TURNING CHARACTERISTICS IN PATIENTS WITH PARKINSON’S DISEASE DURING TIMED UP AND GO

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This study aimed to investigate turning characteristics of patients with PD, using 3D analysis during the TUG test, to examine associations with the severity of PD. A total of 30 individuals performed the TUG test: 10 patients with Hoehn and Yahr stages 2.5 and 3.0 PD (group I), 10 patients with H&Y stage 2.0 PD (group II), and 10 healthy elderly controls. Walking speed; step length; ROM of the hip, knee, and shoulder joint; foot clearance height; were significantly different between PD patients and controls. Step length and foot clearance height were significantly different between group I and group II. In conclusion, the TUG test may be a useful task for identifying turning characteristics of the severity of PD and to differentiate between PD patients and controls.

KEYWORDS: Parkinson’s disease (PD), Timed Up & Go (TUG), kinematics, spatiotemporal variables, gait

INTRODUCTION: Patients with parkinson’s disease experience movement impairments, such as tremors, rigidity, bradykinesia, flexed postures, and freezing of gait (Buckley, Pitsokoulis, & Hass, 2008; Jankovic, 2008). Further, PD patients experience considerable difficulty when walking and turning, and during complex motor and cognitive tasks (Camicioli, Oken, Sexton, Kaye, & Nutt, 1998; Morris, Morris, & Iansek, 2001). Thus, PD patients often experience falls and fall-related injuries, and suffer from a high rate of recurrent falling. However, previous studies have primarily compared PD patients and controls. Additionally, there remains a lack of generalized information regarding variables of gait in PD patients. Timed Up and Go (TUG) test has been used as a measure of balance and mobility in elderly and PD patients during walking and turning tasks (Weiss et al., 2010; Zampieri et al., 2010). The TUG test is highly correlated with functional mobility, gait velocity, and falls in the elderly (Nocera, Roemmich, Elrod, Altmann, & Hass, 2013; Viccaro, Perera, & Studenski, 2011). However, the majority of studies have used manual clocks and accelerometers to obtain measurements during the TUG test (Weiss et al., 2010; Zampieri et al., 2010). In addition, variables in the TUG test have classically been limited to elapsed time and total steps; therefore, a wealth of information may be ascertained when using the TUG test in combination with 3D motion analysis systems. The purpose of this study was to investigate turning characteristics of patients with PD, using 3D analysis during the TUG test, in order to classify the severity of PD.

METHODS: This study enrolled a total of 30 subjects; 10 patients exhibiting Hoehn and Yahr stages 2.5 or 3.0 PD (group I), 10 patients exhibiting H&Y stage 2.0 PD (group II), and 10 elderly controls from a local elderly center, who were matched with respect to age. The inclusion criteria were: (a) diagnosis of idiopathic PD, (b) H&Y stages 2 to 3, (c) currently receiving anti-Parkinsonism medications, and (d) no cognitive impairment. Cognitive impairment was defined as any score on the Mini Mental State Exam [MMSE] < 24. Subjects with any impairment of the lower limbs within 6 months prior to the testing, those unable to walk unassisted, or exhibiting neurological disorders, were excluded. Experimental protocols were approved by the Institutional Review Board. All subjects provided written informed consent prior to participation.

The TUG test was captured by 6 infrared cameras (Vicon, MX-T10, UK) on an 8-meter walkway. A 39-marker Plug-in-gait model was used, according to the modified Helen Hayes Marker Set, with 14 mm spherical reflective markers. PD patients were tested in an off-medication state, after abstaining from anti-parkinsonism medications for a minimum of 12 hours prior to the trial. All subjects performed the TUG test as follows: patients were asked to
stand from a chair and walk 2.44 meters forwards, as marked by a circular cone, and then
turn and return to the chair, before sitting down. Subjects were instructed to perform the test
safely but as quickly as possible (Persson, Danielsson, Sunnerhagen, Grimby-Ekman, &
Hansson, 2014). The turning phase was defined as the 2 steps immediately after the start of
turning. Furthermore, the more affected side (MAS) and less affected side (LAS) was defined
as the side exhibiting the greatest degree of PD symptoms. The sampling frequency for
kinematic data was set at 100 Hz, with the collected data filtered using digital low-pass filters
(2nd-order Butterworth filters) at 6 Hz. All spatiotemporal and kinematic variables were
analyzed by averaging 3 trials.
All statistical analyses were performed using SPSS (version 21.0, SPSS Inc, Chicago, IL).
Descriptive statistical analysis, using mean and standard deviation, was used to describe the
characteristics of each variable. After confirmation of normality using the Shapiro-Wilk test, a
repeated measures multi-way ANOVA was used to examine interactions and main effects
between groups, and within steps and directions, during the turning phase. Moreover, 1-way
ANOVA between groups, with Tukey’s Honest Significant Difference post-hoc test, and t-
tests for paired samples were used to determine significant differences. Significance was set
at p < 0.05.

RESULTS: Walking speed, step length, range of motion (ROM) for the hip, knee and
shoulder, foot clearance height, significantly differed between PD groups and controls.
Additionally, step length and foot clearance height significantly differed between group I and
group II. Furthermore, walking speed, step length, the ROM of the hip, knee, and shoulder,
and foot clearance height significantly differed within steps and directions (Table 1).

DISCUSSION: In comparisons between individuals with and without PD, significant
differences in walking speed; step length; ROM of the hip, knee, and shoulder joint; and foot
clearance height were observed. Crenna et al. (2007) have shown with 3D analysis that
walking speed is significantly different between PD patients and controls during the
approached turning 90° task using patient-preferred walking speed. Yang et al. (2016)
compared differences between PD patients and controls using a 3D motion capture system
during the TUG test, with results showing significant differences in sagittal and frontal
inclination angles, stride length, and stride time. These results might account for
characteristics of hypokinesia in PD patients (Huxham, Baker, Morris, & Iansek, 2008), which
is typified by difficulties with planning, initiating, and executing movement, and with
performing sequential and simultaneous tasks (Jankovic 2008). Further, hypokinesia in PD
patients might be associated with a decreased step length and walking speed (Roiz et al.,
2010). The present study observed a significant difference in the ROM of the hip, knee, and
shoulder joints between PD patients and controls; these results are in agreement with those
observed previously. Additionally, reduced hip and knee ROM may lead to reduced step
length. The hip and knee ROM may be the result of a reduction in foot clearance height; thus,
variables detecting PD severity include step length and foot clearance height.
When examining results for the walking speed of the MAS and LAS steps, ROM of the hip
and shoulder, and foot clearance height, it can be seen that groups I and II exhibited
significant differences in all such cases. Controls were observed to have coordination
between the MAS and LAS steps, regardless of the turning direction in the TUG test.
Successful turning is defined as a reduction in stride length and ROM of the lower limb on
the inside step, with a concomitant increase on the outside step (Orendurff et al., 2006).
However, PD patients showed a reduction in step length, compared to controls, for both MAS
and LAS steps. Individuals with PD typically exhibit turning characteristics such as en bloc
turning, impeded craniocaudal sequence (Yang et al., 2016), and asymmetry of the lower
limbs (Orendurff et al., 2006). PD patients in this study exhibited poorer coordination
between steps in the MAS and LAS turning directions. En bloc turning is a technique
whereby an individual reduces the dimensionality of the interconnected chain of axial
segments, to create just 1 degree of freedom in order to compensate for hypokinesia (Bhatt,
Pieruccini-Faria, & Almeida, 2013). These turning characteristics may lead to reduced ROM
in the sagittal plane for the hip and knee, and a reduction in foot clearance height. Conversely, healthy controls tend to exhibit a pivoting strategy in turning movements, whereby the individual steps across their stance limb (Orendurff et al., 2006; Bhatt et al., 2013). Previous studies have also observed these phenomena, particularly that of en bloc turning to the MAS direction in group I, and to the LAS direction in group II.

Table 1. The results of spatiotemporal and kinematic variables during turning phase

<table>
<thead>
<tr>
<th>Variables</th>
<th>Direction</th>
<th>Step</th>
<th>Group I</th>
<th>Group II</th>
<th>Controls</th>
<th>F</th>
<th>Post-hoc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking speed (m/s)</td>
<td>MAS</td>
<td>0.58 ± 0.21</td>
<td>0.60 ± 0.18</td>
<td>0.70 ± 0.17</td>
<td>1.235</td>
<td>NS</td>
<td></td>
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<tr>
<td></td>
<td>LAS</td>
<td>0.59 ± 0.20</td>
<td>0.60 ± 0.18</td>
<td>0.90 ± 0.12#</td>
<td>10.426*</td>
<td>C &gt; II, I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAS</td>
<td>0.53 ± 0.16</td>
<td>0.69 ± 0.22</td>
<td>0.96 ± 0.15#</td>
<td>13.980*</td>
<td>C &gt; II, I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>0.52 ± 0.16#</td>
<td>0.70 ± 0.22</td>
<td>0.63 ± 0.11†#</td>
<td>2.773</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Step time (s)</td>
<td>MAS</td>
<td>0.44 ± 0.06</td>
<td>0.48 ± 0.06</td>
<td>0.44 ± 0.05</td>
<td>1.527</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>0.49 ± 0.09#</td>
<td>0.48 ± 0.05</td>
<td>0.43 ± 0.05</td>
<td>2.476</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAS</td>
<td>0.46 ± 0.06#</td>
<td>0.49 ± 0.05</td>
<td>0.44 ± 0.05</td>
<td>1.488</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>0.45 ± 0.07</td>
<td>0.47 ± 0.05</td>
<td>0.45 ± 0.06</td>
<td>0.655</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Step length (m)</td>
<td>MAS</td>
<td>0.33 ± 0.07</td>
<td>0.44 ± 0.09</td>
<td>0.33 ± 0.08</td>
<td>6.129*</td>
<td>II &gt; I, C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>0.32 ± 0.07</td>
<td>0.36 ± 0.09#</td>
<td>0.39 ± 0.08</td>
<td>1.651</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAS</td>
<td>0.28 ± 0.07#</td>
<td>0.42 ± 0.13</td>
<td>0.40 ± 0.13</td>
<td>4.861*</td>
<td>II &gt; I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>0.33 ± 0.08†</td>
<td>0.42 ± 0.07†</td>
<td>0.32 ± 0.08</td>
<td>4.962*</td>
<td>II &gt; I, C</td>
<td></td>
</tr>
<tr>
<td>ROM of hip (°)</td>
<td>MAS</td>
<td>28.41 ± 5.78</td>
<td>30.60 ± 9.45</td>
<td>35.55 ± 7.15</td>
<td>2.358</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>30.78 ± 4.89</td>
<td>29.97 ± 8.97</td>
<td>34.69 ± 7.21</td>
<td>1.218</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAS</td>
<td>30.00 ± 5.63</td>
<td>31.78 ± 6.95</td>
<td>37.11 ± 5.43</td>
<td>3.753*</td>
<td>C &gt; I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>30.11 ± 8.38</td>
<td>30.57 ± 7.91</td>
<td>32.15 ± 5.95#</td>
<td>0.204</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>ROM of knee (°)</td>
<td>MAS</td>
<td>47.13 ± 10.50</td>
<td>45.47 ± 12.78</td>
<td>59.21 ± 8.47</td>
<td>4.888*</td>
<td>C &gt; I, II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>50.47 ± 5.26</td>
<td>46.64 ± 9.66</td>
<td>55.06 ± 7.00</td>
<td>3.135</td>
<td>C &gt; II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAS</td>
<td>44.75 ± 7.14</td>
<td>47.44 ± 9.96</td>
<td>52.15 ± 4.83</td>
<td>2.429</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>50.95 ± 11.39#</td>
<td>48.72 ± 8.80</td>
<td>59.61 ± 8.69#</td>
<td>3.513*</td>
<td>C &gt; II</td>
<td></td>
</tr>
<tr>
<td>ROM of ankle (°)</td>
<td>MAS</td>
<td>21.68 ± 5.51</td>
<td>23.32 ± 9.90</td>
<td>27.56 ± 13.28</td>
<td>0.907</td>
<td>NS</td>
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</tr>
<tr>
<td></td>
<td>LAS</td>
<td>23.26 ± 4.66#</td>
<td>22.11 ± 5.38</td>
<td>23.89 ± 5.54</td>
<td>0.301</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MAS</td>
<td>21.34 ± 5.10</td>
<td>23.78 ± 7.24</td>
<td>25.89 ± 5.45</td>
<td>1.438</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>22.66 ± 6.33</td>
<td>21.10 ± 3.18</td>
<td>22.83 ± 4.86</td>
<td>0.058</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>ROM of shoulder (°)</td>
<td>MAS</td>
<td>13.72 ± 5.71</td>
<td>18.83 ± 9.67</td>
<td>26.44 ± 14.91</td>
<td>3.526*</td>
<td>C &gt; I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>20.06 ± 9.33#</td>
<td>25.08 ± 11.73</td>
<td>30.49 ± 15.65</td>
<td>1.738</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>17.68 ± 7.35</td>
<td>23.08 ± 10.18</td>
<td>24.66 ± 11.82</td>
<td>1.352</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td>Foot clearance height (cm)</td>
<td>MAS</td>
<td>14.28 ± 3.51</td>
<td>17.58 ± 3.66</td>
<td>19.65 ± 1.92</td>
<td>7.477*</td>
<td>C &gt; I</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>16.71 ± 2.60#</td>
<td>19.44 ± 2.28#</td>
<td>21.25 ± 2.02#</td>
<td>9.727*</td>
<td>C, II &gt; I</td>
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<tr>
<td></td>
<td>MAS</td>
<td>18.70 ± 7.03</td>
<td>19.96 ± 2.74</td>
<td>22.04 ± 2.09#</td>
<td>1.392</td>
<td>NS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAS</td>
<td>14.20 ± 3.17†</td>
<td>18.32 ± 2.80†</td>
<td>19.47 ± 2.28#</td>
<td>9.963*</td>
<td>C, II &gt; I</td>
<td></td>
</tr>
</tbody>
</table>

All data are given as mean ± standard deviations. MAS: more affected side, LAS: less affected side, ROM: range of motion, I: group I, II: group II, C: controls. #: Denotes significant difference between steps (p < 0.05), †: Denotes significant difference between groups (p < 0.05).
CONCLUSION: TUG test may be a useful task for identifying turning characteristics of the MAS and LAS side, the severity of PD, and as a method to differentiate between PD patients and controls.

REFERENCES:

Acknowledgements
This study was supported by the Dong-A University research fund.