Original Article

Effect of Hypovitaminosis D on Gait Impairments in Urban Elderly Evaluated by Instrumented Treadmill Gait Analysis System

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Objective: To compare gait parameters analyzed with instrumented treadmill gait analysis system in urban elderly who had hypovitaminosis D with a group of healthy normal serum vitamin D.

Materials and Methods: This prospective study on urban community-dwellers adults aged 65 to 85 years who attended Physical Medicine and Rehabilitation out-patient clinic in our hospital between January 2015 and December 2015. Demographic data including history of falls within the past 12 months were collected. Serum 25-hydroxyvitamin D [25OHD] was measured. Gait analysis, particularly temporospatial gait parameters, was evaluated with instrumented treadmill system (Zebris). The participants were divided into 3 groups as normal serum 25OHD level (>30 ng/ml) or hypovitaminosis D including insufficient (20 to 30 ng/ml) and deficient (<20 ng/ml).

Results: Among 114 enrolled participants, 86 completed the study. The study found 39.5% had normal serum 25 OHD, 41.9% had insufficient and 18.6% had deficient level. Age and body mass index [BMI] were comparable among the 3 groups. The participants with hypovitaminosis D tended to have longer double-limb support than those who had normal serum OHD levels. Other temporospatial gait parameters were not different among groups. Participants with the history of falls in previous 12 months (46.5%) had significantly wider step width which was interpreted as less gait stability than those without previous falls (p = 0.026).

Conclusion: Hypovitaminosis D tended to affect temporospatial gait parameter particularly double-limb support phase. History of falls was significantly associated with wider step width and less stability. The instrumented treadmill gait analysis system should be used in clinical practice especially in individuals with a tendency to fall.

Keywords: Hypovitaminosis D, Gait analysis, Gait impairments

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In the past two decades, the role of vitamin D beyond calcium homeostasis has become more widely recognized[1]. Experimental studies revealed vitamin D receptors [VDR] in skeletal muscle[2,3], and vitamin D metabolites were found to affect muscle metabolism by stimulating protein synthesis, increasing the proportion of type II muscle fibers and improving muscle function[4-6]. Histochemical findings of fiber composition after treatment with alpha-hydroxycholecalciferol induced a relative increase of muscle fiber type II A (or fast-twitch a) fibers and a reduction of muscle fiber type II B (or fast-twitch b) fibers. The cross-sectional area of the fast-twitch fibers also increased with the treatment[7].

Clinical studies on elderly people showed that low serum levels of 25-hydroxyvitamin D [25OHD] correlated with a decrease in lower-extremity muscle strength, poorer performances in rising from a chair

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and balance, and increased risks of falls(8-10). Other studies had inconsistent findings and could not demonstrate such correlation(11).

Recently, data in a cohort of community-dwelling older women showed that low serum 25 OHD concentrations were associated with slow walk in gait speed evaluation measured either at usual or fast paces(12). The results could speculate that hypovitaminosis D may increase risk of falls by its action on neuromuscular system involving in gait stability control(13,14).

While walking at normal self-selected speed, a subject may reproduce comparable limb-coordinated movements from stride to stride. Stride-to-stride variability of stride time [STV] is a measure of limb movement variability. Because gait is an automated regular rhythmic motor behavior, STV is typically low in healthy subjects. The STV is a reliable marker of gait control, and may be used as a clinical index of gait stability. Low serum 25 OHD concentrations were associated with high STV reflecting a disturbed gait control(14).

Low levels of vitamin D were also associated with postural instability. This association could also have an effect on gait velocity and increased risk of falls(15). Lower 25 OHD levels are associated with a worse coordination and weaker lower-extremity muscles evaluated by the 5-timed chair stands in women, a slower walking time and a lower upper limb strength in men, and a weaker aerobic capacity evaluated by 6-minute walking in both genders(16). The study showed the association of lower 25 OHD levels and worse coordination and weaker lower-extremity muscles.

With the advent of modern instrumented treadmill gait analysis system, basic temporospatial gait parameters have been increasingly used by clinicians to define the characteristics of normal and pathological gaits. This instrumented treadmill gait analysis system has many advantages over the traditional gait analysis system that it allows rapid determination of temporospatial parameters during overground walking, less working space required, simple, inexpensive, not provoking discomfort to subjects, reproducible, and was proven to have good agreement with parameters derived from 3-D motional analysis systems(17,18). Hence, it allows the clinician to monitor the progress of rehabilitation training(19).

Previous studies used classical instrumented walkway gait analysis system to evaluate any gait deviation in patients with hypovitaminosis D. The function of new instrumented treadmill gait analysis system has never been reported in the individuals with hypovitaminosis D. The purpose of this study was to objectively assess gait parameters in elderly participants who had hypovitaminosis D with the instrumented treadmill gait analysis system. Associations of history of falls with 25 OHD levels and gait parameters were also studied.

Materials and Methods

The study received approval from the institution Ethics Committee involving human subjects (COA 19/2014) and was undertaken under the principles outlined in the Declaration of Helsinki. Inclusion criteria were healthy adults aged 65 to 85 years who were community-dwellers in urban area (in and around Bangkok), attended Physical Medicine and Rehabilitation out-patient clinic between January 2015 and December 2015, and consented to participate in the study. Exclusion criteria were individuals with body mass index [BMI] >40 kg/m^2, estimated glomerular filtration rate [eGFR] <60 ml/min/1.73 m^2, had impaired perception or cognition, had medical condition, musculoskeletal or neurological diseases that could interfere with the gait analysis, and those who ambulated with any kinds of gait aid. The individuals who declined to have serum 25 OHD levels determination were also excluded.

Serum 25 OHD was performed in the university laboratory. Venous blood samples were taken at the hospital phlebotomy unit of the university in the morning around 8 am and analyzed separately for each participant. Serum 25 OHD levels were measured by electrochemiluminescence immunoassay with Cobas e 601 immunoassay analyzer (Roche Diagnostics, Switzerland). The specificity to 25 (OH) D3 was 95% and to 25 (OH) D2 was 81% with repeatability: concentration ≤15 ng/ml, SD ≤1 ng/ml, concentration >15 ng/ml, coefficients of variation [CV] ≤6.5% and reproducibility: concentration ≤15 ng/ml, SD ≤1.7 ng/ml, concentration >15 ng/ml, CV ≤11.5%, respectively(20). The reference range for the assay is 30 ng/ml for vitamin D sufficiency, 20 to 29 ng/ml for vitamin D insufficiency and less than 20 ng/ml for vitamin D deficiency(21). Serum creatinine levels were also measured by using the same blood samples to estimate eGFR of each participant.

The participants were divided into 3 groups according to serum 25 OHD level: normal (>30 ng/ml), insufficient (20 to 30 ng/ml) and deficient (<20 ng/ml)(21). The insufficient and deficient groups were collectively called as hypovitaminosis D group.

Gait analysis by Zebris instrumented gait analysis system (Zebris instrumented treadmill gait analysis system FDM-THM-S, Zebris Medical GmbH, Germany) was conducted within 30 days of serum 25 OHD measurements. Temporospatial gait data were collected from a capacitance-based foot pressure platform housed within a treadmill. The pressure platform had a sensing area of 108.4x47.4 cm and incorporated 7,168 sensors, each approximately 0.85x0.85 cm. The treadmill has a contact surface of 150x50 cm and its speed could be adjusted between 0.2 and 22 km/hr, at intervals of 0.1 km/hr. Although the grade of the contact surface of the treadmill is adjustable in 1% increments up to 25%, it was maintained in a horizontal position (0%) throughout testing. High levels of between- and within-day reliability have been reported for the majority of temporospatial gait parameters recorded by the Zebris system during walking in healthy elderly[22].

Gait parameters recorded in this study were temporospatial parameters which included step width, stride length, stride time, stride-to-stride variability of stride time [STV], double-limb support [DLS] phase, cadence and gait velocity. Participants were asked to walk with their usual self-selected walking speed in a quiet room with bare feet on the treadmill belt. They were demonstrated first about how to walk on the treadmill and were allowed to walk without gait recording for trial for 5 minute and then recorded the gait parameters when they were well prepared and could walk with confidence (Figure 1).

We collected data of age, gender, BMI, history of falls within the past 12 months, serum 25 OHD, and temporospatial gait parameters.

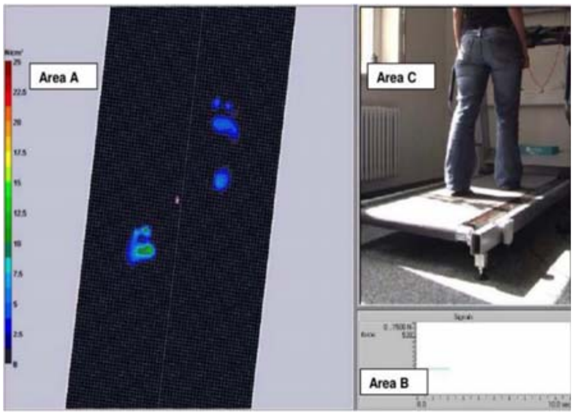

Figure 1. Gait analysis by instrumented treadmill system. Area A) Demonstrated the picture of footprints taken from the monitor.
Area B) Demonstrated the line graph plotted by the software which can show temporospatial gait parameters and pressure of each step.
Area C) Demonstrated the treadmill which the participant walked on.

Statistical analysis

Sample size for each group was calculated using power of analysis of 90% with effect size of 1.43 to demonstrate clinically important differences of gait velocity of 10 cm/sec. Demographic data of the patients and gait parameters were summarized as means with standard deviations or number with percentages. Baseline characteristics of gender, age, BMI, and gait parameters were compared according to serum 25 OHD levels. Gait parameters were also studied by the history of falls to detect the differences between fallers and non-fallers including history of falls, serum 25 OHD, and gait parameters. Data were compared using ANOVA for continuous data and Chi-square or Fisher-exact test for categorical data. Logistic regression analysis was used to compare differences of falls among the three groups of different serum 25 OHD levels. All statistics were performed using STATA software (version 14.2; STATA Corp. Tx) when *p*-value <0.05 will be considered as statistically significant.

Results

Total of 114 community-dwellers in urban area who aged 65-85 years attended our clinic during the study period. Eighteen were excluded because they declined to have serum 25 OHD determination (n = 4) or were lost to follow-up before gait analysis (n = 14). Therefore, 86 participants met all inclusion criteria and were included in the study. Flow chart of the study sample and population definition is shown in Figure 2. Mean age of 86 participants included in the study was 72.81±5.34 years with 23.47±4.46 kg/m^2 mean BMI. Majority was female (81.4%). Based on the established cut-off points for vitamin D status, 44.2% had normal serum 25 OHD, 37.2% had insufficient and 18.6% had deficient 25 OHD levels. No significant differences of gender, age, and BMI among the 3 groups of vitamin D status. However, numbers of participants with history of falls was highest in 25 OHD insufficient group but there was no statistical differences among 3 groups. Basic characteristic features and history of falls according to vitamin D status are shown in Table 1.

From gait analysis, this study found that the 25 OHD deficient group had longer double-limb support

[DLS] phase than the insufficient and normal groups: 55.75% in the deficient group compared to 46.50% in normal and 48.85% in insufficiency groups (Table 2).

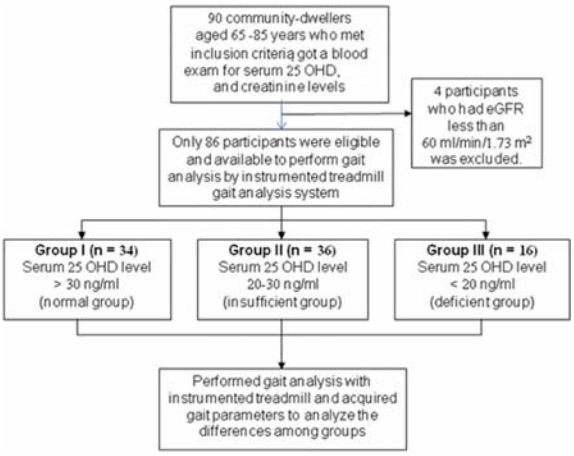

Figure 2. Flow chart of the study sample and population definition.

However, the difference was not statistically significant ($p = 0.120$).

When this study assessed the association of gait parameters and history of falls, the participants with history of falls had significantly wider step width: 11.7±3.83 cm vs. 11.04±2.74 cm ($p = 0.026$). There were no significant gait parameters between those who had history of falls or not. Data of gait parameters according to the history of falls are shown in Table 3.

Discussion

The results from this study showed that community-dwelling elders aged 65 to 85 years with low serum 25 OHD levels tended to have longer double-limb support [DLS] phase in gait cycle compared to those with normal serum 25 OHD concentrations. Although the difference was not statistically significant, the results might imply that this particular phase of walking (both feet on the ground before toeing off) was prolonged to secure the balance during walking. Theoretically, these associations may be explained by combined adverse effects of vitamin D

Table 1. Demographic data of participants (n = 86)

Serum OHD group	Normal (n = 38)	Insufficiency (n = 32)	Deficiency (n = 16)	*p*-value
Gender				
Male (%)	6 (7.0)	2 (2.3)	8 (9.3)	
Female (%)	32 (37.2)	30 (34.9)	8 (9.3)	
Mean age, (SD), years	73.05 (5.16)	72.34 (5.92)	72.71 (4.67)	0.860
Mean BMI, (SD), kg/m^2	22.99 (3.90)	23.14 (5.44)	25.25 (3.05)	0.110
History of falling				
Yes	11	20	9	0.050
No	27	12	7	

Table 2. Gait parameters analyzed among groups with different serum OHD groups, mean (SD)

Gait parameters	Serum OHD group			*p*-value
	Normal (n = 38)	Insufficiency (n = 32)	Deficiency (n = 16)	
DLS phase (%)	46.50 (7.90)	48.85 (8.77)	55.75 (16.41)	0.120
Step width (cm)	11.38 (2.81)	11.75 (3.91)	10.37 (2.63)	0.430
Stride length (cm)	40.29 (22.18)	38.78 (21.09)	32.87 (11.66)	0.570
Stride time (sec)	1.52 (0.55)	1.45 (0.50)	1.43 (0.35)	0.760
Stride-to-stride variability	7.97 (12.69)	13.74 (25.99)	11.75 (18.43)	0.420
Cadence (steps/min)	86.32 (20.49)	92.61 (20.84)	90.88 (18.90)	0.380
Velocity (km/h)	0.99 (0.4)	0.97 (0.35)	0.84 (0.31)	0.430

Table 3. Gait parameters analyzed by history of falling, mean (SD)

Gait parameters	History of falling within previous 12 months		*p*-value
	Yes, n = 40, (46.5%)	No, n = 46, (53.5%)	
Step width (cm)	11.70 (3.83)	11.04 (2.74)	0.026*
DLS phase (%)	48.87 (8.68)	49.47 (12.28)	0.883
Stride length (cm)	38.65 (22.16)	37.95 (18.44)	0.442
Stride time (sec)	1.49 (0.55)	1.46 (0.45)	0.513
Stride-to-stride variability	12.23 (20.82)	11.00 (19.81)	0.354
Cadence (steps/min)	89.30 (19.78)	90.24 (21.01)	0.851
Velocity (km/h)	0.95 (0.46)	0.96 (0.35)	0.155

* *p*-value <0.05

deficiency on the complex physiologic function of muscular and nervous systems.

Regarding the method of gait assessment, one previous study measured gait speed (metre per second) of two walks at usual pace along 4-metre corridor and reported the best performance among participants who were allowed to use canes or walkers[16]. Although the gait speed measurement in that study was simpler, however, it was less accurate than the gait velocity recorded in the authors' study using the instrumented treadmill walkway gait analysis system. Furthermore, the authors' study excluded participants who ambulated with gait aids, so the gait velocities should be more genuine than their study.

Few studies had reported the association of vitamin D deficiency and gait[15,23]. One previous study, using a simple 6-minute walk test to assess gait speed in metre per second, also reported the associations between vitamin D deficiency (below 50 nmol/L or 20 ng/ml) and impairments in physiological functions such as weaker upper and lower limb strength, slower gait speed and impaired neurophysiological functions in community-dwelling elders between 70 to 90 years of age[23]. Another study which assessed gait velocity by instrumented walkway system (GaitRite®) in community-dwelling elderly subjects age 65 years and older among 3 groups of vitamin D levels[15]. They found lower gait velocity of the subjects with low vitamin D level (<30 nmol/L or 12 ng/ml) than those with higher levels[15]. Their study used very low cut-off levels of vitamin D at 30 nmol/L or 12 ng/ml (representing more severe hypovitaminosis D) whereas this study used 20 ng/ml (less severe hypovitaminosis D), so the authors' study could not detect any impact of low vitamin D on temporospatial gait parameters.

Previous studies reported the relationship between history of fall and gait. The elderly participants who had history of falls were found to have higher gait variability, less stable gait patterns and poorer local dynamic stability compared to non-fallers[24,25]. The authors from those studies proposed that increased variability of walking patterns may be an important gait risk factor in elderly people with history of falls. In line with previous studies, this study found that participants with history of falls had significantly wider step width than those without (p = 0.026). However, the statistical gait difference of 6.6 millimeters may not be of clinical significance. Furthermore, a small number of participants (regarding) may preclude a definite conclusion. Nevertheless, this positive finding could be an issue of interest for further study.

Regional variation of 25 OHD levels was studied in Thailand in 2011 in a large cohort survey in 15 to 98 year-old population[26]. Highest prevalence of hypovitaminosis D in Thailand, which accounted for 64.6% of the prevalence, was in Bangkok especially in female[26]. The authors' study, which included only the elderly, had slightly lower prevalence of hypovitaminosis D (60.5%). This may be due to a mean lower age of the subjects in this study than the survey study[26]. Although the number of subjects in this study was not as large as that in the national survey study, this study which additional analyzed and could demonstrate that the elderly with hypovitaminosis D had a significantly higher risk of falls than those with normal vitamin D status.

This study had some limitations that the participants comprised a high proportion of elderly who were relatively healthy and in whom high levels of outdoor physical activity and outdoor mobility may lead to increased exposure to environmental hazards[27,28]. However, the greater exposure to sunlight would also lead to higher levels of serum 25 OHD with few presented with vitamin D deficiency. Furthermore, most of our subjects were female, and may not represent general community-dwelling population. In addition, the cross-sectional nature of study prevents us from confirming causal relationships between 25 OHD levels and deviated gait parameters.

There should be further studied with a large number of participants to compare gait parameters. An intervention with specific exercises to the patient with hypovitaminosis D for the decrease of gait deviation which was detected from this study, and the potential falls.

Conclusion

This study investigated the relationship between serum 25 OHD and gait deviation in a sample of healthy community-dwelling older people. In a geographical region of high ambient ultraviolet rays, hypovitaminosis D were presented about 60% of the elders. Participants who had hypovitaminosis D tended to have increased gait instability as shown in higher double-limb support phase in gait cycle than participants with normal serum 25 OHD level. Elderly with negative history of falls in previous 12 months showed better gait stability.

What is already known in this topic?

Low serum levels of 25-hydroxyvitamin D (25 OHD) correlated with decreased lower-extremity muscle strength, and poorer performance rising from a chair, balance and increased risk of falling in older people.

What this study adds?

The elderly with 25 OHD less than 20 ng/ml tended to have gait instability as shown in higher double-limb support phase in gait cycle than those with normal 25 OHD level. Elderly with no history of falling in previous 12 months before gait analysis with instrumented treadmill gait analysis system showed better gait stability.

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Potential conflicts of interest

The authors declare no conflict of interest.

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