INTRODUCTION

Multiple sclerosis (MS) is a chronic disease of the nervous system. This debilitating disorder often results in a general degradation of motor function. In particular, individuals with MS often exhibit altered balance dynamics while standing [1]. One of the characteristics of this altered balance is a large amount of postural sway [1]. Altered dynamic balance during walking with increased medial-lateral motion of the trunk has also been observed, even in individuals with very mild MS [2]. Static center of pressure measurements have predominantly been used to quantify balance decrements in individuals with MS. However, a recent study utilizing a dynamic measure of balance, margin of stability (MOS), reported individuals with MS exhibit a greater range in MOS than their healthy counterparts [3]. MOS accounts not only for the position of the center of mass but also its velocity [4]. As the MOS decreases, the associated gait is considered to be more mechanically unstable. Cutler et al.'s [3] findings confirm observations of increased medial-lateral sway in MS patients during gait[2] and are indicative of a decreased ability to control the trajectory of the center of mass.

However, it is unknown if dynamic balance during gait, measured by MOS, can be improved through an intervention for patients with MS. Elliptical exercise has been effective in improving both joint kinetics and quality of life measures in individuals with MS [5,6]. This particular exercise intervention was utilized because it provides a lower limb motion similar to walking and is better able to accommodate individuals with MS than treadmill exercise. Thus, the purpose of this study was to determine if participation in an elliptical exercise program by individuals with MS could improve dynamic balance by improving MOS during gait.

METHODS

Nine subjects (age: 40.3±10.7 yrs, height: 64.8±2.5 cm, mass: 89.9±23.3 kg) diagnosed with MS were consented for and participated in this study. Lower extremity kinematics were recorded by an eight camera system (60 Hz; Motion Analysis Corp., Santa Rosa, CA, USA) while each subject walked over-ground at a self selected pace. Five trials were collected from each subject for each limb. Each subject then participated in 15 exercise training sessions over the course of six weeks. This training was conducted on elliptical machines (Precor, Woodinville, WA, USA) and each session was 30 minutes in duration. Subjects repeated the aforementioned data collection process after completion of the elliptical exercise program.

A custom MATLAB (MathWorks Inc., Natick, MA) code was used to calculate the MOS. Eigenfrequency ($\omega_0$) of the inverted pendulum was calculated, per the equation $\omega_0 = \sqrt{g/2l}$, using leg length ($l$) and the acceleration due to gravity ($g$). The MOS time series was calculated for each trial, per the equation $MOS = |u_{max} - (x + v/\omega_0)|$, using the position ($x$) and velocity ($v$) of the subject's center of mass and boundary of support of the right foot ($u_{max}$). The mean, maximum, minimum, and range for the MOS were calculated and used as the outcome variables of this study. A paired t-test was used to test for significant differences with alpha at the 0.05 level.
**RESULTS AND DISCUSSION**

The elliptical training program had little effect on the mean MOS measurement exhibited by subjects with a decline of less than 0.004 m (Figure 1). The minimum MOS value did increase by 0.008 m post-training. As a result of the exercise training program the maximum MOS value decreased by 0.030 m, which was statistically significant. This post-training increase in minimum MOS and decrease in maximum MOS resulted in a significantly reduced range of MOS after the completion of the exercise training. This reduction was 0.038 m in magnitude.

![Figure 1: Margin of stability pre vs. post exercise training. *pre vs. post, p<0.05.](image)

As the MOS decreases, the associated gait is considered to be more mechanically unstable. As the extrapolated center of mass nears the border of support a fall becomes more likely to occur [4]. It would appear from our results that neither the mean nor the minimum of the MOS were substantially affected by the elliptical training program. This is indicative of the idea that the training did not cause the medial-lateral path of the extrapolated center of mass to move further away from the boundary of support, a result which would have indicated a reduced risk of falling. However there is a clear decrease in the range of the trajectory of the extrapolated center of mass through the gait cycle after the elliptical training. The decreased range of MOS demonstrates a reduced medial-lateral travel of the extrapolated center of mass. This result is indicative of reduced medial-lateral center of mass sway during gait in subjects with MS who participated in an elliptical exercise training program. Since greater medial-lateral sway is observed in the gait of subjects with MS as compared to healthy controls [2,3], it would appear that elliptical exercise may be able to assist in reducing the effects of MS on dynamic balance during walking.

**CONCLUSIONS**

Participation in an elliptical exercise training program reduced the medial-lateral center of mass sway in individuals with MS during walking. This represents a change in behavior approaching that of healthy individuals. Elliptical exercise may be able to assist in reducing the effects MS on dynamic balance during walking. Future work will need to determine the best dosing as well as possible other dynamic movement exercise interventions to determine if elliptical is the best method for improving dynamic balance.

**REFERENCES**


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