VALIDATION OF SEATED POSTURAL CONTROL MEASURES IN NON-AMBULATORY PERSONS WITH MULTIPLE SCLEROSIS

BY

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THESIS

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Abstract

Poor seated postural control negatively impacts the performance of daily activities in non-ambulatory persons with Multiple Sclerosis (PwMS) and may be a potential target of rehabilitation. However, there is a lack of validated clinical measures of seated postural control in persons with MS, thus limiting evaluation of rehabilitation treatments. The purpose of this study is to determine 1) if non-ambulatory persons with MS have impaired seated postural control compared to healthy age and gender match controls and 2) whether the Function in Sitting Test (FIST) is a valid measure of a seated postural control in non-ambulatory PwMS. Thirty-four participants (17 with MS and 17 controls) participated in seated postural assessments. Sitting balance was evaluated using posturography and the FIST. The seated posturography assessment involved participants sitting on a force platform without support for 30s. The center of pressure was determined based on the output of the force platform and the amount of seated postural sway was calculated. The FIST is a 14-Item clinical functional assessment of sitting balance validated in adults with acute stroke. The MS group’s (157 mm²) postural sway was significantly greater than the control group (35mm²) (U= 48, \( p=0.001 \)). There was a significant, negative correlation between FIST and postural sway (rho=-0.487, \( p=0.028 \)). The observations provide evidence that PwMS have poor seated postural control when compared to age and gender matched controls; and FIST may be a valid tool to assess seated postural control in non-ambulatory PwMS.
TABLE OF CONTENTS

Chapter 1: Introduction ........................................................................................................1
Chapter 2: Methods ...............................................................................................................4
  2.1. Participants ..................................................................................................................4
  2.2. Experimental Protocol ...............................................................................................4
  2.3. Statistical Analysis .....................................................................................................6
Chapter 3: Results ...............................................................................................................7
  3.1. Demographics ............................................................................................................7
  3.2. Seated Postural Control .............................................................................................7
  3.3. Center of Pressure .....................................................................................................8
Chapter 4: Discussion ..........................................................................................................10
  4.1. Limitations of This Study .........................................................................................12
  4.2. Future Directions .....................................................................................................13
Chapter 5: Conclusion .........................................................................................................14
Chapter 6: Acknowledgements ............................................................................................15
Chapter 7: References .........................................................................................................16
Chapter 1

Introduction

Approximately 400,000 persons in the United States and 2.3 million individuals worldwide have multiple sclerosis (MS) [1-2]. MS is an autoimmune, chronic disabling, neurologic disease that is typically diagnosed among people between the ages of 20 and 50 years and women are affected two to three times more often than men [1-3]. This chronic, neurologic disease is reported more in Central and Northern Europe, North America, and Australia than in Asia, Africa, and South America [4].

The exact cause of MS is not clear, but it is believed to result from a combination of genetic and environmental factors [1]. MS involves inflammation of the central nervous system (CNS) that triggers demyelization, a process in which the myelin sheath is damaged [2]. Consequently, this damage in the CNS leads to a vast array of symptoms including but not limited to muscle weakness, cognitive impairment, sensory disturbances, declines in postural control, fatigue, spasticity, and incontinence [5].

Given these symptoms, it is not surprising that individuals with MS have mobility impairment. As MS progresses and mobility declines, people begin to use assistive technology [6]. It has been suggested that up to 50% of PwMS will require mobility assistance within 15 years of MS diagnosis [3] and a significant portion of the MS population will become non-ambulatory. A non-ambulatory person is defined as an individual who primarily utilizes a wheeled mobility device in their living environment and community [7]. It is estimated that 40% of PwMS use a wheelchair in some circumstances [8] and 25% of the MS population is non-ambulatory [7,9].
There are several important physical abilities that are required for safe and effective wheeled mobility [7]. For instance, seated postural control, or the ability to maintain equilibrium against perturbations while in a sitting position, is essential for many activities of wheeled mobility [7, 10, 11]. Impairments in seated postural control may lead to declines in mobility, decreased physiological functions, decreased quality of life, and falls [7, 10, 11]. Although there is some evidence that ambulatory PwMS have less trunk stability than persons without MS, there is limited information concerning seated postural control in persons with MS who utilize wheeled mobility [12].

One possible reason for the limited information concerning seated postural control in non-ambulatory persons with MS is the lack of validated outcome measures in this segment of the MS community. Indeed, a recent systematic review concludes that there is a lack of validated outcome measures to effectively assess impairments on seated postural control in non-ambulatory individuals [7]. The lack of validated measures minimizes the opportunity to design, implement and test rehabilitation interventions targeting seated postural control.

A review of the postural control literature provides several potential seated postural control outcomes. From a biomechanical standpoint, the gold standard for measuring seated postural control is posturography using a force platform [13-15] because it objectively measures the center of pressure (COP). The COP provides a reflection of the system’s neuromuscular response to the imbalances of the body’s center of gravity [16]. Despite the advantages of posturography, its clinical utility is limited because of cost of necessary equipment.
There are several clinically feasible measures of seating balance that have been explored in clinical populations. An example of a clinically feasible measure of seated postural control is the Function in Sitting Test (FIST) [17]. The FIST was designed to capture the complex interaction between seated postural control and functional performance. The 14-item test is scored on the patient’s ability to maintain seated position when performing static and dynamic sitting tasks such as reaching, scooting, and responding to perturbations. The FIST was found to be a reliable and valid measure of seated postural control in 31 adults 1-3 months post stroke [17]. However, it has not been validated in other populations.

To our knowledge, there is no clinically feasible measure of seated postural control that is valid in non-ambulatory persons with MS. Consequently, the purpose of this investigation was two-fold. First to determine whether non-ambulatory persons with MS have impaired seated postural control compared to healthy age/gender match controls. Secondly, to determine if the FIST is a valid measure of seated postural control in non-ambulatory PwMS. Based on extant literature, it was predicted that PwMS will have decreased seated postural control compared to controls and that seated postural control, as indexed by the FIST, will be associated with force platform metrics. The outcomes of this investigation will inform clinical assessments of seated postural control in non-ambulatory persons with MS.
Chapter 2

Methods

The experimental procedures were approved by the local institutional review board and all participants provided written informed consent.

2.1. Participants

A total of 34 participants volunteered for the investigation. Seventeen of whom had MS and utilized a wheelchair for at least 80% of their outside mobility. The remaining 17 participants did not have MS and were ambulatory. Participants with MS were all enrolled in a randomized control trial examining the efficacy of transfer training in wheeled mobility users with MS.

PwMS were recruited from the North American Research Committee on Multiple Sclerosis (NARCOMS) patient registry, existing UIUC registries and local support groups. Inclusion criteria for MS participants included having a diagnosis of MS, being over the age of 18, using a wheelchair as their main form of mobility (>80% of daily mobility), having self-reported inability to ambulate outside of the home, and self-reported ability to transfer with moderate assistance or less. Inclusion criteria for the control group included being over the age of 18, ambulatory, and have no history of neuromuscular diseases and/or stroke.

2.2. Experimental Protocol

To determine whether non-ambulatory persons with MS have impaired seated postural control compared to healthy age/gender match controls, seated postural control was assessed with the gold standard of posturography. Specifically, all participants sat
unsupported on a force platform (Bertec, Inc, Model FP4060-05) that was placed on a
Table, in a standardized position (i.e. arms resting in their lap, feet and back unsupported).
Participants were instructed to sit quietly, while visually focusing on a fixed object at eye
level approximately 3 meters directly in front of them. The trial lasted for 30 s.

The center of pressure (COP) was determined from the output of the force
platform. The COP trajectory reflects each participant’s neuromuscular response to
imbalances of the body’s center of gravity. COP trajectory was quantified with sway area
with standardize calculations [16]. Larger sway area during quiet sitting is interpreted as
impaired postural control. Force platform data were sampled at 1000 Hz, and down
sampled to 100 Hz.

Additionally, it was of interest to determine if the Function in Sitting Test (FIST) is
a valid measure of seated postural control in non-ambulatory PwMS. Only the MS
group underwent the FIST. The FIST was administered while participants sat on the mat
table with their feet supported on the floor and ¾ of their femur on the table. One trained
researcher (C.O.) administered the FIST. Per guidelines [17], each item was scored on a
scale from 0-4, with 0 being incapable of performing the sitting task and 4 being fully
capability of performing the sitting task. Individual item scores are summed yielding a
total score ranging from 0-56, where 0 equates to inability to perform sitting tasks and 56
equates to full ability to perform all of the tested tasks.
2.3. **Statistical Analysis**

Kolmogorov-Smirnove and Shapiro-Wilk tests of normality ($P<0.05$) were conducted first. Since sway area was not normally distributed, nonparametric statistical analysis was used to compare the differences seen between groups. Mann-Whitney U tests, where $p$-value was set at $<0.05$ *a priori*, were used to test the null hypothesis that there is no difference in sway area between PwMS and controls.

Concurrent validity was determined by performing Spearman ranked ordered correlations between sway area and FIST score.
Chapter 3
Results

3.1. Demographics

The MS group’s ranged in age from 27-83 years with an average age of 56 years. Duration of MS ranged from 7-34 years with an average of 17 and the years of wheelchair use ranged from 1-19 years with an average of 6. The MS group consisted of 5 males and 12 females. The control group’s age ranged from 27-73 years and had an average of 61 and consisted of 4 males and 13 females. There were no significant differences in age or gender composition between groups (p’s > 0.05).

Table 1. Participant Demographics

<table>
<thead>
<tr>
<th></th>
<th>MS (n=17)</th>
<th>Control (n=17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>55.82 (11.2)</td>
<td>27-83</td>
</tr>
<tr>
<td>Gender</td>
<td>Male= 5 Female= 12</td>
<td>N/A</td>
</tr>
<tr>
<td>MS duration (yrs)</td>
<td>17 (9.0)</td>
<td>7-34</td>
</tr>
<tr>
<td>Wheelchair use (yrs)</td>
<td>5.79 (4.9)</td>
<td>1-19</td>
</tr>
</tbody>
</table>

3.2. Seated Postural Control

Figure 1 illustrates the COP trajectory during quiet sitting of a 49-year-old female participant with MS and that of age and gender matched control participant. It is clear in the figure that there is a greater amount of postural sway in the participant with MS compared to the participant without MS.
3.3. Center of Pressure

The MS group’s postural sway area ranged from 18-742mm² with an average of 157 mm² whereas the control’s group postural sway ranged from 12-119mm² with an average of 35mm² (Table 2). Mann-Whitney U tests revealed there was a group difference in sway area (U=48, p=0.001) indicating the MS group had impairments in seated postural control.

Figure 1. This plot represents the COP of a PwMS and a healthy control.
Once it was determined that non-ambulatory PwMS have impairments in seated postural control, it was of interest to examine if the FIST is a valid assessments of seated postural control in this population. Performance on the FIST ranged from 31-56 with an average of 51. Spearman correlations analysis found there to be a significant, negative correlation between FIST and seated postural sway (rho=-0.487, p=0.028).

Table 2. Seated Postural Control Performance

<table>
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<tr>
<th></th>
<th>MS (n=17)</th>
<th>Control (n=17)</th>
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<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Range</td>
</tr>
<tr>
<td>FIST</td>
<td>51.24(6.3)</td>
<td>31-56</td>
</tr>
<tr>
<td>TSA (mm²)</td>
<td>157.23(204.4)</td>
<td>18.30-741.97</td>
</tr>
</tbody>
</table>
Chapter 4
Discussion

The purpose of this investigation was two fold: 1) to determine if non-ambulatory persons with MS have impaired seated postural control compared to healthy age/gender match controls; and 2) to determine whether the FIST could be used as a valid measure of a seated postural control in non-ambulatory PwMS. Overall, there were two novel findings: (1) PwMS had a larger sway area than persons without MS and (2) FIST was significantly correlated with objectively quantified seated postural control (i.e. sway area). These findings indicate that non-ambulatory PwMS have greater impairments in seated postural control compared to age and gender matched controls; and that FIST is a valid measure of seated postural control in non-ambulatory PwMS.

The current observations are congruent with previous reports on seated postural control in ambulatory persons with MS. Lanzetta and colleagues (2004) evaluated trunk stability as a measure of seated postural control in ambulatory PwMS and controls. Sitting posture was assessed using a sitting balance test, which required the participant to sit unsupported for 15 seconds with potential perturbations [18]. They found that PwMS had greater instability compared to controls and that amount of instability was related to functional disability [12]. Given that their study highlighted increased instability while sitting in PwMS compared to controls, it is not surprising that we also found a large difference in seated postural sway between PwMS and controls. In the current investigation, the MS group’s seated postural sway was almost four times the amount of the control’s group seated postural sway.
The cause of impaired postural control in non-ambulatory persons is unclear. Visual, proprioceptive, and vestibular systems contribute to postural control [19]. It is apparent that postural control impairment is common in MS [20-22]. Given the wide distribution of CNS lesions in people with MS, poor balance control in this population may be caused by impairments in cognitive, visual, vestibular, motor, and sensory. The contributions of each of these factors may vary among individuals [23]. The visual system may be disturbed as a result of optic nerve damage, leading to blindness, blurred vision, or diplopia [24]; involvement of the vestibular tracts can be associated with vertigo [25]; and lesions in the long ascending sensory tracts can cause problems with proprioception [25].

Building an understanding of mechanisms responsible for postural control in non-ambulatory PwMS is essential to developing successful rehabilitation strategies. It is logical to assume that weak trunk stability and poor integration of input from visual, proprioceptive, and vestibular systems may be the underlining factors of poor postural control, but there is limited data to support this claim. Future work should examine the underlying mechanisms responsible for impaired seated postural control.

Another gap in our understanding is validated clinical outcomes related to seated postural control. Refinement of clinical outcomes could put researchers a step closer to developing and implementing rehabilitation programs focusing on seated postural control. This would also be of significant benefit for clinicians to be able to objectively evaluate seated postural control to determine when an impairment exists. Indeed a recent systematic review highlighted the need for validated clinical seated postural control outcomes [7].
Consequently, the second purpose of this study was to validate the FIST as a seated postural control assessment in non-ambulatory PwMS. Despite the current tools used to measure seated postural control, there is no clinically feasible measure of seated postural control that is valid in PwMS. In our population, a significant moderately high, negative correlation between the FIST and sway area \((r=-0.487)\) was observed. The correlation observed indicates that there is an indirect relationship between the tested clinical measure, FIST, and force platform metrics. As the FIST score increased, the total sway decreased. A correlation higher than this would suggest a stronger correlation. This was not expected because the FIST evaluates different aspects of seated balance (i.e. reaching, scooting, responding to perturbations), whereas the force platform only analyzes seated posture during quiet sitting.

4.1. Limitations of This Study

Although there was an observation of significant correlation between FIST and force platform metrics, ceiling effects were also observed. Indeed nearly a quarter of the MS group had a maximal score of 56. The FIST is acceptable for those with some form of impaired seated postural control more than persons without impaired seated postural control. Almost one fourth of our sample received a maximum score on the FIST indicating that a ceiling effect may have been observed.

This investigation utilized a relatively small sample of 34 people with only 17 undergoing the FIST, which can contribute to the limited conclusions about the scoring scale and potential ceiling effects.
4.2. Future Directions

To counteract ceiling effects in the future, small alterations can be made in the FIST. For example, the following items should be given a set time to complete: “lift uninvolved foot,” “Reach behind with uninvolved arm,” and “Pick up object from floor.” If not given a set time to complete the task, too much room for variation will occur. Providing specific time ranges to complete certain tasks could streamline the assessment more. Aside from this, items “Forward reach,” and “Lateral reach” should require a set distance to be reach before being given a score. It may be hard to score someone appropriately during these reaching tasks without having any indication of how far they could or should actually reach. Making these alterations to the FIST makes it more sensitive to seated postural control impairment.
Chapter 5

Conclusion

The observations provide evidence that PwMS have poor seated postural control when compared to age and gender matched controls; and FIST may be a valid tool to assess seated postural control in non-ambulatory PwMS although potential questions about ceiling effects remain. FIST can be used as a clinical assessment to measure seated postural control in non-ambulatory PwMS.
Chapter 6

Acknowledgements

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Chapter 7

References


