

Postural Stability in Non-insulin Dependent Diabetics

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Abstract

Postural stability in 55 non-insulin dependent diabetics was compared with 53 non-diabetic controls matched for age and gender. The study was conducted in a primary care clinic, using a computerised postural sway system. Changes in the centre of pressure while the subjects stood on a force platform were recorded, and sway parameters computed using customised software. Clinical data were obtained by interview, physical examination, and from case records. Results of the study showed that non-insulin dependent diabetics were more unstable than the non-diabetic controls for four out of the six parameters studied (namely L, length of sway path; Vel, average speed of centre of pressure along its path; A, area included within the path of the centre of pressure; and A₉₅, 95% confidence elliptical area), after adjusting for height, weight, adequate sleep and alcohol intake the night before, and history of bone or thyroid disorders. Amongst diabetic subjects, significant factors associated with postural stability were age, weight, presence of peripheral neuropathy or cataract, metformin use, and HbA1c levels >9%. Further studies are indicated to look into factors affecting postural stability (other than diabetic neuropathy) in greater depth.

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Introduction

Human postural control is maintained by somatosensory, vestibular and visual feedback, integrated within the locomotor and central nervous systems.* Postural instability is associated with an increased risk of falling, especially in the elderly,²⁻⁵ and is also a predictor of fractures.^{6,7}

Recent studies, mainly among insulin dependent diabetics, have shown that diabetics are more unstable than non-diabetics, and that peripheral neuropathy is a major contributor to postural instability.^{8,9} Simoneau et al¹⁰ compared diabetic subjects with and without sensory neuropathy, with subjects who were neither diabetic nor neuropathic, and found that postural instability was significantly associated with diabetics with sensory neuropathy, and not with diabetics who had no neuropathy. Age was also found to be correlated with stability. The diabetic subjects in Simoneau's study consisted of both insulin dependent and non-insulin dependent individuals.

In a study on 25 older diabetics (aged 55 to 83 years), one of whom was insulin dependent, Lord et al¹¹ found that, when compared with non-diabetic controls, diabet-

ics performed poorly in tests of body sway on both firm and compliant surfaces, as measured by a swaymeter. Again, significant associations were found between postural instability with impaired sensori-motor function and age.

In all these studies, subjects were either pre-selected for the presence of peripheral neuropathy⁸⁻¹⁰ or assessed for the presence of it.¹¹ There may be other factors associated with postural stability in diabetics, in addition to peripheral neuropathy, such as the degree of blood sugar control and duration of diabetes, which have not been looked into. In addition, there is also a paucity of studies on postural stability in non-insulin dependent diabetics.

The objectives of this study were to assess the postural stability of non-insulin dependent diabetics, and to look into factors in addition to neuropathy that may be associated with it.

Materials and Methods

Study Population

The study was carried out in a Government Polyclinic in Singapore. The Polyclinic is a one-stop primary care

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clinic which provides preventive, curative and rehabilitative services. Diabetic patients form about 2% of the total patient population registered with this clinic, and diabetic consultations take up approximately 11% of all consultations.*

The diabetic subjects for this study were drawn from patients who came for follow-up visits for continuing care of diabetes. A total of 55 patients who consented to participate in the study were recruited. Patients with associated problems likely to cause postural instability were excluded. These were patients with musculoskeletal problems such as amputated lower limbs, residual disability from previous cerebrovascular accidents, patients with known vestibular problems, and those who were on antihypertensives.

The subjects who acted as controls were selected from patients who attended the Polyclinic for reasons such as routine preventive check-ups (e.g. Papanicolaou smears), health screening, and treatment of minor ailments (e.g. skin problems and upper respiratory tract infections). The controls were matched for age (± 5 years) and gender with the diabetic subjects. The same set of exclusion criteria applied. A total of 53 controls were recruited.

There was no significant difference in height between the controls and diabetic subjects. The diabetics were, however, heavier in weight than the controls (mean weight for diabetics and controls were 62.6 kg and 57.9 kg, respectively; $P < 0.05$). There was no difference in mean standing systolic and diastolic blood pressures between the controls and diabetics.

Study Protocol

Questionnaire and clinical examination: For both diabetics and controls, information was gathered on medical history of hypertension, thyroid disease and musculoskeletal problems, history of medication and alcohol intake, and whether sleep was adequate the night before. For the diabetic subjects, further history on duration since diagnosis and current diabetic treatment were included. Physical examination for both groups consisted of examination for postural hypotension (decrease in systolic or diastolic pressure of >10 mmHg from lying to standing position), the presence of clinical signs of peripheral vascular disease (temperature and colour change of lower extremities, absence of dorsalis pedis and posterior tibial pulses), proximal myopathy (weakness and wasting of hip muscles) and peripheral neuropathy (absence of pain, position and vibration senses, and absent knee and ankle reflexes). Information on diabetic retinopathy (fundal examination by ophthalmologists and retinal photography), blood sugar estimations (fasting or 2-hour post-prandial sugar, HbA1c) were also obtained from the case records. One trained field investigator assisted the author (HCY) throughout the study. Physical examination

for all subjects was conducted by the same author throughout.

Computerised postural sway assessment: In this study, measurement of postural stability was conducted for both diabetics and controls, using the method described below. This computerised sway system has earlier been used in two other studies to assess postural stability among workers exposed to neurotoxic metals.^{13,14}

Each subject was given two sets of tests. The first set consisted of three tests (each lasting 20 seconds) conducted with the eyes open. The second set consisted of three tests (also 20 seconds each) were conducted with the eyes closed. Each subject was asked to focus his sight on a fixed picture placed at his eye level throughout the measurement. For the eyes-closed tests, a strict 10 seconds' interval was observed between closing eyes and start of recording. The subjects stood with their bare feet on the platform, arms at their side, and feet apart. The position of the feet was established by footprints marked on the platform surface. All the subjects had the tests done between 9.00 am and 12.00 pm. This was to reduce possible effects of circadian rhythms. All the measurements were conducted blind by only one trained technician throughout the study.

The technician monitored the postural sway of the subjects on the computer screen as the tests were conducted. A particular test was repeated when any extraneous body movements were identified during the measurement.

Sway parameter data were collected using an Advance Mechanical Technology Inc (AMTI) computerised biomechanics platform system, described earlier.^{13,14} The sway parameters used for detecting performance changes were: X_o , Y_o —mean centre of pressure relative to the centre of the platform; L—length of sway path; Vel—mean velocity of the centre of pressure along its path; and A_o —area included within the path of the centre of pressure.

Reproducibility of sway parameters: During the commencement of the study, seven separate subject's postural sways were tested involving the same procedure. Each of the subjects had repeated measures of the postural sway test done for six consecutive days. Analysis of the results of the seven subjects collected over six days, using analysis of variance did not show any significant intra-subject variation at $P < 0.05$ level.

Statistical Analysis

Logarithmic transformation was applied to all sway parameter data to improve their normality. Proximal myopathy and peripheral neuropathy were determined by clinical methods. Diabetic subjects were considered to have proximal or peripheral neuropathy according to the examination conducted for the various categories as

listed in Table III. Diabetic control was judged to be not satisfactory if the fasting blood sugar taken on the day of examination was >8 mmol/L, or if the HbA1c taken within 3 months of the examination date was $>9\%$.

In univariate analysis, unpaired t-tests were used for individual parameters to ascertain the presence of any significant differences in the postural sway data between the subgroups, both when the eyes were opened and closed. Multiple logistic regression analysis was done to adjust for the effect of possible confounding variables on postural stability, namely weight, height, sleep, alcohol intake and history of thyroid or bone problems. Age and gender were not included in the model since the diabetics and controls were matched for these. As for the diabetic subjects, stepwise regression was used to identify the factors most likely to be associated with postural stability.

All statistical analysis was done using the SAS System for Personal Computers release 6.04.¹⁵

Results

Demographic and Clinical Data

Table I shows the comparison between diabetic subjects and controls. There was no significant difference between the two groups with reference to the variables listed. The clinical profiles of the diabetic subjects are as shown in Table II. Information on ophthalmic assessment was obtained from the patients' case notes, similarly for record of HbA1c estimation done within three months from the day the postural sway test was conducted. Fasting blood sugar levels were estimated on the day of the test itself.

In Table III, the prevalence of signs suggestive of diabetic neuropathy were compared between the dia-

betic subjects and non-diabetic controls. There was a difference in the prevalence of signs with regard to absent tendon reflexes and weakness of hip muscles between the two comparison groups. These were entered into the model for multivariate analysis, when comparing postural sway data between diabetics and controls.

Postural Sway Data

Table IV shows that age was significantly correlated with more postural sway parameters than height or weight. When comparing diabetics and controls with eyes open, the differences between diabetics and con-

TABLE II: CLINICAL PROFILE OF DIABETIC SUBJECTS

Profile	
Known duration of diabetes (years)	
Mean	7.7
Range	<1 to 24
≤10 years	39/55 (70.9%)
Diabetic treatment	
Dietary control	11/55 (20.0%)
Single drug regimen	
Glibenclamide or tolbutamide	21/55 (38.2%)
Metformin	1/55 (1.8%)
Combination (sulphonylurea and metformin)	18/55 (32.7%)
Insulin	4/55 (7.3%)
Ophthalmic assessment	
Retinopathy	4/32 (12.5%)
Cataract	11/27 (40.7%)
Blood sugar estimation	
Fasting blood sugar >8 mmol/L	34/55 (61.8%)
HbA1c $>9\%$	10/32

TABLE I: COMPARISON BETWEEN DIABETIC SUBJECTS AND CONTROLS

Variable		Diabetics n = 55	Controls n = 53
Age (years)	Mean	59.7	57.5
	Range	35 to 84	32 to 79
Gender	Male	28 (50.9%)	26 (49.0%)
	Female	27 (49.1%)	27 (51.0%)
Ethnic group	Chinese	42 (76.4%)	45 (84.9%)
	Malay	5 (9.1%)	5 (9.4%)
	Indian	8 (14.5%)	3 (5.7%)
Past history	Hypertension	8 (14.5%)	4 (7.5%)
	Thyroid disease	0 (0.0%)	1 (1.9%)
	Musculoskeletal problems	2 (3.6%)	4 (7.5%)
Alcohol intake	Occasional	14 (25.5%)	20 (37.7%)
	Regular	4 (7.3%)	3 (5.7%)
	Previous night	1 (1.8%)	4 (7.5%)
Sleep	Slept well	45 (81.8%)	43 (81.1%)

TABLE III: PRESENCE OF NEUROPATHIC SIGNS-COMPARISON BETWEEN DIABETICS AND CONTROLS

Sign	Patients n = 55 (%)	Controls n = 53 (%)
Generalized polyneuropathy		
Distal symmetric polyneuropathy		
Absent pin prick sensation	4 (7.3)	0 (0.0)
Absent position sense	2 (3.6)	3 (5.7)
Absent tendon reflexes	19 (34.6)	7 (13.2)*
Autonomic neuropathy		
Tachycardia (> 1 00/min)	0 (0.0)	0 (0.0)
Postural drop in blood pressure (>10 mmHg)	11 (20.0)	3 (5.7)
Multiple mononeuropathy		
Lower extremity proximal neuropathy		
Hip flexors and extensors (power ≤grade 4)	13 (23.6)	3 (5.7)*
Wasting of hip or thigh muscles	1 (1.8)	0 (0.0)

* Denotes significant difference in proportions between diabetic subjects and controls at $P < 0.05$.

TABLE IV: CORRELATION COEFFICIENT (R) FOR AGE, HEIGHT AND WEIGHT WITH POSTURAL SWAY IN DIABETICS AND CONTROLS (WITH EYES OPEN AND EYES CLOSED)

Sway parameter	Eyes Open			Eyes Closed		
	Age (y)	Height (cm)	Weight (kg)	Age (y)	Height (cm)	Weight (kg)
X_o (cm)	0.02	-0.15	0.04	0.07	-0.16	0.09
Y_o (cm)	0.11	0.12	0.07	0.04	-0.19	0.09
Vel (cm/s)	0.29**	0.05	0.17	0.38**	0.03	0.05
L (cm)	0.29**	0.05	0.17	0.38**	0.03	0.05
A_o (cm)	0.13	0.21*	0.04**	0.20*	0.20*	0.22*
A_c (cm)	0.03	0.25**	0.38**	0.07	0.25**	0.32**

** $P < 0.01$; * $P < 0.05$

ns: not significant at the 95% level; X_o , Y_o : average position of centre of pressure on platform; Vel: average speed of centre of pressure along its path; L: length of sway path; A_o : area included within the path of the centre of pressure; A_c : 95% confidence elliptical area

trols for Vel, L, A_o and A_c were statistically significant. With eyes closed, the parameters which were significantly different were X_o , A_o and A_c (Table V). In diabetic subjects, weight was significantly associated with many of the postural sway parameters, followed by metformin use and HbA1c levels. Age and the presence of cataracts were associated with postural stability when eyes were opened, but not when eyes were closed. Height and clinical signs of neuropathy were associated with each of the two parameters studied (Y_o and L for height; Y_o and Vel for neuropathy) (Table VI). In addition, presence of proximal myopathy was significantly associated with only one parameter, Y_o , when eyes were opened ($P = 0.03$). No significant associations were found between postural sway parameters and the use of other diabetic medications (namely glibenclamide and tolbutamide), duration of diabetes (≤ 10 years versus > 10 years), and fasting blood sugar levels (≤ 8 mmol/L versus > 8 mmol/L).

Discussion

The results of this study confirmed what was found in other studies,¹¹ that is, non-insulin dependent diabetics, similar to those who are insulin dependent, were more unstable when compared with non-diabetic subjects for the same gender and age groups. The clinical implications of postural instability are two-fold. Firstly, younger diabetic subjects who are in the working age group may not be suitable for certain occupations which require good postural balance, such as in the construction industry. Secondly, as mentioned earlier, older subjects who are unstable have been documented to be at greater risk of falls. Postural instability, in fact, was demonstrated to be a predictor of fractures in the elderly.

This study was conducted in a primary care clinic using patients who came for either follow-up management of diabetes (diabetic subjects), or patients who attended the clinic for other reasons (controls). Therefore, certain aspects of data collection were subjected to

TABLE V: POSTURAL SWAY PARAMETERS-COMPARISON BETWEEN DIABETICS AND CONTROLS

Postural sway parameters	Diabetics* n = 55 Mean (SE)	Controls* n = 53 Mean (SE)	P value
Eyes open			
X_o (cm)	0.75 (0.68)	1.01 (0.65)	ns
Y_o (cm)	0.24 (0.83)	0.31 (0.81)	ns
Vel (cm/s)	1.00 (0.18)	0.88 (0.17)	0.02
L (cm)	20.09 (0.18)	17.81 (0.17)	0.02
A_o (cm)	2.08 (0.34)	1.62 (0.33)	0.03
A_c (cm)	0.92 (0.39)	0.71 (0.37)	0.04
Eyes closed			
X_o (cm)	0.99 (0.66)	0.63 (0.64)	0.01
Y_o (cm)	0.90 (0.76)	0.82 (0.73)	ns
Vel (cm/s)	1.11 (0.20)	0.98 (0.20)	ns
L (cm)	22.20 (0.20)	19.69 (0.20)	ns
A_o (cm)	2.32 (0.39)	1.73 (0.38)	0.03
A_c (cm)	1.16 (0.43)	0.89 (0.41)	0.05

* Geometric mean value adjusted for height, weight, sleep, alcohol, bone and thyroid diseases.

SE: standard error; ns: not significant;

X_o , Y_o : average position of centre of pressure on platform; Vel: average speed of centre of pressure along its path; L: length of sway path; A_o : area included within the path of the centre of pressure; A_c : 95% confidence elliptical area

the constraints of this setting. These included the use of entries in the case notes for information such as presence of cataracts, and estimation of HbA1c levels within three months from the date of the study. The use of clinical criteria for the detection of the presence of neuropathy was also not as sensitive as laboratory methods, and could perhaps have contributed to the many statistically non-significant associations found. Within these limitations, however, the results of this exploratory study indicated that postural stability in non-insulin diabetics should not be attributed to the presence of peripheral neuropathy alone.

In this study, weight was a prominent factor associ-

TABLE VI: FACTORS ASSOCIATED WITH POSTURAL STABILITY IN DIABETICS

Postural sway parameters	<i>P</i> values						
	Weight	Height	Age	Neuropathy	Cataract	HbA1c	Metformin
Eyes open							
X _o (cm)	ns	ns	ns	ns	ns	ns	ns
Y _o (cm)	ns	0.006	ns	0.048	ns	ns	0.032
Vel (cm/s)	0.044	ns	0.057	ns	ns	ns	ns
L (cm)	0.044	ns	0.057	ns	ns	ns	ns
A _o (cm)	0.000	ns	0.034	ns	0.039	0.046	0.017
A _c (cm)	0.001	ns	0.017	ns	0.012	0.029	0.018
Eyes closed							
X _o (cm)	ns	ns	ns	ns	ns	ns	ns
Y _o (cm)	0.035	ns	ns	ns	ns	ns	ns
Vel (cm/s)	ns	ns	ns	0.019	ns	(0.059)	ns
L (cm)	ns	0.019	ns	ns	ns	(0.059)	ns
A _o (cm)	0.004	ns	ns	ns	ns	0.040	0.049
A _c (cm)	0.000	ns	ns	ns	ns	0.023	(0.059)

ns: not significant

X_o, Y_o: average position of centre of pressure on platform; Vel: average speed of centre of pressure along its path; L: length of sway path; A_o: area included within the path of the centre of pressure; A_c: 95% confidence elliptical area

ated with postural sway. As non-insulin dependent diabetics are generally heavier than insulin dependent diabetics, weight probably contributed more to postural instability in non-insulin dependent diabetes patients than it does for those with insulin dependent diabetes. The biomechanics of how the force due to the weight is distributed is not quite clear. In a group of diabetic men studied by Cavanagh et al,¹⁶ body mass was only mildly related to plantar pressure ($r=0.37$), and accounted for just 14% of the variation in peak plantar pressure. The authors postulated that factors such as joint mobility and skeletal structure of the feet would also affect the area over which force is distributed.

The association of metformin use with postural stability has not been reported previously. Chan et al¹⁷ reported in 1993 that the use of metformin in non-insulin dependent diabetes patients was associated with greater reductions in body weight, plasma total cholesterol concentration and erect diastolic pressure, when compared with glibenclamide. Possible explanations for this association could therefore be the change in body weight and the reduction in diastolic blood pressure with metformin use. Another reason could also be the lowering of blood sugar levels by metformin, which is effected mainly through increased glucose utilisation, without stimulation of insulin secretion.¹⁸ However, one would then expect this to be the case with the use of sulphonylureas such as glibenclamide as well, as the efficacy of these two medications in glycaemic control were comparable.¹⁹

The degree of diabetic control as determined by the HbA1c levels was also identified as a possible determinant of postural stability in NIDDMs. While it is well known that hypoglycaemia would result in giddiness,

the effect of persistent hyperglycaemia or fluctuation in blood sugar levels on postural stability has not been so well documented. There could be other mechanisms associated with poor diabetic control which could affect postural stability. Increasing age is known to be associated with postural stability in diabetics.¹⁰ It was interesting to note that, in this study, the association was only significant with the eyes open. A brief review of the literature revealed conflicting reports. In a study comparing postural sway between young and elderly subjects, Blaszczyk et al²⁰ found that elderly subjects showed greater mediolateral oscillation of the centre of gravity while leaning forward with their eyes open. This was in contrast to the report by Nakagawa from Japan²¹ that visual cues influenced postural stability in the elderly to a greater degree than they did in young controls. Elderly subjects swayed more than the young students who were used as controls. No difference was found in the sway parameter when visual feedback was used to minimise body sway. Lord et al²² used a battery of 13 tests, which included those testing the visual, vestibular and sensory-motor components, on 95 elderly subjects. They found that sensory input from the periphery was the most important factor associated with postural stability in the elderly, especially when standing on a firm surface. Visual acuity played a part (in addition to peripheral sensation) when the elderly subject stood on a compliant surface. In a more recent study, Hageman et al²³ concluded that older adults demonstrated larger areas of sway regardless of whether the eyes were opened or closed. All these studies were conducted in non-diabetic subjects. One could postulate that the increased postural sway in older diabetic subjects with eyes open could be related to the increased prevalence of cataracts

(and thus poorer visual acuity) in diabetics compared to non-diabetics of the same age group.²⁴ Indeed, in our study, the presence of cataracts was also associated with increased postural sway in diabetic subjects when eyes were opened. In addition, the visual impairment as a result of more severe grades of diabetic retinopathy might also have played a contributory role.

In conclusion, therefore, this study demonstrated that non-insulin dependent diabetics were more unstable when compared with non-diabetic controls. This has potentially far-reaching implications with regard to, firstly, the type of occupations that should be considered unsafe for younger patients with NIDDM and, secondly, the increased risk of falling in older patients with NIDDM and the attending health care considerations. The factors associated with postural stability may be multiple, and further studies are needed to look into how these factors may influence posture in patients with NIDDM, in particular the use of drugs such as metformin.

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