Original Article
Correlation between vitamin D levels and static postural balance of both feet in type 2 diabetes mellitus patients

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Abstract: Objective: To analyze the differences in indicators of static postural balance in type 2 diabetes mellitus (T2DM) patients with different vitamin D levels and to investigate the association between vitamin D levels and fall risks in T2DM patients. Methods: A total of 125 T2DM patients were selected between Dec. 2014 and Oct. 2015. The patients were divided into the following groups according to their 25(OH)D levels: the severe deficiency group (group A), deficiency group (group B), insufficiency group (group C), and normal group (group D). Platform plantar pressure was measured to compare the differences in the total traveled way (TTW) of the center of pressure (COP) and the ellipse area (EA) enclosing the TTW of the COP among the 4 groups. Variables that affected the TTW of the COP and the EA enclosing the TTW of the COP were used for the Pearson correlation analysis. All factors with P<0.05 were included in the stepwise multiple linear regression analysis. Results: The TTW of the COP and the EA enclosing the 95% TTW of the COP in the vitamin D severe deficiency and deficiency groups were significantly higher than those in the insufficiency and normal groups. The stepwise multiple linear regression analysis showed that the 25(OH)D level had an independent negative correlation with the TTW of the COP and the EA enclosing the 95% TTW of the COP. Conclusions: The vitamin D level had an independent negative correlation with the static postural balance. Thus, when the vitamin D level in T2DM patients was lower, the fall risk was higher.

Keywords: Vitamin D, type 2 diabetes mellitus, balance

Introduction

Falls are an independent risk factor for fractures [1]. A reduction in balance ability is a major physiological reason for falls [2]. Balance ability is the ability to maintain body posture and is divided into static and dynamic postural balance. Static postural balance is the ability to control the body center in a relatively static condition. Current studies have confirmed that age, extension of reaction time, weakened righting reflex, decreased muscle strength, and reduced vision can all cause a reduction in the balance ability [3]. However, the influence of vitamin D (VitD) on balance ability is unknown.

Older Type 2 diabetic patients are at greater risk of falls [4, 5], and the increasing age, previous falls history, increased postural sway as well as presence of diabetes are major risk factors for falling [6, 7]. Diabetes can impair balance when compared with that in normal elderly subjects [8].

This study used the Footscan Balance 7.7 platform plantar pressure measurement system to detect the total traveled way (TTW) of the center of pressure (COP) and the 95% confidence ellipse area (EA) enclosing the TTW of the COP in subjects in a double leg stance. This procedure was used to evaluate the static postural balance ability and the association between vitamin D levels in type 2 diabetes mellitus (T2DM) patients and balance performance.

Materials and methods

Patients

T2DM patients treated in the Department of Endocrinology in the West Coast Medical Center of Qingdao University from December 2014 to October 2015 were selected. All patients met the diagnostic standards for T2DM. Their ages were between 30 and 60 years. The exclusion criteria were as follows: (1) patients with combined diseases that affected VitD metabolism,
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such as primary hyperparathyroidism, severe liver diseases, kidney diseases, and malignant tumors; (2) patients with combined diseases that affected their balance ability, such as cerebrovascular diseases, severe osteoarthritis, and Meniere’s syndrome; and (3) patients who took drugs that affected bone and VitD metabolism, such as the administration of bisphosphonate preparations in the past year and estrogen, estrogen receptor modulators, calcitonin, calcium, or VitD within the past 3 months. A total of 125 patients (62 men and 63 women) were enrolled in this study.

Collection of medical history

A specially assigned person performed the investigation and recorded the patients’ medical histories, including past health conditions, systemic diseases, medication history, fall history, and trauma history.

Body measurement

All investigation subjects were measured by the same person. The height, body weight, waistline, hipline, calculated body mass index (BMI), and waist-to-hip ratio were recorded. The accuracy of the height measurement was 0.1 cm, the accuracy of the body weight measurement was 0.1 kg, and the BMI was calculated as BMI = body weight (kg)/height$^2$ (m$^2$). During the waistline measurement, the subjects wore thin underwear. The waistline measurement was the circumference enclosing the navel horizontally once around with an accuracy of 0.1 cm.

Laboratory examination

Fasting serum samples were collected after fasting for 8 h. Indicators including 25-hydroxyvitamin D$_3$ (25(OH)D$_3$), glycated hemoglobin (HbA1c), blood glucose, liver function, and kidney function were measured. Detection of 25(OH)D$_3$ was performed using the electrochemiluminescent immunoassay (ELICIA) reagent kit (Roche Diagnostics, Basel, Switzerland). The minimum limit of human serum 25(OH)D$_3$ detection using this method was 4 ng/ml.

Bone mineral density (BMD)

The calcaneus bone density was measured using a calcaneus bone densitometer (SAHARA). The left foot and right foot were measured separately, and the mean value was obtained.

Measurement of static postural balance

The Footscan Balance 7.7 platform plantar pressure measurement system (Rscan, Belgium) was used to measure the travel distance of the COP of both of the patient’s feet in a double leg stance in the X and Y directions (Cop X and Cop Y, respectively), the TTW of the COP, and the 95% confidence EA enclosing the TTW of the COP.

The double leg stance

The subjects stood barefoot on the testing platform in a bright and quiet environment. The tips of both feet were separated and formed an angle of approximately 30 degrees. Both hands hung down naturally. Both eyes looked straight ahead. The measurement was performed for 30 s.

Statistical analysis

The SPSS 21.0 software was used for the statistical analysis. Continuous variables that conformed to a normal distribution were presented as $x \pm s$. The data were analyzed according to the feature of the distribution of the clinical information of all groups. Measurement data that conformed to a normal distribution and had homogeneous variances between groups were compared using analysis of variance (ANOVA). Comparisons inside a group were performed using the LSD method. Pairwise correlation between variables was performed using partial correlation analysis. Variables that had statistical significance were used for the stepwise multiple linear regression analysis. $P<0.05$ indicated that the difference had statistical significance.

Results

General condition

The subjects were divided into groups according to their 25(OH)D$_3$ levels as follows: <10 ng/ml was the severe deficiency group (group A), $\geq$10 ng/ml and <20 ng/ml was the deficiency group (group B), $\geq$20 ng/ml and <30 ng/ml was the insufficiency group (group C), and $\geq$30 ng/ml and <50 ng/ml was the normal group (group
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Table 1. Comparison of clinical information among groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of cases (M/F)</th>
<th>Age (years)</th>
<th>Disease history (years)</th>
<th>BMI (kg/m²)</th>
<th>Waist to hip ratio</th>
<th>Bone mineral density (g/cm²)</th>
<th>HbA1c (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe deficiency group (A)</td>
<td>33 (17/16)</td>
<td>49.73±7.28</td>
<td>5.85±3.11</td>
<td>24.21±1.44</td>
<td>0.89±0.04</td>
<td>0.50±0.13</td>
<td>8.26±0.77</td>
</tr>
<tr>
<td>Deficiency group (B)</td>
<td>31 (15/16)</td>
<td>50.19±5.74</td>
<td>5.65±3.05</td>
<td>23.99±1.57</td>
<td>0.87±0.00</td>
<td>0.49±0.12</td>
<td>8.02±1.11</td>
</tr>
<tr>
<td>Insufficiency group (C)</td>
<td>31 (15/16)</td>
<td>48.87±6.59</td>
<td>6.26±2.92</td>
<td>24.32±2.18</td>
<td>0.89±0.05</td>
<td>0.50±0.11</td>
<td>8.10±0.75</td>
</tr>
<tr>
<td>Normal group (D)</td>
<td>30 (15/15)</td>
<td>49.00±6.73</td>
<td>5.67±3.06</td>
<td>24.11±2.02</td>
<td>0.88±0.04</td>
<td>0.50±0.12</td>
<td>7.98±0.83</td>
</tr>
</tbody>
</table>

F value 0.275 0.270 0.186 1.362 0.616 0.067
P value 0.843 0.847 0.906 0.258 0.606 0.977

Note: M-male, F-female.

Table 2. Comparison of the TTW and EA among all groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Cop X (mm)</th>
<th>Cop Y (mm)</th>
<th>TTW (mm)</th>
<th>EA (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe deficiency group (A)</td>
<td>7.09±3.57</td>
<td>10.48±4.47</td>
<td>126.48±47.51</td>
<td>11.23±8.83*</td>
</tr>
<tr>
<td>Deficiency group (B)</td>
<td>6.71±3.50</td>
<td>10.23±5.81</td>
<td>117.03±42.81</td>
<td>9.23±8.59*</td>
</tr>
<tr>
<td>Insufficiency group (C)</td>
<td>5.87±2.62</td>
<td>8.39±3.17</td>
<td>93.35±28.67</td>
<td>7.37±4.82</td>
</tr>
<tr>
<td>Normal group (D)</td>
<td>6.40±2.49</td>
<td>8.43±3.42</td>
<td>82.53±14.38</td>
<td>5.33±2.81</td>
</tr>
</tbody>
</table>

F value 0.883 2.110 9.977 4.297
P value 0.452 0.103 0.000 0.006

Note: *Compared with group C, P<0.05; **Compared with group D, P<0.05.

D) [9]. No significant differences were observed for the age, gender, medical history, HbA1c, BMI, waist to hip ratio, and BMD between groups (P>0.05) (Table 1).

Comparison of static postural balance among different vitamin D groups

No significant differences were detected in the travel distances of the COP in the X direction (Cop X) and in the Y direction (Cop Y) between the subjects in all groups. The TTWs of the COP in group A and group B were significantly higher than those in group C and group D (P<0.05). However, the differences between group A and group B and between group C and group D did not achieve statistical significance. The differences in the EA enclosing the 95% confidence intervals of the TTWs of the COPs between group A and group C, between group A and group D, and between group B and group D were all significant (Table 2).

Correlation analysis between the 25(OH)D₃ levels and balance indicators

The Pearson correlation analysis showed that 25(OH)D₃ was negatively correlated with the total traveled length in the Y direction (CopY) (r=-0.191, P=0.033), the TTW of the COP (r=-0.443, P=0.000), and the EA enclosing 95% of the TTW of the COP (r=-0.320, P=0.000) but not correlated with the total traveled length in the X direction (r=-0.096, P=0.285). The BMD did not correlate with the TTW or the EA. The TTW and EA were used individually as dependent variables, and age and 25(OH)D₃ related to the TTW and EA were used as independent variables in the stepwise multiple linear regression analysis. The results showed that 25(OH)D₃ entered the equation and was independently correlated with the TTW (regression equation: TTW=137.722-1.703 25(OH)D₃, P=0.000) and EA (regression equation: EA=12.524-0.219 25(OH)D₃, P=0.000) (Figures 1 and 2).

Discussion

Human static postural balance is the ability to control the body center under a relatively static status. Static postural balance is transmitted into the central nervous system. After comprehensive analysis by the central nervous system, the nerve impulse is issued by the pyramidal tract to regulate the muscle and bone systems, which correct the deviation of the body at any time to maintain balance. The maintenance of balance requires the coordinated functions of the nervous system, the muscles, and the skeleton [10].
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The results in this study suggested that significant differences existed in the balance abilities of T2DM populations with different VitD levels. The linear regression analysis suggested that VitD levels had a significant negative correlation with the two balance indicators (TTW and EA). Similarly to our results, Dhesi et al. [11] showed that serum 25(OH)D$_3$ levels were associated with posture stability and body reaction time. Therefore, the authors speculated that VitD might improve the balance ability by improving the functions of the muscles and the central nervous system. Their study also supplemented VitD3 with VitD deficiency in elderly people to effectively improve physiological functions, reaction times, balance ability, and postural sway and to reduce falls. Tang et al. [12] performed a meta-analysis on VitD supplementation and fall prevention and showed that a high dose of general VitD could reduce the incidence of falls in elderly people.

This study did not find a correlation between BMD and static postural balance indicators. Past studies showed that female osteoporosis patients had larger amplitude of postural sway and changes in balance control strategies [13]. Fan et al. showed that lumbar BMD was positively correlated with fall indicators and suggested that patients with higher risks of falls had higher lumbar BMDs [14]. The authors did not show a correlation between femoral neck BMD and fall indicators. Therefore, these authors hypothesized that BMD did not significantly affect balance functions and that changes in lumbar BMD were compensatory changes. Our study measured the calcaneal BMD. Combined with previous results, our results suggested that BMD did not significantly affect static postural balance.
The mechanism underlying the effect of VitD on balance ability is not completely clear. Current studies have shown that VitD may play a major role in muscle strength. Muscle tissues express receptors for 1,25(OH)\textsubscript{2}D\textsubscript{3} and can respond to 1,25(OH)\textsubscript{3}D\textsubscript{3} at a physiological concentration. Stimulation of the receptors can induce an increase in the area of type II muscle fibers. The muscle fiber area gradually decreases and the sample size in this study was relatively small. Therefore, the mechanism requires further study.

In summary, the results in this study indicated that the VitD level in T2DM patients had an independent negative correlation with the maintenance of static postural balance. However, the mechanism underlying the influence of vitamin D on static postural balance is not clear and the sample size in this study was relatively small. Therefore, the mechanism requires further study.

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Disclosure of conflict of interest

None.

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