INTRODUCTION

Gait termination (GT) is a destabilizing transitional task that requires a shift from a dynamic state of motion to a static position [3]. GT can either be in response to unanticipated or anticipated stopping. While deficits in gait and gait initiation have been reported in individuals with essential tremor (ET), there is an absence in information regarding GT in those with ET, making it difficult for clinicians to design interventions to improve the ability to terminate gait quickly and efficiently.

ET is one of the most prevalent neurological disorders and yet when it comes to gait dysfunction there appears to be a void. Although, gait abnormality in ET has been documented as milder than that seen in patients with Parkinson’s disease and cerebellar ataxia, it does seem to have functional consequences [1]. Recently, investigations of cerebellar dysfunction have supported the manifestation of motor disturbances in ET [1]. These investigations have shown that there is increased gait variability, increased dysfunction during tandem gait and difficulty initiating gait in ET.

However, to date no studies have been performed to analyze and compare planned and unplanned gait termination strategies in ET. In light of the movement control problems reported for patients with ET, the purpose of the study was to examine the lower extremity control strategies, specifically braking and propulsive ground reaction forces, dynamic postural stability and spatiotemporal characteristics during planned (feedforward) and unplanned (feedback) GT.

METHODS

Seventeen individuals with ET (mean ± SD age: 67.4 ± 9.1 years, mean height: 173.2 ± 3.3 cm, mean body mass: 95.3 ± 19.4 kg) participated in this study. Subjects using a self-selected walking speed, traversed an 8 meter walkway with three force plates (360 Hz; Bertec Corporation, Columbus, Ohio) mounted flush with the walking surface. Kinematic data, time-synchronized to the kinetic collection, were collected using an 8 camera Optical Capture System (120 Hz, Vicon Nexus, Vicon, Oxford, UK).

Subjects completed five planned and unplanned gait termination trials, with normal gait trials randomly mixed in to prevent anticipation of stopping for unplanned trials. This investigation utilized a two-step termination paradigm. Braking and propulsive forces under the lead and trail limb were calculated using the peak ground reaction forces from two force plates. Peak propulsive and braking forces were normalized to the subject's mass. Dynamic postural stability index (DPSI) was calculated from ground reaction force data [3] during a 1-sec interval starting from onset of heel strike on the second force plate (by the trail limb). Additionally, spatiotemporal variables of gait, step length (SL), step velocity (SV) and step time (ST) were measured on the lead limb (terminating limb of GT) as well as the average velocity prior to the terminating step.

Ground reaction forces during the braking and propulsive phases of gait termination were analyzed using a paired sample t-test. Additionally, a paired sample t-test was used to compare the mean differences in spatiotemporal variables, gait velocity and DPSI (and component indices) between conditions (Planned vs Unplanned) with α=0.05.

RESULTS AND DISCUSSION
Braking forces were significantly greater during unplanned GT compared to planned GT (217.74 N/kg ± 67.9 vs 157.11 N/kg ± 49.5, p < .05). (Figure 1). There were no statistical differences in propulsive forces. The analysis revealed there were no differences in DPSI scores between the planned and unplanned condition. However, further analysis revealed significantly higher value in the component indices during unplanned GT; specifically in the AP (81.5 ± 40.8 vs 32.3 ± 9.7, p < .001) and ML (177.6 ± 69.1 vs 90.6 ± 25.8, p < .001) directions. Results of the spatiotemporal variables of the lead limb in GT are found in Table 1.

![Propulsive and Braking Forces](image)

**Figure 1:** Propulsive and braking forces with standard deviation during planned and unplanned gait termination. (*Denotes significant value p < .05)

The current investigation found during unplanned GT performance was characterized by a mild decrease in the propulsive force of the penultimate limb and statistical increase in the braking force of the termination limb. Research has shown that the ability to produce sufficient anterior–posterior ground reaction forces is crucial for stopping efficiently and safely.

It has been shown during tandem gait an increased number of mis-steps and variability during tandem gait is a risk factor for future falls [2]. Gait dysfunction during tandem gait is an apparent issue in ET [1]. In the current investigation, postural stability scores in ET, specifically in the APSI and MLSI directions, suggested less stability during unplanned GT. The results of the current investigation, in combination with previous literature in tandem gait, suggest ET have impaired postural stability. This investigation indicated less stability during unplanned GT as compared to planned GT and thus more likely to become unstable when forced to terminate gait abruptly and could lead to higher incidence of falls.

The results of the current investigation converge with previous findings, that during unplanned GT, the control strategy is modulated so that the terminal limb would attenuate the forward velocity. This is evidence by the increased step length and velocity in the unplanned condition and the increased time in the planned condition of GT. The lack of statistically difference between the gait speeds prior to the terminal/lead step in planned and unplanned GT may imply that there is an inability to voluntarily adapt gait velocity in preparation for gait termination.

**CONCLUSIONS**

GT involves a rapid deceleration of the body's forward momentum and requires a complex interaction of the neuromuscular system, it is possible to challenge both the feedforward and feedback neuromuscular control. Inconsequence, we were able to ascertain that patients with ET utilized alternative biomechanical control strategies during planned and unplanned gait termination.

**REFERENCES**

1. Louis ED, Okun MS. It is time to remove the 'benign' from the essential tremor label. Parkinsonism Relat Disord 2011;17(7):516-520.

<table>
<thead>
<tr>
<th>Outcome Measures</th>
<th>Planned (±SD)</th>
<th>Unplanned (±SD)</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step Length (m)</td>
<td>.47±.06</td>
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<tr>
<td>Step Velocity (m/s)</td>
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<tr>
<td>Step Time (s)</td>
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<tr>
<td>Gait Velocity (m/s)</td>
<td>.73±.14</td>
<td>.77±.11</td>
<td>.26</td>
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Table 1: Spatiotemporal variables of terminating limb and gait velocity during planned and unplanned stopping.