples were collected from all patients after an overnight fast. Serum 25(OH)D levels were measured using manual radioimmunoassay using single-batch reagents (IDS, England). The intra-assay and inter-assay variation coefficients were lower than 10%.

Blood sampling was divided into two seasonal groups as winter (October–March) and summer (April–September) peri-

Table 1. Socio-demographic characteristics

	Total n=200	Hypo- vitaminosis group (<50.0 nmol/l) n=77	Normal group (≥ 50.0 nmol/l) n=123
Age (years, mean±SD)	67.3±6.0	67.7±6.1	67.0±5.9
BMI (kg/m ² , mean±SD)	29.4±4.8	29.6±4.8	29.2±4.9
Education level (n, %)*			
< 5 schooling years	139 (69.5)	58 (75.4)	81 (65.9)
5 to 12 schooling years	32 (16.0)	13 (16.9)	19 (15.4)
> 12 schooling years	29 (14.5)	6 (7.8)	23 (18.7)
Vitamin D supplementation (n, %)*	63 (31.5)	13 (16.9)	50 (40.7)*
History of falls (n, %)*			
1 fall	36 (18.0)	14 (18.2)	22 (11.5)
> 1 fall	18 (9.0)	9 (11.7)	9 (9.6)
Season of blood collection			
Winter (n, %)*	123 (61.5)	48 (62.5)	75 (61.0)
Summer (n, %)*	77 (38.5)	29 (37.7)	48 (39.0)
Using of loop and/or thiazide diuretics (n, %)*	38 (19.0)	14 (18.2)	24 (19.5)
Using of psychotropic medications (n, %)*	34 (17)	9 (11.7)	25 (20.3)
Number of births (mean±SD)	3.3±1.9	3.5±2.0	3.1±1.8
Ocular problems (n, %) [†]	179 (89.5)	68 (88.3)	111 (90.2)
25-OH-vitamin D (nmol/l, mean±SD)	68.7±38.7	34.0±9.4	90.4±33.9*

Student t test, [†]χ² test
*p<0.05

ods. Participants were classified based in their 25(OH)D values using previously published cut-offs: hypo-vitaminosis group (less than 50.0 nmol/l) and normal group (50.0 and greater)²⁰.

Statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS) 15.0. Crosstabs were created on variants from nominal and ordinal scales, and Chi-Square analysis was conducted. Shapiro Wilk test was used to assess the distribution of the variables. For variables with normal distribution, Student's t test was used in the comparison of the groups. Their results were expressed as mean ± SD (standard deviation). Comparison analyses of the other variables were carried out by the Mann Whitney U test. In their results, median, minimum and maximum values were given.

RESULTS

The demographic and clinical characteristics are reported in Table 1. There was no significant difference between the groups except Vitamin D supplementation (13 subjects-16.9% vs. 50 subjects- 40.7%, p<0.05).

A comparison of the serum 25(OH)D level groups (hypo-vitaminosis group and normal group) for the clinical assessment parameters is presented in Table 2. SPPB scores, SI and WDI results on posturography were given as median values because normal distribution could not be obtained. Standing balance, gait, and chair stand performance scores were significantly better in patients with serum 25(OH)D levels higher than 50.0 nmol/l (p<0.05). Total SPPB scores were also different between the groups, indicating that the group with serum 25(OH)D levels higher than 50.0 nmol/l had significantly better lower extremity functions (p<0.05). Similarly, falling risk and SI values in the most of the postures were significantly higher in the hypovitaminosis group (p<0.05). WDI was not different between the groups.

DISCUSSION

This study showed that serum 25(OH)D levels were significantly associated with clinical balance test results, falling risk and SI values on Tetrax posturography. This finding was confirmed with comparison analyses showing better balance control, lower extremity function, and less falling risk in the patients with serum 25(OH)D levels higher than 50.0 nmol/l.

Falling is a significant concern in elderly individuals, resulting in complex problems related to the personal and societal impact of aging. Recently, there has been a growing field of research concerned with reducing the risk of falls and increasing muscle strength in at-risk subjects. For this purpose, major institutions such as the International Osteoporosis Foundation, Endocrine Society and US Preventive Services Task Force recommend giving Vitamin D to elderly people in order to reduce the risk of falling. Indeed, Vitamin D plays an important role in musculoskeletal health. Muscle weakness, muscle pain (especially in the proximal muscles), and gait disorders are commonly seen in Vitamin D deficiency³⁻⁶. From previous data,

Table 2. Comparison of the groups for clinical tests

	Hypo-vitaminosis group (<50.0 nmol/l) n=77	Normal group (≥ 50.0 nmol/l) n=123
Standing balance, median (min/max)	3 (0–4)	4 (1–4)*
Gait, median (min/max)	3 (1–4)	3 (1–4)*
Chair stand performance, median (min/max)	2 (0–4)	3 (0–4)*
SPPB total, median (min/max)	8 (1–12)	10 (2–12)*
IPAQ [†]		
Sedentary (n, %)	59 (76.6)	78 (63.4)*
Low physical activity (n, %)	18 (23.4)	45 (36.6)*
Hand grip, jamar (kg, mean \pm SD)	18.3 \pm 4.9	19.5 \pm 4.6
Tetrax- Falling Risk, (mean \pm SD) [‡]	55.7 \pm 25.8	41.1 \pm 25.0*
Tetrax- SI, median (min/max)		
NO	19.6 (7.7–48.5)	15.8 (6.4–54.0)*
NC	21.2 (8.3–97.5)	18.3 (7.8–65.8)*
PO	20.2 (8.7–78.6)	19.6 (8.8–56.2)
PC	28.3 (12.7–76.3)	21.1 (8.9–90.4)*
HR	23.3 (13.2–98.2)	22.3 (8.3–87.7)
HL	24.5 (10.2–89.3)	22.0 (7.8–88.4)*
HB	24.9 (12.2–71.4)	20.2 (8.3–124.6)*
HF	22.5 (10.5–113.6)	21.18 (9.13–89.33)
Total	190.9 (115.0–607.0)	167.7 (80.3–614.2)*
Tetrax- WDI, median (min-max)		
NO	5.9 (1.0–20.0)	6.0 (1.25–18.9)
NC	5.6 (0–19.1)	5.5 (0–19.1)
PO	8.4 (2.0–20.9)	9.1 (0.9–29.1)
PC	9.1 (1.8–21.3)	9.0 (2.0–27.8)
HR	7.2 (1.3–21.3)	5.9 (1.6–18.1)
HL	7.3 (0.7–17.8)	6.2 (0.6–19.5)
HB	7.3 (1.0–19.1)	7.0 (1.0–18.4)
HF	6.5 (0.6–18.2)	5.0 (0.5–16.9)
Total	57.0 (17.3–156.0)	52.7 (22.4–146.8)

SPPB: Short Physical Performance Battery, IPAQ: International Physical Activity Questionnaire, SI: Stability index, WDI: Weight distribution index, NO: Neutral position with eyes open, NC: Neutral position with eyes closed, PO: Eyes open on pillows, PC: Eyes closed on pillows, HR: Head turned right and eyes closed, HL: Head turned left and eyes closed, HB: Eyes closed raising head backward 30°, HF: Eyes closed with head forward approximately 30°

Mann Whitney U test. [†] χ^2 test. [‡] Student t-test

*p<0.05

it has been demonstrated that the lower extremity functions were better with higher 25(OH)D levels in older people^{21–24}. Our findings, in accordance with these reports, support the importance of Vitamin D in lower extremity functions.

An accurate evaluation of balance control in elderly patients is necessary before effective treatment can be recommended or developed. SPPB, which is comprised of standing balance, usual gait, and chair stand performance, is a widely-used test for this purpose¹⁸. Although such clinical tests may allow for interference of subjective factors, it is easy to use and is reported to have high validity and reliability. In our study, we found significant differences between the two groups for all subtests, and the total score of SPPB indicated better performance in the patients with serum 25(OH)D levels higher than 50.0 nmol/l.

Posturography is a balance-status measurement that is used to quantitatively assess human postural stability and postural responses²⁵. It is based on computerized elaboration of electronic signals emitted by four footplates, one for each heel and toe²⁵. In this way, it provides the investigation of visual, somatosensory, motor and central nervous processes and their effect on stability. ST, which quantitatively measures the postural sway according to changes in the pivoting center with high values indicating worse postural performance, was higher in most of the postures of hypovitaminosis group compared to those of the other group. On Tetrax posturography, falling risk is a comprehensive result based on all results in all positions, with higher

values indicating that the patient is at risk of falling. Falling risk was significantly higher in the hypovitaminosis group in our study. In the regression analysis, serum 25(OH)D concentrations were also associated with falling risk, supporting this result, even with adjustment for confounding variables and potential mediators of fall risk. On the other hand, WDI was not different between the groups. WDI is a discrepancy from equal weight distribution (25% of weight on each plate). Considering its role on balance, with high values indicating orthopedic problems, this result may be explained.

According to our findings, the anti-fall effect of vitamin D is supported by the results of the clinical balance test and Tetrax posturography are inconsistent with previous observations. In many studies on elderly people, a clear relation between Vitamin D deficiency and postural instability has been demonstrated^{5, 14, 26}. However, most of these studies used SPPB as a balance test in evaluating this relationship. Among the studies which used posturography, a similar study investigating the effects of Vitamin D on postural balance was conducted by Boersma D et al¹⁴. In that study, it was concluded that posture was impaired in vitamin D deficiency (<30 nmol/l) in comparison to patients with vitamin D levels between 30 to 50 nmol/l and higher than 50 nmol/l. When compared with our study, it seems that their results are of a similar nature, but are not completely comparable due to the variability in Vitamin D boundaries, parameters, and method used. Indeed, the absence of standardization of method –particularly regarding the range of Vitamin D levels- in such studies leads to incompatible results. There is no clear consensus on what is the optimal range of vitamin D in the prevention of deterioration of balance and neuromuscular functions. The American Endocrine Society defines levels of 50 nmol/l or below as deficiency²⁰. Thus, we grouped our patients according to serum 25(OH)D levels below or above 50 nmol/l.

The mechanism of how vitamin D may affect balance is difficult to explain. Recent research has provided an increasing number of arguments in favor of an action of vitamin D on muscles and the central nervous system. It is well known that 1.25-dihydroxy vitamin D, the active vitamin D metabolite, binds to a vitamin-D-specific nuclear receptor (VDR) in muscle tissue²⁷⁻²⁹, leading to de novo protein synthesis³⁰ and muscle cell growth²⁹. Vitamin D may improve muscle strength and function, as well as balance due to the improved strength. On the other hand, VDRs have been demonstrated in some parts of the brain, especially in the cortical, subcortical and spinal motor zones^{31, 32}. According to this evidence, it seems that vitamin D plays a role in the cerebral processes of postural balance.

Our study had several limitations. Since only women aged 60 and above were enrolled into the study, we cannot apply our results to all older people in this age population. Secondly, since Tetrax usually evaluates stability in the static condition, it is difficult to assess the problems of balance control in the dynamic state. Another limitation could be addressed through a pilot study to investigate whether the Tetrax balance control index is confounded by age, weight, or height, which is currently lacking. Because a difference regarding these parameters could not be found between the two groups in our study, any confounding effects of age, weight, or height may be limited.

In summary, this study showed better balance control, better lower extremity function, and less falling risk in patients with serum 25(OH)D levels higher than 50.0 nmol/l in women aged 60 and above. This finding was supported using both clinical tests of postural balance and Tetrax posturography. Nevertheless, our results should be confirmed by further studies on wider populations to establish definitive effectiveness.

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