

## The Relationship between Strength and Balance in Individuals with Parkinson's Disease

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### Abstract

**Objective:** To test the hypothesis that strength will have a correlation with balance in individuals with Parkinson's Disease (PD) and will not be associated with balance in our healthy controls.

**Design:** Cross-sectional

**Setting:** Tertiary care university hospital and Veteran's Hospital.

**Participants:** 27 individuals with a diagnosis of PD and 25 age and gender matched controls

**Intervention:** Not applicable.

**Main Outcome Measures:** Balance as measured by sensory organization test scores separated into trials 1-3 (static balance) and 4-6 (dynamic balance) and strength as measured by work and power in knee flexion and extension.

**Results:** Strength and balance were not found to have a significant association in the control group. However, in the PD group dynamic balance was found to have significant associations with all measures of strength: work of knee extension, work of knee flexion, power of knee extension and power of knee flexion.

**Conclusions:** Knee flexion and extension strength have a significant correlation with dynamic, but not static, balance in individuals with PD and no significant correlation was found between strength and balance in the control group.

**Keywords:** Parkinson's disease; Muscle strength; Postural balance

**Abbreviations:** COG: Center of Gravity; PD: Parkinson's Disease; SOT: Sensory Organization Test

### Introduction

Falls are a major cause of morbidity and mortality in individuals with Parkinson's disease (PD). Postural instability, a fundamental feature of PD, is felt to be the predominant cause of falls in PD. The risk of falls increases as PD progresses and there are no pharmaceutical or surgical therapies that clearly improve balance function. Seventy percent of individuals with PD experience at least one fall a year despite available medical therapy [1,2]. These falls have a significant financial impact, with one in four falls resulting in a use of healthcare resources [3]. Additionally, they also take a toll on quality of life as fear of falling can lead to self-induced activity restriction, anxiety, and depression [4,5].

Current research into the relationship between strength and balance is limited. Two studies in healthy young populations found no correlation between strength and balance measures [6,7]. Strength intervention studies have shown mixed results in terms of falls [8,9]. A couple of studies have shown improvement in strength in PD with resistance training [10-12]. In this study we examined strength and balance in individuals with PD and age matched controls in an attempt to characterize the relationship between these two measures in a PD and control population.

### Material and Methods

**Subjects:** Data collection for the PD group was achieved using a convenience sample of baseline measurements being obtained in a larger study on the effects of Vitamin D supplementation in individuals with PD. Inclusion criteria for PD subjects were: medically confirmed diagnosis of PD by a movement disorder's specialist, ability to ambulate

50 feet without assistance from a person or device, at least one fall or 2 near falls in the past month, and ability to cooperate with balance testing. The inclusion criteria for the control subjects were: over the age of 59, gender and age-matched (within 3 years) of main protocol participants. The exclusion criteria for both our PD and control samples were another neurological or orthopedic deficit that would have a significant impact on gait (e.g. stroke or fracture) or significant cognitive deficits as defined by a Mini Mental Status Exam of <25. We chose to look at healthy controls because the relationship between a pathological and non-pathological state (normal aging) would be the most interesting relationship. We matched on age and gender as these are factors likely to have the largest impact on strength and balance and with our fairly small sample size did not want to make the study design overly complex.

**Balance testing:** Balance was tested using computerized dynamic posturography (SMART Balance Master<sup>b</sup>) following the sensory organized testing (SOT) protocol [8,13]. The SOT consists of three trials under six different conditions. SOT conditions 1-3 measure static balance and consist of: a still platform with eyes open, a still platform

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with eyes closed, and a still platform with eyes open and moving visual surround. SOT conditions 4-6 measure dynamic balance with the same condition as 1-3 but the platform is mobile in the anterior-posterior direction. The SOT quantifies center of gravity sway (COG) under each condition and reports the result as a score from 0 (fall) to 100 (no COG sway). Trials were halted early under the following conditions: the subject falls, the subject steps off of the force plate to prevent falling, or the examiner judges the patient will fall without intervention. Early terminations are marked as a fall and given a score of 0.

**Strength testing:** Strength was measured through the use of a computerized dynamometer (Biodex system 4 pro<sup>a</sup>) following standardized testing protocol as established by the device manufacturer. We assessed strength metrics for both legs at two fixed rotational velocities. Subjects performed five repetitions of maximal effort knee flexion and extension at 60 degrees/second then ten repetitions at 120 degrees/second on both the right and left leg. The strength metrics assessed were total work and average power in flexion and extension per repetition. Measurements from each individual's weakest leg were used for data analysis.

**Data analysis:** Statistical analysis was performed using statistical software (StataSE 12.1, StataCorp). SOT scores were subdivided to examine the relationship of strength to static balance (average of SOT conditions 1-3) and dynamic balance (average of SOT 4-6). Correlations coefficients were calculated between our measures of balance (both static and dynamic) and our strength measures for both groups. Measures of strength and balance were compared between groups using unpaired 2 sample t-tests (Table 2).

The research protocol was approved by the facility institutional review board.

## Results

Data for 27 individuals with PD and 25 age and gender matched controls was collected. Characteristics for each population and our measures of strength and balance are shown in Table 1. The two populations did not differ significantly in regard to age, gender, or performance on static and dynamic balance testing. Persons with PD had less work in knee extension and flexion. Power for knee extension and flexion was not significantly different between the groups, but there was a trend (p=0.06) for less power in the PD group in knee flexion.

For both populations no significant correlations were found between static balance and our measures of knee flexion (PD work p=0.44, PD power p=0.48, Control work p=0.12, Control power p=0.13) or extension strength (PD work p=0.90, PD power p=0.80, Control work p=0.43, Control power p=0.27). For the PD population significant correlations were found between dynamic balance and work of knee extension (r=0.45, p=0.02), work of knee flexion (r=0.59, p<0.01), power of knee extension (r=0.39, p=0.05) and power of knee flexion (r=0.57, p<0.01). No significant correlation was found between dynamic balance and strength measures in the control population (p = 0.14 - 0.61). Figure 1 demonstrates the significant association between dynamic balance vs work in knee flexion (p<0.01) in the PD group and the non-significant association in the control group (p=0.43). The Hoehn and Yahr score, a clinical measure of PD severity largely based on performance on pull test, showed the following relationship with static (r=0.11, p=0.57) and dynamic (r=0.03, p=0.90) SOT.

## Discussion

Results of this study revealed potentially important associations between measures of knee strength and dynamic balance. Knowing that

these associations exist indicate that there may be need for further research into the role that strength plays in the balance of individuals with PD.

Interestingly enough the observed values for static and dynamic balance were not significantly different between our control group and the PD population. However, as per prior research our study found no relationship between measures of strength and balance in our control group where one was displayed in our PD group. While two of our four measures of strength (work of knee flexion and extension) were significantly different between the two groups the association between strength and dynamic balance was demonstrated in all four of the strength measurements for the PD group. Perhaps this is due to postural instability and impaired postural responses in the PD population requiring a larger absolute strength reaction in response to a perturbation.

Finding no significant associations between static balance and our measures of strength in both populations was not surprising. Static balance is less demanding than dynamic balance and thus it is logical that less strength would be required to correct against minor perturbations that may occur in quiet stance.

Given our results demonstrating an association between strength and balance in the PD population it may be beneficial to conduct further research into this association and more importantly if interventions targeted at increasing strength would yield an improvement in balance. If improved strength leads to improved balance perhaps the end result would be fewer falls in this at risk population.

	PD	Control	p-value
	mean (95% CI)	mean (95% CI)	
Age	67.6 yrs, SD 6.8	69.8 yrs, SD 6.8	p=0.23
Education	17.4 yrs, SD 3.1	15.6 yrs, SD 3.4	p=0.05
Gender	68% Male	72% Male	p=0.67
Hoehn and Yahr	2.43 (2.27-2.58)	n/a	n/a
Static SOT	86.4 (82.9 - 89.8)	89.2 (88.1 - 90.3)	p=0.11
Dynamic SOT	58.8 (50.7-66.8)	65.5 (60.4-70.5)	p=0.15
Work, knee extension (joules)	492.2 (406.6-577.7)	624.6 (543.8-705.4)	p=0.02
Work, knee flexion (joules)	133.7 (102.4-165.1)	197.5 ( 153.6-241.5)	p=0.02
Power, knee extension (watts)	67.87 (57.4-78.4)	76.8 (67.7-85.8)	p=0.10
Power, knee flexion (watts)	18.4 (14.3-22.5)	24.6 (19.1-30.1)	p=0.06

Table 1: Population characteristics.

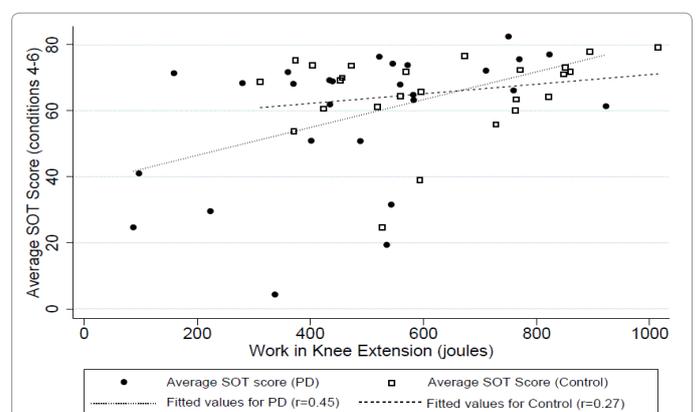


Figure 1: Illustrates the relationship between dynamic balance (SOT 4-6) and knee extension work for those with PD (closed circle) and controls (open square).

	PD Subjects		Control Subjects	
	SOT 1-3 (Static)	SOT 4-6 (Dynamic)	SOT 1-3 (Static)	SOT 4-6 (Dynamic)
Average total work of extension	0.0215 p=0.9152	0.4417 p=0.0211	0.1240 p=0.2410	0.2430 p=0.2410
Average total work of flexion	0.1717 p=0.3917	0.5897 p=0.0012	0.31460 p=0.0900	0.1710 p=0.4130
Average power of extension	-0.0531 p=0.7926	0.3862 p=0.0466	0.0180 p=0.9330	0.2080 p=0.3190
Average power of flexion	0.1419 p=0.4803	0.5655 p=0.0021	0.3240 p=0.1150	0.1810 p=0.3860

**Table 2:** Correlation between strength and balance testing.

## Study limitations

The primary limitation of this study is the sample size. A larger sample size in the control could have possibly demonstrated a significant relationship between balance and strength. However it is clear that the relationship is more robust in person's with PD. An additional limitation is not examining gait more closely. Certainly both strength and balance may have effects on gait and events such as trip and mis-steps.

## Conclusions

This study is the first to examine the relationship between leg strength and balance measures in a PD population as compared to a control group that were are aware of. The results provide initial evidence regarding the relationship between quantifiable measures of strength and balance. This may allow for further research targeted at improvement of strength with a goal of a resultant improvement in balance.

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