Evaluation of Postural Stability in Elderly With Diabetic Neuropathy

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OBJECTIVE — The objective of this study was to compare clinical and biomechanical characteristics of balance in diabetic polyneuropathic elderly patients and normal age-matched subjects.

RESEARCH DESIGN AND METHODS — Fifteen elderly with distal neuropathy (DNP) and 15 healthy age-matched subjects were evaluated with the biomechanical variable COP-COM, which represents the distance between the center of pressure (COP) and the center of mass (COM). Measurements were taken in the quiet position with a double-leg stance, in eyes-open (EO) and eyes-closed (EC) conditions. Subjects were also assessed with clinical balance evaluations.

RESULTS — The COP-COM variable was statistically significantly larger in the DNP group than in the healthy group in anterior-posterior (A/P) and medial-lateral (M/L) directions. Furthermore, the DNP group showed statistically significantly larger amplitudes of the COP-COM variable without vision. The severity of the neuropathy, as quantified using the Valk scoring system, was correlated with COP-COM amplitude in both directions.

CONCLUSIONS — Evaluation of the postural stability of an elderly diabetic population using the COP-COM variable can detect a very small change in postural stability and could be helpful in identifying elderly with DNP at risk of falling.

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The prevalence of diabetes increases markedly in the elderly population (1). Over the course of the disease, diabetes leads to various disabilities and, at times, lifelong chronic complications, with diabetic neuropathy being the most common symptomatic complication (2). Approximately 50% of diabetic patients >60 years of age show evidence of peripheral neuropathy (3,4). Only a few studies focused on the postural problem in the elderly with diabetic neuropathy (5–9).

The small amount of evidence on the effect of distal neuropathy (DNP) on postural control could be attributable to the poor measures available to detect postural instability. Until recently, there were few reliable and valid measures that accurately described postural control in the quiet standing position for the elderly population with and without disabilities. All of these selected measures show considerable variability (10). The center of pressure (COP) variable has often been used to measure postural control. However, higher COP parameters, such as length, area, displacement, or velocity, are not necessarily indicative of a risk of falling (11). COP movements may successfully stabilize the center of mass (COM) by maintaining the COM over the base of support and thereby reducing the risk of falling (12). To overcome these limitations, it has been suggested that the combined interpretation of COP and COM displacements provides better insight into the assessment of balance than COP and COM taken separately (11,13–15). Thus, a new biomechanical variable (COP-COM), which represents the scalar distance at a given time between the COP and COM (13), has been proposed. This variable showed good test-retest and interrater reliability (16).

The work presented here addresses 2 questions: 1) Are biomechanical COP-COM and clinical variables different in healthy and DNP elderly subjects and 2) Is COP-COM amplitude associated with increased neuropathy severity as quantified using the scoring system devised by Valk et al. (17)?

RESEARCH DESIGN AND METHODS

Subjects

Fifteen elderly patients with type 2 diabetes with DNP and 15 healthy elderly were studied. Only diabetic subjects with neuropathy were selected because postural instability was previously found to be significantly associated with sensory neuropathy but not with diabetes per se (6). The DNP subjects were recruited from a specialty diabetes clinic. The polyneuropathy was quantified using a scoring system developed and described by Valk and colleagues (17,18). The scoring system has 4 levels of neuropathy: normal, mild, moderate, and severe. Briefly, it consists of clinical testing of 1) sensory modalities (pinprick, light touch, vibration, and pain), 2) the anatomic level below which light touch sensation is impaired, 3) muscle strength, and 4) ankle jerk. The total score can vary between 0 and 33. A total score of 0 is graded as no polyneuropathy, 1–9 as mild, 10–18 as moderate, and 19–33 as severe polyneuropathy. This clinical evalu-
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had to have a fasting blood sugar level
ous onset of diabetes, the healthy elderly
in the past 6 months. Because of the insidi-
dysfunction or if they reported at least 1 fall
jects. The eligibility criteria consisted of
sex, height, and weight with the DNP sub-
(19). They were matched according to age,
register of subjects who showed an interest
and did not present with ulceration.

Healthy subjects were recruited from a
register of subjects who showed an interest
in studies carried out at the research center
(19). They were matched according to age,
sex, height, and weight with the DNP sub-
jects. The eligibility criteria consisted of
being at least 60 years of age, living inde-
pendently in the community, and having no
neurological or musculoskeletal impair-
ments, such as a history of stroke, transient
ischemia attacks, Parkinson’s disease, or
lower-extremity joint replacement. Subjects
were excluded if they reported visual
somatosensory impairments or vestibular
dysfunction or if they reported at least 1 fall
in the past 6 months. Because of the insidi-
ous onset of diabetes, the healthy elderly
had to have a fasting blood sugar level < 7.8
mmol/l and an HbA1c < 11.1 mmol/l to be
eligible for the study. The minor abnormal-
ities found on physical examination of the
healthy elderly, such as a reduction in vibra-
tion sense at the malleolus and a reduction
in Achilles’ tendon reflexes, are commonly
associated with aging (20, 21). Conse-
quently, control subjects were selected if
they scored lower than 2 on the Valk scale.

Data collection procedure
All subjects in this study were participants
in a previous study, which determined the
test-retest and interrater reliability of the
COP-COM variable (16). Two different
evaluation sessions were used to collect all
of the measurements. At the first session,
the subject characteristics, stability mea-
ures, and strength data were collected. At
the second session, the somatosensory
valuations were performed.

Stability measure
The procedure used was the same as in the
previous studies (22, 23). Subjects stood
quietly on 2 adjacent force platforms in a
double-leg stance with feet at pelvis-width
while measurements were made. Some
degrees of hip external rotation were
allowed to minimize discomfort and con-
straints on the subjects’ preferred position
(24). To ensure that this position remained
constant, tracings were taken of foot place-
ment, and subjects were required to remain
within these tracings for all of the trials. To
evaluate the subjects in an ecological situa-
tion, all subjects wore flat-soled shoes usu-
ally used for walking.

The subjects were instructed to look
straight ahead with their head erect and to
maintain balance. Their arms were placed in
a comfortable position hanging at their
sides. For all subjects, data were collected
for 4 successive trials lasting 120 s with eyes
open (EO) with a rest period of -5 min
between trials. Then, after a rest of 10 min,
all subjects performed the 2-min task 4
times with eyes closed (EC). The EO and
EC conditions were repeated in the same
order for all of the subjects. The 4 trials were
averaged under each condition. The mini-
mal metrically detectable difference for the
COP-COM variable was estimated to be
0.01 cm in the anterior-posterior (A/P)
direction and 0.02 cm in the medio-lateral
(M/L) direction (22). Anthropometric
tables were used to estimate total COM. Full
details of the anthropometric data marker
placement protocol (25), apparatus, and
methods (23) have been described in detail
elsewhere and will be summarized here.

The model consists of 4 trunk segments, 1
pelvis, 2 thighs, 2 legs and feet, 2 upper
arms, 2 forearms, and 1 head. There were
21 infrared light–emitting diodes attached
bilaterally to anatomical landmarks to
define a 14-segment model. There are
Opto-
track sensors (Northern Digital, Waterloo,
Ontario, Canada) recorded marker dis-
placement while ground reaction forces and
moments were recorded by 2 AMTI force
platforms (Advanced Mechanical Technol-
ogy, Watertown, MA). The Optotrak’s reso-
nution is 0.01 mm and its accuracy in root
mean square (RMS) is 0.1 mm. The resolu-
tion of the AMTI force platform is 0.08 µV ·
V−1 · N−1. The accuracy of the COP mea-
sured in the present study was 0.2 mm.
Both devices were interfaced to an A/D con-
verter with a sampling rate of 20 Hz. Data
were processed on a Pentium PC using the
software written for Matlab 5.1 (Math-
works, Natick, MA).

Clinical evaluations
After a rest period of ~30 min lying down
on a bed, all of the clinical evaluations of
sensation were done. Somatosensory func-
tion tests included evaluation of touch-
pressure and vibratory perception threshold.
For the sensory tests, the sub-
jects were in a supine position.

The full set of 20 Semmes-Weinstein
monofilaments (the higher the number, the
more severe the neuropathy) was used for
evaluating touch-pressure sensation (26).
The protocol developed by Sosenko et al.
(27) was used. The lateral aspect of the dis-
tal phalanx of the first toe was evaluated.
The vibration perception threshold (VPT)
was assessed using a fixed frequency (120
Hz) variable amplitude vibrometer (Vibra-
tor IV; Somedic Instruments, Farsta, Swe-
den). The subject was instructed to say
when the vibration first appeared (the VPT)
and when it disappeared (the vibration dis-
appearance threshold [VDT]). According
to the classical methods of limits, the vibration
threshold (VT) is the average of VPT and
VDT. Two kinds of visual evaluations were
chosen: distal acuity using the Snellen Card
(28) and peripheral vision of each eye (29).

One functional evaluation of balance
was administered: the modified scale
developed by Tinetti (30). Tinetti’s mobili-
ity scale consists of 24 balance and 16 gait
maneuvers. Each item is graded on a 3-point
scale, 0–2, or on a 2-point scale, 0–1, for a
total score of 40.

The strength of the main muscle of the
lower extremity was measured. Plantar
flexor and abductor strength were tested
with a handheld dynamometer (Nicholas
MMT; Lafayette Instruments, Lafayette,
IN). The knee extensor, hip flexor, and
dorsiflexor muscles were tested with a
belt-resistant method (31). The simple
reaction time, the interval times between
the presentation of the visual stimuli, and
the tapping of the space bar were also
measured (32). The computer program
React II was used (React II; Life Science
Associates, Bayport, NY).

Data analysis
The characteristics of the study sample are
described by the mean and the SD for con-
tinuous variables and by frequency and per-
centage for categorical variables. The root
mean square (RMS) amplitudes were calcu-
larized for the COP-COM variables in both
A/P and M/L directions. The Mann-Whit-
ney U test was used to compare control sub-
jects with DNP subjects, and Wilcoxon’s
signed-rank test was used to compare vision
conditions. Spearman’s correlation coeffi-
cient was used to evaluate the correlation of
the COP-COM variable with the index
developed by Valk et al. (17). Some DNP
subjects with the most severe neuropathy
exceeded values for the vibratory sensation.
In these cases, the subjects were assigned
the maximal value possible for those tests
(33). Statistical significance was assumed at
P < 0.05 (2-tailed). A sample size of 15
Table 1—Descriptive characteristics of the subjects

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Patients with DNP</th>
<th>Control subjects</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>15</td>
<td>15</td>
<td>—</td>
</tr>
<tr>
<td>Age (years)</td>
<td>68.8 ± 5.5*</td>
<td>69.3 ± 5.1</td>
<td>0.78</td>
</tr>
<tr>
<td>HbA1c (mmol/l)</td>
<td>7.7 ± 1.5</td>
<td>5.7 ± 0.55</td>
<td>0.001</td>
</tr>
<tr>
<td>Fasting blood glucose (mmol/l)</td>
<td>8.0 ± 2.0</td>
<td>5.4 ± 0.72</td>
<td>0.001</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.6 ± 0.1</td>
<td>1.6 ± 0.1</td>
<td>0.62</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.2 ± 9.6</td>
<td>74.3 ± 10.4</td>
<td>0.97</td>
</tr>
<tr>
<td>Vision (Snellen card) (% &gt;20/16)</td>
<td>33.3</td>
<td>93.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Valk scale (/33)</td>
<td>15 ± 8.2</td>
<td>0.4 ± 0.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Vibration first toe (µm)</td>
<td>26.8 ± 35</td>
<td>1 ± 0.53</td>
<td>0.001</td>
</tr>
<tr>
<td>Filament first toe (% &gt;3.84)</td>
<td>87.7</td>
<td>20.0</td>
<td>0.002</td>
</tr>
<tr>
<td>React II (s)</td>
<td>0.46 ± 0.1</td>
<td>0.38 ± 0.6</td>
<td>0.007</td>
</tr>
<tr>
<td>Tinetti (/40)</td>
<td>35.4 ± 5.7</td>
<td>40 ± 0</td>
<td>0.002</td>
</tr>
</tbody>
</table>

Strength

<table>
<thead>
<tr>
<th></th>
<th>Patients with DNP</th>
<th>Control subjects</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right hip flexion (N)*</td>
<td>231.5 ± 82.6</td>
<td>314.1 ± 65.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left hip flexion (N)</td>
<td>197.0 ± 108.3</td>
<td>312.1 ± 63.5</td>
<td>0.004</td>
</tr>
<tr>
<td>Right abductor (kg)†</td>
<td>9.4 ± 3.6</td>
<td>12.0 ± 2.5</td>
<td>0.146</td>
</tr>
<tr>
<td>Left abductor (kg)</td>
<td>9.4 ± 2.3</td>
<td>10.9 ± 1.9</td>
<td>0.146</td>
</tr>
<tr>
<td>Right quadriceps (N)</td>
<td>344.1 ± 140.0</td>
<td>482.2 ± 133.2</td>
<td>0.009</td>
</tr>
<tr>
<td>Left quadriceps (N)</td>
<td>330.3 ± 143.0</td>
<td>471.1 ± 124.3</td>
<td>0.009</td>
</tr>
<tr>
<td>Right dorsiflexion (N)</td>
<td>197.8 ± 86.0</td>
<td>244.0 ± 44.0</td>
<td>0.146</td>
</tr>
<tr>
<td>Left dorsiflexion (N)</td>
<td>193.0 ± 78.2</td>
<td>248.0 ± 46.7</td>
<td>0.063</td>
</tr>
<tr>
<td>Right plantarflexion (kg)</td>
<td>11.9 ± 2.9</td>
<td>18.0 ± 7.2</td>
<td>0.000</td>
</tr>
<tr>
<td>Left plantarflexion (kg)</td>
<td>11.6 ± 3.7</td>
<td>15.9 ± 6.6</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Data are n, %, or means ± SD. *Measured with microfet; †measured with Nicholas dynamometer.

individuals per group allowed for detection of a difference of 1 SD of the COP-COM amplitude between groups with a power of 80% (34).

RESULTS—In each group, 6 women and 9 men were evaluated. Using a polyneuropathy severity index developed by Valk et al. (17), 5 DNP subjects were classified as mild, 7 as moderate, and 3 as severe polyneuropathic cases. Duration of type 2 diabetes was 15.7 ± 9.9 years. Three diabetic subjects had a peripheral vascular disease. Additionally, none of the subjects were using tricyclic antidepressants or antipsychotic drugs. Ten subjects in the diabetic group and 3 subjects in the control group were on various doses of ACE inhibitors, β-blockers, or calcium channel blockers for stable hypertension or cardiac problems. During testing, no subject in either group complained of symptoms of cerebral hypoperfusion. All normal subjects had a Valk score under 2. There were significant differences between the 2 groups in all sensory tests, the Tinetti mobility scale, and reaction time. The hip flexor, knee extensor, and plantar flexor strength were significantly different, but not the abductor and dorsal flexor muscle. A complete comparison of subject characteristics for the 2 groups is provided in Table 1.

Table 2 shows the RMS scores obtained for the COP-COM variable for both EO and EC conditions and A/P and M/L directions. A statistically significant difference was found between the 2 groups in both EO and EC conditions in A/P (P < 0.021 and P < 0.005, respectively) and M/L (P < 0.009) directions.

CONCLUSION—The main objective of this study was to compare DNP patients with healthy elderly patients using the biomechanical COP-COM variable. The neuropathy group showed less stable posture than the control group, with and without vision. The difference found between the 2 groups in the present study was 0.06 and 0.07 cm, respectively, in the A/P direction in EO and EC conditions. It was previously reported that the clinically significant diff-

Table 2—COP-COM amplitude (in centimeters) obtained in diabetic DNP and healthy subjects for EO and EC conditions and A/P and M/L directions

<table>
<thead>
<tr>
<th>COP-COM</th>
<th>Patients with DNP</th>
<th>Control subjects</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/P</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO</td>
<td>0.13 ± 0.05</td>
<td>0.09 ± 0.02</td>
<td>0.021</td>
</tr>
<tr>
<td>EC</td>
<td>0.20 ± 0.09</td>
<td>0.13 ± 0.04</td>
<td>0.005</td>
</tr>
<tr>
<td>EO/EC difference</td>
<td>0.06 ± 0.05</td>
<td>0.03 ± 0.04</td>
<td>0.001</td>
</tr>
<tr>
<td>P†</td>
<td>0.001</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>M/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EO</td>
<td>0.11 ± 0.04</td>
<td>0.07 ± 0.01</td>
<td>0.003</td>
</tr>
<tr>
<td>EC</td>
<td>0.14 ± 0.06</td>
<td>0.08 ± 0.02</td>
<td>0.002</td>
</tr>
<tr>
<td>EO/EC difference</td>
<td>0.03 ± 0.02</td>
<td>0.01 ± 0.02</td>
<td>0.025</td>
</tr>
<tr>
<td>P†</td>
<td>0.02</td>
<td>0.256</td>
<td></td>
</tr>
</tbody>
</table>

Data are means ± SD, unless otherwise indicated. *Measured by Mann-Whitney U test; †measured by Wilcoxon’s signed-rank test.
Moreover, the statistically significant difference in quiet standing (37) found in the abductor muscles, which and knee extensor), but no difference was between the 2 groups (P < 0.027). Boucher et al. (7) stated that even with vision, the postural stability of the diabetic patient with DNP is impaired. However, in this latter study, vision was not evaluated. In the present study, even though vision was corrected by laser surgery for some diabetic subjects and was considered functional (over 20/25 on the Snellen test), because of its high reliability (16) and the excellent resolution and accuracy of the instrument used to measure the COP-COM. Interestingly, even though the reliability of the COP-COM in the M/L direction was not as good as the reliability in the A/P direction, a statistically significant difference was found between the 2 groups. Consequently, it seems that despite the noise from the measurement error, the postural instability in the M/L direction was large enough to be detected by the COP-COM variable. These results confirm the importance of lateral stability in quiet standing on this population (35).

The difference between the healthy and DNP groups was greatest when vision was absent. The increase in the RMS amplitude in the DNP group during the EC condition compared with the control group under the same condition could underscore their reliance on vision to compensate for their somatosensory impairment. But in the M/L direction, the DNP subjects showed larger COP-COM amplitude, demonstrating a poorer performance during EO conditions than the healthy elderly during EC conditions (P < 0.027). Boucher et al. (7) stated that even with vision, the postural stability of the diabetic patient with DNP is impaired. However, in this latter study, vision was not evaluated. In the present study, even though vision was corrected by laser surgery for some diabetic subjects and was considered functional (over 20/25 on the Snellen test), a statistically significant difference was found between the 2 groups (P < 0.001) (Table 1). Our results suggest that vision was impaired enough to limit the redundancy function of the systems, which implied and confirmed the importance of both sensory systems (vision and somatosensory) in controlling postural stability in quiet standing (36).

The diabetic subjects showed weakness in some proximal muscles (hip flexor and knee extensor), but no difference was found in the abductor muscles, which were previously found to be important for lateral stability in quiet standing (37). Moreover, the statistically significant difference found between the 2 groups in both vision conditions (EO and EC) suggests that vision and peripheral sensation affect postural stability in our diabetic subjects. Consequently, muscle weakness alone could hardly be responsible for loss of postural stability. Unfortunately, a motor nerve conduction measure was not done to confirm a possibility of motor myopathy, which is a limitation of this study. Nevertheless, the results of this study confirm the presence of postural instability in the elderly with DNP diabetes and suggest abnormalities of the different systems in this population. Moreover, they confirm that it can be difficult to isolate somatosensory problems for the control of stability in diabetic patients with neuropathy (38).

The severity of the neuropathy significantly correlated with COP-COM amplitude. We used a clinical evaluation demonstrated to have a significant correlation with scores obtained from a neuro-physiological examination (r = 0.7, P < 0.005) (17). Another study (7) found a significant correlation between the severity of the neuropathy and the biomechanical variable using the same index of severity.

Evaluating the postural stability of the elderly diabetic population using the COP-COM variable can detect a small change and deterioration in postural stability and could be helpful in identifying diabetic subjects at risk of falling. Using the COP-COM variable in the quiet position has several advantages. First, static posturography in the quiet position with head straight compared with other positions constitutes an easy task for elderly people with disabilities (6,9). Second, the COP-COM variable is related to falls, as shown by its good correlation with COM acceleration (13). Furthermore, in this study, the average mean of the Tinetti score for the neuropathic group is 35.4. Recent studies have demonstrated that subjects with a score lower than 36 had twice the risk of falling in the following year (39,40).

In this study, the DNP patients were not selected on the basis of complaints of instability. This means that the impairment of postural control in the elderly with DNP is not always apparent at an early stage but would be more important under challenging postural conditions. Because functional changes in both peripheral sensory and motor nerves can be present at a duration of diabetes of 4 years (41), it may be important to evaluate postural control in such patients as soon as possible to prevent injuries and other consequences of falls.

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**References**


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