Title: Gait Performances in Children with Tourette Syndrome: A Preliminary Study

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Author Disclosures:

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Objective: To compared the gait characteristics in children with Tourette syndrome (TS) to the healthy controls (HC).

Design: Sixteen children aged 7-12 years voluntarily participated in this study. All the children were instructed to walk at 2 self-selected speeds: “preferred” and “fastest.” All gait parameters were collected using an electronic walkway (GAITRite system, CIR Systems Inc., Havertown). A two-way ANOVA with one repeated factor (group vs. speed) were performed for statistical analysis of differences in gait between two groups and across two walking speeds.

Results: Children with TS demonstrated similar gait characteristics as the healthy controls under different walking speeds in most measures. Despite the small sample, salient changes in gait performance were identified from children with TS. Essentially, children with TS walked less symmetrically in their preferred speed as shown by lager asymmetrical ratio (p = 0.002) of step length and greater left-right discrepancy of step length in both walking speeds (p = 0.013).

Conclusions: Similar to healthy children, those affected by TS were capable of increasing their walking speeds by increasing their stride length and cadence. However, the results of our study suggest that children with TS may exhibit gait anomalies, such as irregular step length.
Key Words: Tourette Syndrome, gait, speed-up
**Introduction**

Tourette syndrome (TS) is a childhood-onset neuro-developmental disorder that is defined by the presence of vocal and motor tics. Tics are involuntary, brief, rapid and non-rhythmic muscle contractions occurring on a background of daily activity and causing purposeless, stereotyped motor actions (motor tics) and sounds (vocal tics).\(^1\) Although the definite pathophysiology of TS is not yet fully understood, there is a hypothesis that the basal ganglia and related thalamocortical circuitry are involved.\(^2\), \(^3\), \(^4\) Basal ganglia play an important role in motor control system, especially in learning and selection of the most appropriate motor or behavioral programs,\(^5\) also essential for postural changes necessary to initiate and maintain locomotion.\(^6\) The inhibitory mechanism in basal ganglia-thalamocortical circuitry act as a general brake to modulate expression of motor and behavioral outputs of human,\(^5\), \(^7\) enable the intended movement and prevent the interference from the competing movement.\(^7\) Therefore, children with TS may exhibit motor or gait anomalies from healthy children due to the deficits in basal ganglia and related thalamocortical circuitry. The disorder of “brake” mechanism in basal ganglia-thalamocortical circuitry might effect the speed regulation in gait performances.

The studies of the motor symptoms of TS point out the center of body pressure sway range higher than healthy children during static standing activity and fine motor abilities deficits at Purdue Pegboard test.\(^8\), \(^9\) To our best knowledge, only one case study described that a child with TS with comorbid disorder exhibited weird gait characteristics as walked on his ball of feet and had coordination difficulties.\(^10\) No
other study had been reported gait in children with TS. The gait performances in children with TS warrant an examination because severe gait disturbances have been noted in other conditions with deficits in basal ganglia and related thalamocortical circuitry, such as Parkinson’s disease, Attention Deficit Hyperactivity Disorder (ADHD) and Developmental Coordination Disorder (DCD). Patients with Parkinson’s disease exhibit problem in regulation of stride length and relative increase in cadence as a compensatory mechanism for speed-up walking. Children with ADHD or DCD also had problem in regulation of stride time and stride length in slower speed and preferred walking speed. It might also subsist problems in children with TS when execution speed-mediated walking task. The aim of the present study was to explore the gait characteristics in children with TS and compare to the healthy controls in fastest speed and preferred speed walking.

Methods

This study was approved by the institutional review board at Chang Gang Memorial Hospital, Taiwan(97-2203B). Informed consent was gathered from parents of all participants. Children with TS were recruited from Department of Pediatric Neurology in Chang Gung Memorial Hospital- Children’s Hospital, Taiwan(ROC). Healthy control(HC) children were recruited using convenient sample. For the TS group, children were diagnosed by pediatric neurologist according to DSM-IV-TR (APA, 2000). Inclusion criteria for children with TS was age between 5-12 years old, attended to regular classes at elementary school, no other know diagnosis, healthy control children need to meet the inclusion criteria
except had been diagnosis as TS. Participants were excluded from this study if they matched following conditions: inability to follow verbal orders, had history of head injury or other neurological disorders and musculoskeletal diagnosis. As a result, eight children with TS (eight boys; mean age 9y 7mo [SD 1y 8mo]) and eight healthy control children (five boys, three girls; mean age 9y 6mo [SD 1y 7mo]). Participants in this study physical characteristics data were summarized in table 1.

Procedures

The GAITRite system (CIR Systems Inc., Haverton) was used to gather gait temporal spatial data. The GAITRite system employ an electronic walkway, contains six sensor pads encapsulated in a roll-up carpet giving an active area of 61cm wide by 366cm long. In order to exclude the gait variation due to gait initiation and termination, the stop and end lines 140cm far from the walkway were set to eliminate the record of the about the first and last two steps. (Figure 1)

Children in both groups received screening tests to insure their abilities for participation. The screening tests included: one leg standing for 10 seconds, hop for 10 steps. Then all participants will be collected basic data, including body height, weight and leg length. For each walking conditions, children performed two practiced trials and three formal trials. Children participated in the preferred speed walking following by the fastest speed. In the preferred walking condition, children walk using their preferred (normal) gait were instructed to ‘walk as you walk in daily life, you can swing your hands freely, just relax’. In the fastest walking condition, children were instructed to ‘walk as fast as you can, but not
Two-way ANOVA with one repeated factor (group vs. speed) were performed for statistical analysis of differences in gait between two groups and across two walking speed conditions. To exclude the body height effect in gait parameters, normalization of step length (nSL): (average of left and right step length)/leg length were used for data reduction. To see the symmetric in walking parameters, symmetry index: R (parameters)/ L (parameters) were used for data reduction. The following variables were compared by using two-way ANOVA with one repeated factor (group vs. speed): step time(s), cycle time(s), swing time(%), stance time(%), step length(cm), step length(normalize), stride length (cm), stride length(normalize), base of support, velocity(normalize), cadence(steps/min), step time differentiation (left–right discrepancy of step time), step length differentiation (left–right discrepancy of step length), and cycle time differentiation (left–right discrepancy of cycle time).

Results

Children in both groups were capable to increase walking speed upon the verbal commands (Table II). In order to speed-up, both group increasing speed, cadence and step length. The main effect in changing most gait parameters in different walking speed conditions is due to the speed factor, and no interactions between group and speed. Except step length differentiation, the main effect is the group factor (p=0.013), no interaction between group and speed (p=0.63). Children with TS exhibit greater left-right discrepancy of step length in both walking speeds (Figure 2). Besides, swing time and stance
time parameter in left leg changing in different walking speeds have interaction between group and speed (p<0.05). By using ANOVA to see the differences, children with TS perform longer swing time (p=0.027) and shorter stance time (p=0.026) than healthy control.

In most symmetric index, there are no significant differences between children with TS and healthy control. The main effect in changing most symmetric index in different walking speeds is due to the speed factor, and no interactions between group and speed. Excluding step length symmetry index has interaction between group and speed (p = 0.023). By using ANOVA to see the differences, children with TS exhibit less symmetrically in their preferred speed as shown by larger asymmetrical ratio (p = 0.002) of step length. (Figure 3)

**Discussion**

The results of this investigation provide considerable evidence that children with TS can increase their walking speed upon the verbal instruction as healthy control children, by increasing their cadence, step length. However, children with TS demonstrated the significant larger left-right discrepancy of step length in preferred and fast walking condition, also exhibit less symmetrically step length in their preferred speed compare with healthy control. This point out those children with TS has underlying motor control deficit in gait performance.

Although children with TS have similar pathology in patients with PD, their gait performances are not the same. Patients with PD walk more slowly and have shorter step length, higher cadence than
normal in preferred walking and fast walking. Children with TS have very similar temporal-spatial gait patterns with healthy control. But, they both have regulated problem in step length in common.

Morris et al (1994) made the point that it is possible that cadence regulation is not under basal ganglia influence whereas stride length control is mediated by the basal ganglia. Similar to this assumption, both children with TS and patients with PD can mediated their cadence properly in preferred and fast speed walking, but children with TS have asymmetry regulation in step length and patients with PD have decrease amplitude of stride length regulation. It may be the deficient in basal ganglia and related thalamocortical circuitry affect the step length regulation in children with TS.

Compare with children with ADHD have higher stride time variability during preferred walking speed, children with TS do not represent the problem in stride time regulation. However, it is interesting that children with ADHD gait performance improve during dual-task condition, similar phenomenon in children with TS. When children with TS ask to increase their walking speed, their asymmetry in step length no more present in gait performance in fast walking. It may be fast walking conditions creates an “automatic pilot” control of gait. This is consistent with the hypothesis which an external focus promotes the use of more automatic control processes. Zachry et al (2005) suggested that, “an external focus of attention enhances movement economy, and presumably reduces ‘noise’ in the motor system that hampers fine movement control and makes the outcome of the movement less reliable”. This theory could explain the reduction asymmetry in children with TS during fast speed walking.
Although this study has clarified the nature of basic deficit in gait performances in children with TS, there still have terra incognita in gait performance with TS. Further study is needed to explore the other gait information about kinematics, kinetics and electromyogram parameters.
References:


Figure 1: Experimental set-up.
Figure 2: Gait velocity, cadence, step length and step length differentiation for children with TS expressed as percentage of the value for healthy control.
Figure 3: Interaction in step length symmetry ratio between group $\times$ speed factors

* indicated there has significant difference between two groups (TS vs. HC) in the preferred condition.
### Table I

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Tourette Syndrome</th>
<th>Healthy control</th>
<th>t-test P value</th>
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<td></td>
<td>Mean ± SD</td>
<td>Mean ± SD</td>
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<td></td>
<td>9.6 ± 1.68</td>
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<td>Height (cm)</td>
<td>137.9 ± 2.51</td>
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<tr>
<td>Leg length (cm)</td>
<td>73.1 ± 6.58</td>
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<td>Weight (kg)</td>
<td>32.2 ± 11.42</td>
<td>34.8 ± 7.14</td>
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<tr>
<td>YGTSS (mild: moderate)</td>
<td>23.3 ± 9.16</td>
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### Table II: Comparisons of measurements between two groups using two-way ANOVA

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<tr>
<th>Swing time (%)</th>
<th>Leg</th>
<th>Speed condition</th>
<th>TS Mean ± SD</th>
<th>HC Mean ± SD</th>
<th>Factor</th>
<th>P</th>
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<td>L</td>
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<td>41.28 ± 1.10</td>
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<td>46.59 ± 2.33****</td>
<td>43.9 ± 2.06</td>
<td>Speed</td>
<td>&lt;0.05*</td>
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<td></td>
<td></td>
<td>Interaction</td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
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<td>Speed</td>
<td>&lt;0.05*</td>
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<td>Interaction</td>
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<td>0.28</td>
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<table>
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<th>Stance time (%)</th>
<th>Leg</th>
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<th>HC Mean ± SD</th>
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<tr>
<td>L</td>
<td>Free</td>
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<td>Group</td>
<td>Interaction</td>
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<td>53.38±2.41****</td>
<td>56.14±2.06</td>
<td>&lt;0.05*</td>
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<td>55.3±2.27</td>
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<td>&lt;0.05*</td>
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<td>R Free</td>
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<td>58.94±1.47</td>
<td>Group 0.26</td>
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<td>Fast</td>
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<td>56.18±1.77</td>
<td>Speed &lt;0.05</td>
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<td>1.09±0.08</td>
<td>1.08±0.07</td>
<td>Speed &lt;0.05</td>
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<td>Group 0.257</td>
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<tr>
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<td>1.00±0.15</td>
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<td>Speed &lt;0.05</td>
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<td></td>
<td>0.90±0.11</td>
<td>0.82±0.12</td>
<td>Speed &lt;0.05</td>
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<tr>
<td>Interaction</td>
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<th>Interaction</th>
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<tr>
<td>Cadence (steps/min)</td>
<td>126.44±10.41</td>
<td>122.74±7.15</td>
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<tr>
<td>Fast</td>
<td>181.38±18.09</td>
<td>183.13±27.88</td>
<td>Speed &lt;0.05*</td>
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<td>Interaction</td>
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<th>Group</th>
<th>Interaction</th>
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<td>Normalized velocity (m/s)</td>
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<td>1.68±0.20</td>
<td>Group 1.81</td>
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<tr>
<td>Fast</td>
<td>3.29±0.42</td>
<td>3.04±0.58</td>
<td>Speed &lt;0.05*</td>
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<tr>
<td>Interaction</td>
<td>0.81</td>
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<th>Group</th>
<th>Interaction</th>
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<tr>
<td>Step length differentiation</td>
<td>2.51±1.31***</td>
<td>0.82±0.69</td>
<td>Group 0.013**</td>
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<td>Fast</td>
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<td>1.87±1.84</td>
<td>Speed 0.171</td>
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<th>Group</th>
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<tbody>
<tr>
<td>Step length symmetry ratio</td>
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<td>0.99±0.01</td>
<td>Group 0.247</td>
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<tr>
<td>Fast</td>
<td>0.99±0.32</td>
<td>1.00±0.04</td>
<td>Speed 0.273</td>
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<tr>
<td>Interaction</td>
<td>0.23</td>
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</table>

* indicated there has significant difference between two conditions (preferred vs. fastest)

** indicated there has significant difference between two groups (TS vs. HC)

*** indicated there has significant difference between two groups (TS vs. HC) in the preferred condition

**** indicated there has significant difference between two groups (TS vs. HC) in the fastest condition