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Reduced performance in balance, walking and turning tasks is associated with increased neck tone in Parkinson's disease

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ABSTRACT

Rigidity or hypertonicity is a cardinal symptom of Parkinson's disease (PD). We hypothesized that hypertonicity of the body axis affects functional performance of tasks involving balance, walking and turning. The magnitude of axial postural tone in the neck, trunk and hip segments of 15 subjects with PD (both ON and OFF levodopa) and 15 control subjects was quantified during unsupported standing in an axial twisting device in our laboratory as resistance to torsional rotation. Subjects also performed six functional tests (walking in a figure of eight [Figure of Eight], Timed Up and Go, Berg Balance Scale, supine rolling task [rollover], Functional Reach, and standing 360-deg turn-in-place) in the ON and OFF state. Results showed that PD subjects had increased tone throughout the axis compared to control subjects ($p = 0.008$) and that this increase was most prominent in the neck. In PD subjects, axial tone was related to functional performance, but most strongly for tone at the neck and accounted for an especially large portion of the variability in the performance of the Figure of Eight test ($r_{OFF} = 0.68$ and $r_{ON} = 0.74$, $p < 0.05$) and the Rollover test ($r_{OFF} = 0.67$and $r_{ON} = 0.55$, $p < 0.05$). Our results suggest that neck tone plays a significant role in functional mobility and that abnormally high postural tone may be an important contributor to balance and mobility disorders in individuals with PD.

Introduction

Rigidity (or muscle hypertonicity), defined as increased resistance to passive movement, is a cardinal sign of Parkinson's disease (PD) (Foster 1892). Previous studies suggest that rigidity may underlie many of the common motor disabilities associated with PD (Nutt et al., 1992; Schenkman et al., 2001). Research on rigidity in subjects with PD has concentrated mainly on the effects of hypertonicity in the distal limb musculature, even though rigidity in axial and proximal muscles may be an important contributor to limited functional mobility (Nagumo and Hirayama, 1993, 1996; Nutt et al., 1992; Schenkman et al., 2001; Steiger et al., 1996).

A number of studies (Horak et al., 1996; Lakke 1985; Nagumo and Hirayama, 1993; Schenkman et al., 2000; Steiger et al., 1996) have attempted to relate axial rigidity to functional performance. However, these studies did not use direct objective measures of axial tone because of the complexity of quantifying tone in the axial segments. For example, some studies have quantified axial trunk tone in the supine position (Nagumo and Hirayama, 1993, 1996) by passively moving the legs and hips. The shortcoming of this technique is that tone is assessed in a resting position, when the body is relaxed such that postural tone is reduced. The clinical measure of rigidity in the UPDRS (Unified Parkinson's disease rating scale, Fahn and Elton, 1987) is also limited by the subjective estimation of tone in the extremities and the neck with a rating scale when the patient is sitting.

In the present study, we used a device recently developed in our laboratory to objectively quantify axial tone in standing PD subjects when the nervous system is actively controlling balance (Gurfinkel et al., 2006; Wright et al., 2007). This device, called "Twister," quantifies axial tone by measuring resistance to passively applied torsional rotation at the neck, trunk and/or hips without constraining anterior–posterior, lateral, or vertical body position (Gurfinkel et al., 2006). Body position is constrained only in the torsional direction. Using the Twister device, we showed that axial tone in healthy adults is not static, but rather involves flexible, active shortening and lengthening reactions (Gurfinkel et al., 2006). Unlike stretch reflexes,

Abbreviations: ADL, activities of daily living; ANOVA, analysis of variance; BBS, Berg Balance Scale; PD, Parkinson's disease; PIGD, postural instability and gait difficulty, items 27–30 in UPDRS; TUG, Timed Up and Go test; UPDRS, Unified Parkinson's disease rating scale.

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in which muscles are activated during muscle lengthening and silenced during muscle shortening, shortening reactions are associated with increased activity during muscle shortening and decreased activity during muscle lengthening (see Sherrington 1909). In another study, we showed that subjects with PD have elevated tone in the trunk and hips compared to age-matched control subjects (Wright et al., 2007); however, this study did not investigate axial tone at the neck.

Axial hypertonicity may contribute to motor disability in PD (Schenkman et al., 2000; Wright et al., 2007). For example, hypertonicity is thought to contribute to the absence of body rotation during sleep (Nutt et al., 1992; Stack and Ashburn, 2006) and may also contribute to abnormal inter-segmental coordination during walking and turning (Crenna et al., 2007; Mesure et al., 1999; Vaugoyeau et al., 2006). While these observations suggest a causal relationship between axial tone and functional performance in PD, no study has directly measured axial tone and its relation to functional performance.

The axial trunk tone might affect the performance during walking and turning because it may hinder normal dissociated rotation of the head and trunk (Stack et al., 2006). Axial hip tone may also affect gait speed and turning because it could impair the control of pelvis on hip rotation (Vaugoyeau et al., 2006). More importantly, increased neck tone may have a major impact on walking, turning and twisting since the head must be free to move to scan surrounding objects and to steer locomotion (Paquette et al., 2006). Therefore, we hypothesize that neck tone will be the locus of hypertonicity and most related to performance impairments in balance, walking and turning tasks in persons with PD. To test this hypothesis, we correlated axial postural tone in the neck, trunk and pelvis segments measured objectively using Twister with measures of balance and mobility in both subjects with PD and age-matched control subjects.

Methods

Subjects

Fifteen male subjects (63 ± 8 years) with a clinical diagnosis of "idiopathic" PD, treated with levodopa and 15 healthy male control subjects (64 ± 9 years old), matched for age, weight and height, participated in the study. The PD subjects had no history suggesting "atypical" PD symptoms, as defined by Hughes et al. (1992) or other existing neuromuscular disorders, including severely flexed posture. We included only PD subjects with Hoehn and Yahr scores of 2 or 3. Characteristics of the PD subjects are presented in Table 1. The control subjects had no recent or unresolved history of musculoskeletal, neuromuscular or motor disorders. Control and PD subjects were able to stand independently for at least 10 min. All subjects provided informed consent in accordance to the Oregon Health and Science University Internal Review Board regulations for human subjects' studies and the Helsinki Declaration.

Protocol

PD subjects were tested OFF medication (OFF) the morning after abstaining from levodopa overnight (washout period ≥ 12 h). The experiment began with the measurement of axial tone at the neck, trunk and hips. Subjects were then instrumented with reflective markers on the skin over bony prominences to measure accurately their active range of motion at the neck, trunk and hips while standing using motion analysis. Six functional performance tests were then performed by each subject: 1) The Figure of Eight test; 2) Supine Rolling task on a therapy mat; 3) the Timed Up and Go (TUG) test; 4) the Berg Balance Scale ([BBS]; 5) the Functional Reach test; 6) Standing, 360 deg turn-in-place. The motor part of the UPDRS (Fahn and Elton, 1987) was then performed by each subject.

The OFF testing session ended with PD subjects taking their usual morning dose of medication, followed by a rest period of 1 h. During that time, the subjects rated themselves on activities of daily living (ADL) as part of the UPDRS (Fahn and Elton, 1987) to quantify activity impairments. After the rest period and once the subjects reported that they felt "ON", the protocol was repeated (i.e., range of motion, functional performance tests, UPDRS and axial tone measurement) with PD subjects ON medication (ON). Control subjects only did the first part of the protocol (i.e., same as for PD OFF).

Measurement of axial tone

Axial tone was quantified in standing subjects using Twister, which has been shown to be a repeatable and reliable measure of axial postural tone in healthy individuals (Gurfinkel et al., 2006) and PD subjects (Wright et al., 2007). Briefly, subjects stood blindfolded on a horizontal platform that slowly (1°/s) rotated left and right (± 10°) with certain axial body segments attached either to an earth-fixed

Table 1
PD subject characteristics.

PD subj	Sex	Duration of PD (yrs)	Age (yrs)	Ht (cm)	Wt (kg)	Side	UPDRS motor part III								ADL	H and Y	Medication
							Total		Rigidity				PIGD				
									Total		Neck						
							ON	OFF	ON	OFF	ON	OFF	ON	OFF			L-DOPA
1	M	8	64	180	99	R	36	52.5	7	11	3	4	5	7.5	28	3	900
2	M	9	56	175	83	L	24	47	9	13	2	4	2	4	9	2.5	1450
3	M	12	81	175	77	L	40.5	46	12	16	3	4	4	4	13	3	800
4	M	3.5	46	180	81	R	31	44.5	4	8	1	2	1	2.5	14	3	333
5	M	10	53	178	68	R	17	39.5	3	8	2	3	1.5	5	6	3	900
6	M	4	66	185	82	R	30	37	4	7	1	1	4	4	14	2.5	850
7	M	5	60	168	73	L	26.5	34.5	10	12	2	3	2.5	4.5	8	2.5	650
8	M	1.5	70	170	94	L	29	32	6	7	3	3	4.5	5	3	2	125
9	M	10	66	180	86	R	23.5	31	5.5	8.5	2	3	2	3.5	14	2	700
10	M	3	71	179	94	S	16.5	23.5	1	2.5	1	1	3.5	5	9	2	450
11	M	9	65	183	75	R	20.5	30	3	5	0	1	2	5	18	2	683
12	M	2	56	180	80	R	16	27	2	3	0	1	2	2	11	2.5	133
13	M	9	66	175	88	L	19.5	30.5	1	1	1	1	2.5	3.5	7	2	875
14	M	12	64	165	68	R	14.5	22	4	5	2	2.5	1.5	3	10	2	1200
15	M	1.5	65	168	70	L	14	18	0	2	0	1	1	1	6	2	100
Mean	–	6.5	63	176	81	–	24	34.5	5	7	1.5	2	2.5	4	11	2.5	
Mean	Cntrls	–	64	174	79	–	0	0	0	0	0	0	0	0	0	–	–

Duration of PD-years since the PD diagnosis, Side—affected side, L—left, R—right, S—symmetrical, Total rigidity—UPDRS, item 22 Neck rigidity—UPDRS, neck part of item 22, PIGD—postural instability and gait difficulty (UPDRS item 27–30 UPDRS), ADL—activities of daily living, L-DOPA—daily dose in mg/day., H and Y = Hoehn and Yahr.