ISB 2013 BRAZIL

XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS

XV BRAZILIAN CONGRESS OF BIOMECHANICS

FOOT PLACEMENT VARIABILITY IN POST STROKE GAIT USING A STEP WIDTH TRACKING TASK

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SUMMARY

Tracking tasks are an established tool in determining the performance capacity of sensory-motor control. Within the post stroke population, upper extremity tracking tasks have been used to quantify specific motor control impairments. We introduce a foot placement tracking task to examine foot placement variability in the disease state. Chronic stroke subjects and age-matched healthy controls performed the tracking task for decreasing static step width targets. In response to the tracking task, a decrease in foot placement variability was identified for the ipsilesional (non-paretic) limb and the control population, but not for the contralesional (paretic) limb. However, foot placement variability was invariant to further changes in target width. For all tracking tasks the foot placement variability of the ipsilesional limb was greater than that of the control group and was typically less than the variability of the contralesional leg. We found no statistical difference in step width variability between stroke and control subjects under normal walking conditions (no tracking task). However, when presented with a step width tracking task equal to their average step width, control subjects were able to significantly reduce their step width variability by an average of 30.1% compared to no statistical reduction in the stroke population for the same task. Results suggest that while step width variability and foot placement variability exhibit similar trends in the control population, foot placement variability provides a stronger characterization of stroke population motor control capabilities than the metric of step width variability alone.

INTRODUCTION

The goal of this study is to evaluate the sensory-motor interactions of dynamic walking control strategies and to characterize the spatiotemporal properties of these strategies in response to varying task complexity. In this study, task complexity was augmented by the addition of a tracking task which required the systematic narrowing of foot placement.
In general, we argue that this step width tracking construct increases the biomechanical demand by constraining the control schemes that may be employed. A utility of the foot placement tracking paradigm is that it allows for the assessment of the motor control signature associated with the control of the contralesional and ipsilesional limbs. The continuous presentation of a static tracking constraint, at a self-selected speed, will establish the basic sensory-motor integration processes associated with walking.

Gait variability in healthy adults exhibits long-range correlations, suggesting that this variability is not random but can be considered a signature of the state of sensory-motor control of gait. In the disease state, it has been suggested that hemisphere specific damage can be expected to manifest as differing intralimb variability patterns for the contralesional and ipsilesional lower limbs [1]. Additionally, it is reasonable to assume that in both the healthy and diseased states, this signature of variability is also sensitive to differing locomotor tasks depending on the imposed spatiotemporal constraints [2]. Unfortunately the nature of step width variability post-stroke has been reported only once in the literature [3]. This study suggested that step width variability under free walking conditions is equal to that of the control population. It is likely that the lack of differences in step width variability between groups is due to the aggregate nature of this metric, a result of the difference in variability of the contralesional and ipsilesional sides. Nevertheless, step width variability fails to capture the relative bilateral differences in the control of the lower limb.

When the tracking task is added to an otherwise normal walking condition, we hypothesized a) that the foot placement variability would decrease for controls relative to the free walking condition. We also hypothesized b) that with the increase in the task complexity, associated with narrowing the foot placement targets, foot placement variability would change. Additionally, we hypothesize c) that similar trends would also be observed in the stroke population bilaterally. Furthermore, we hypothesized d) that foot placement variability of the ipsilesional side would not match that of control subjects. Also in keeping with previous findings, we hypothesized e) that, under nominal walking conditions, control and stroke subjects would demonstrate a similar level of step width variability.

METHODS

The study recruited 14 ambulatory community dwelling subjects, who had experienced a single unilateral stroke, and 8 age matched controls. All subjects were between the ages of 30 and 70, and at least 3 months post stroke. Subjects walked on a treadmill while wearing a safety harness, which did not supply body weight support. Subjects walked at their self-selected speed and average step width was measured. This step width defined the 100% step width task, with narrower targets given as a percentage of this width. For the nominal (free walking) task, subjects walked at their self-selected speed without foot placement targets. For tracking task trials, step width targets were projected on the treadmill belt using two adjustable, calibrated laser lines. Subjects are directed to place their foot such that the lateral edge of their shoe, at the ball of the foot, is as close to the target line as possible and a 3D marker is placed at this foot landmark to determine placement error. A full length mirror is placed in front of the treadmill allowing subjects to see their whole body and the foot placement targets. Step width tasks were presented in decreasing size, recording 100 steps for each task, with breaks between tasks. 3D kinematic data was recorded at 100 Hz using Hawk 200-T cameras (Motion Analysis, CA). Medio-lateral foot placement is defined as the average of a 0.2 second sample following heel and toe contact. Step width is defined as the distance between lateral foot markers on consecutive steps. A Wilcoxon rank sum test was used to determine statistical significance, and is defined as $p < 0.05$.

RESULTS AND DISCUSSION

In Figure 1 the variability (given as standard deviation) in foot placement error is given for the tracking and free walking tasks completed at self-selected speeds. A significant reduction in foot placement variability was found between the free walking and 100% step width task for the ipsilesional limb in the stroke group. However no change was identified for the contralesional limb, suggesting that foot placement variability is insensitive to the application of a tracking task and refuting our hypothesis (c). In the three tracking tasks, ipsilesional foot placement variability was always lower for 9 subjects and lower for all but one trial in 4 subjects. One subject, who walked at the fastest self-selected speed, had a trend of higher ipsilesional variability for all tasks. For all three tasks the foot placement variability of the ipsilesional limb was significantly greater than that of the dominant limb in the control group. This supports our hypothesis (d) that motor control signatures for the ipsilesional lower limb are not equivalent to those of healthy controls and is in accord with studies of motor performance in the ipsilesional upper extremity [4]. Overall, changes in lower limb ipsilesional motor performance are less surprising, particularly in gait, due to their shared coupling with the torso and their shared role in maintaining the upright posture and balance which prerequisite gait.

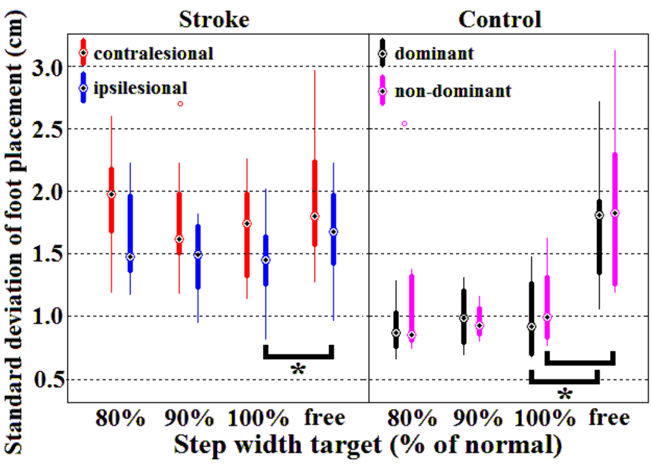

Figure 1: Standard deviation of foot placement across tasks at self-selected speed.

In the control group, both the dominant and non-dominant limbs significantly reduced foot placement variability between the free walking and 100% step width task, in keeping with our hypothesis (a). The stroke group, but not the controls, demonstrated a significant increase in step width variability between the 100% and 80% tasks, suggesting that stroke subjects were sensitive to increasing tracking task complexity, as we had hypothesized (b). Step width variability in the free walking task showed no statistical differences between the stroke and control groups, consistent with the existing study and our hypothesis (e) [3]. Lowest step width variability would be expected for the tracking conditions closest to the free walking condition, in this case the 100% task at self-selected speed. Contrary to our hypothesis, step width variability for the stroke group did not significantly decrease between the free and 100% task conditions. The average percent reduction in variability was only 3.7%. Conversely, control subjects were able to significantly reduce their variability between the free and 100% tasks, by 30.1% on average. Additionally, this reduction in variability was persistent across tasks, but invariant to changes in task condition ($p>0.05$).

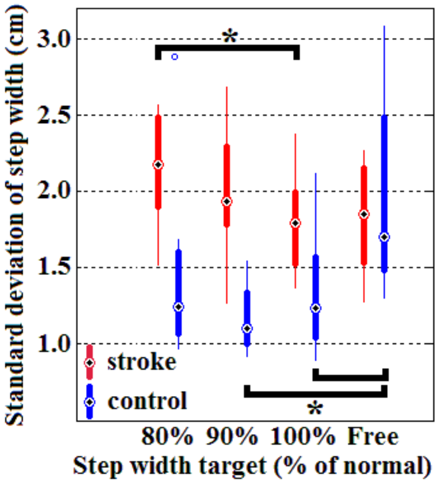

Figure 2: Standard deviation of step width across tasks

CONCLUSIONS

The findings in this study illustrate, that while step width variability and foot placement variability exhibit similar trends in the control population, foot placement variability provides a stronger characterization of stroke population motor control capabilities than step width variability alone. Findings also indicate that foot placement variability, for the ipsilesional stroke and the control, follow a similar trend, but with controls displaying a greater magnitude of decrease in variability between free walking and the 100% tracking task. These differences may be partly contributed to the mechanical coupling between the two limbs during gait.

ACKNOWLEDGEMENTS

Researchers acknowledge the funding sources for this work:
MARS-RERC grant H133E070013 funded by NIDRR
5 R01NS064084-02/NS/NINDS NIH HHS/United States

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