MARGIN OF STABILITY AS A METRIC FOR BALANCE IMPAIRMENT IN MULTIPLE SCLEROSIS

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INTRODUCTION

Multiple sclerosis (MS) is a chronic disease of the nervous system. This potentially debilitating disorder often results in a general degradation of motor function. In particular, MS patients have been shown to exhibit altered balance dynamics while standing [1]. This altered balance is characterized by a large amount of postural sway [1]. Increased postural sway has also been observed in the mediolateral direction during walking, even in patients with very mild MS [2].

Traditionally, static measurements taken during quiet standing have been utilized to assess balance impairment in MS patients [3]. Unfortunately, many of these approaches fail to account for aspects of balance during dynamic activities such as walking. It is particularly important to investigate balance during walking because this has been shown to correlate with fall risk in MS patients [4]. It would be pertinent to use a metric that accounts for not only the position of the center of mass or center of pressure but also its velocity. One such system that includes center of mass motion is the extrapolated center of mass motion and margin of stability [5].

This model utilizes the well established inverted pendulum analog of gait to characterize dynamic balance. The application of this unique metric could produce valuable new insights into the dynamic balance of gait in MS patients. Thus, the purpose of this study was to investigate the differences in dynamic balance between MS subjects and healthy controls in the mediolateral direction utilizing the margin of stability [5].

METHODS

Ten healthy controls and ten MS subjects were used for this study. Lower extremity kinematics (12 camera Motion Analysis; 60Hz) were collected while each subject walked over ground at a self selected pace. Five trials were collected for each subject. A custom MATLAB code was used to calculate the margin of stability. The initial computational step was to calculate the eigenfrequency ($\omega_0$) of the inverted pendulum using leg length (l) and the acceleration due to gravity (g).

$$\omega_0 = \sqrt{\frac{g}{l}}$$

Subsequently, the margin of stability was calculated for each trial using the position (x) and velocity (v) of the subject's center of mass and boundary of support of the right foot ($u_{max}$).

$$b = \left| u_{max} - \left( x + \frac{v}{\omega_0} \right) \right|$$

Figure 1: A schematic of the inverse pendulum model used to calculate margin of stability [5].
The mean, maximum, minimum, and range for the margin of stability were calculated and used as the outcome variables of this study. An independent t-test was used to test for significant differences with alpha at the 0.05 level.

RESULTS AND DISCUSSION

The mean and minimum values of the margin of stability exhibited very little difference between groups (<1 cm) (Figure 2). However, the maximum and range values displayed more substantial differences between groups. Notably, the maximum margin of stability experienced during gait was greater for MS subjects than for healthy controls and the minimum margin of stability experienced during gait was less for MS subjects than healthy controls. This resulted in a greater numerical range for margin of stability for MS subjects than for controls. Only the margin of stability range reached the statistically significant level.

As the extrapolated center of mass nears the border of support a fall becomes more likely to occur [5]. The results indicate that neither the mean nor the minimum of the margin of stability are significantly affected by the presence of MS. This would indicate that MS does not move the medial-lateral path of the extrapolated center of mass toward the boundary of support. The presence of MS, however, does seem to increase the divergence of the trajectory of the extrapolated center of mass through the gait cycle. The increased range in margin of stability demonstrates greater medial-lateral travel of the extrapolated center of mass. This serves as confirmation of the greater side-to-side sway observed in the gait of subjects with MS [2].

CONCLUSIONS

The use of the margin of stability metric in this study confirms previous findings regarding increased medial-lateral sway in MS patients during gait. However, a more mechanically unstable gait as defined by a decreased margin of stability was not observed in this population.

REFERENCES


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