A DUAL TRACK TREADMILL IN A VIRTUAL REALITY ENVIRONMENT AS A COUNTERMEASURE FOR NEUROVESTIBULAR ADAPTATIONS IN MICROGRAVITY

***Susan E. D'Andrea, Ph.D., **Jay G. Horowitz, Ph.D., **Philip A. O'Connor, MS, *John Oas, MD, *Ari Levine, BS**

*Department of Biomedical Engineering and Orthopedic Research Center, Cleveland Clinic Foundation Cleveland, Ohio

**NASA Glenn Research Center Cleveland, Ohio

INTRODUCTION

Exercise is one of the most promising and widely accepted countermeasures to the physiological deconditioning experienced in microgravity. Currently, exercise in space is focuses on aerobic conditioning and often includes the use of a treadmill. This has been shown to mediate muscle atrophy and cardiovascular deconditioning, and to some extent bone loss. Standard treadmills, however, offer little input to the neurovestibular system, in part due to the stationary position of the head during use.

While the neurovestibular system is capable of adapting to altered environments such as microgravity, the adaptive state achieved in space in inadequate for 1G [1]. This leads to gait and postural instabilities when returning to a gravity environment and may create serious problems in future missions to Mars. New methods are needed to improve the understanding of the adaptive capabilities of the human neurovestibular system and to develop more effective countermeasures [2].

The overall purpose of this research is to design, develop and build a dual track treadmill, which utilizes virtual reality in order to challenge the postural control system. In the current study, specific focus was given to the issue of differential belt speeds (left versus right) that were programmed in accordance with a visual display projected on to a screen in front of each subject (Figure 1). It was hypothesized that gaze velocity would be greater for the situation where belt speeds were different and where subjects received real-time visual display of a curved path.

METHODS

Subjects ran on the dual track treadmill at a speed of 8 km/hr under four conditions:

1. Control: Left and right treadmill tracks ran at the same speed, and there was no visual display.
2. Visual: Tracks ran at the same speed, with a visual display.
3. Treadmill: Track speeds varied, but there was no visual display.
4. T and V: Tracks varied in speed according to the curvature of the path that was displayed in front of the subject.

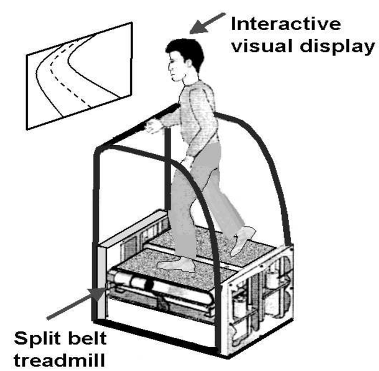

Figure 1. The left and right belt speeds were controlled via a computer in accordance with a prescribed path that was displayed in front of the treadmill.

For each condition, ten seconds of data were collected after an initial warm-up period. The vestibular ocular reflex (VOR) was measured using a pupil tracking system (ISCAN, Burlington, MA) and head angular velocity was measured by tracking head mounted reflective markers (Motion Analysis Corporation, Santa Rosa, CA). A one way repeated measures ANOVA was used to test for differences in the four conditions.

In terms of the most significant findings, walking on a treadmill with no visual display resulted in the lowest gaze velocity, whereas a treadmill with different belt speeds and simultaneous visual display caused subjects to exhibit almost 100% greater range in gaze velocity (Figure 3).

RESULTS

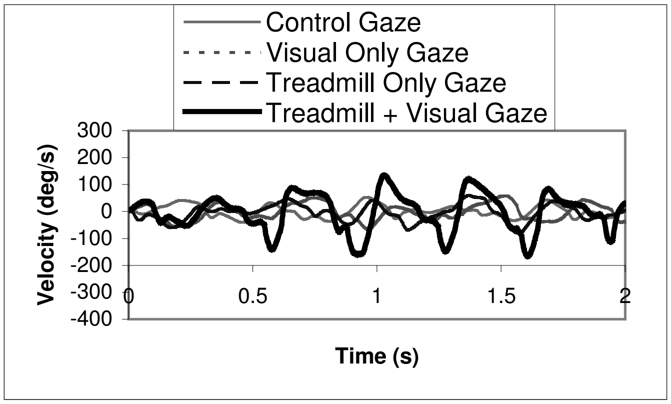

Figure 2. Representative vertical VOR data for one subject. Note the dark (thick) line has the greatest oscillations and corresponds to the condition where the treadmill belt speeds vary and there is a visual display.

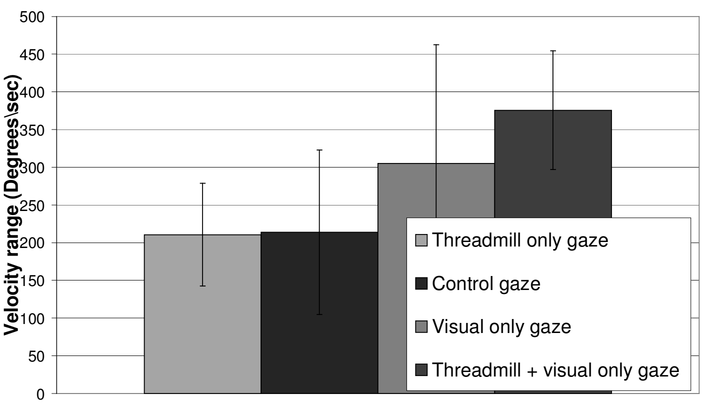

Figure 3. Comparison of the range of gaze velocity in four experimental conditions.

DISCUSSION

Although vestibular disturbances which cause motion sickness can be alleviated by pharmacological agents, astronauts still become disoriented in many situations during their work in space. This is due in part to the disruption of the neurovestibular system and the natural tendency to view the underlying surface as the floor. Even upon returning from a mission in space, coordination and postural balance strategies are often disrupted [2]. The concept behind the current study is that by challenging the neurovestibular system while walking or running, a treadmill-based countermeasure can help to readjust the relationship between the visual, vestibular and proprioceptive signals that are altered in a microgravity environment. As a countermeasure, this device could also benefit the musculoskeletal and cardiovascular systems and at the same time decrease the overall time spent exercising. Secondary advantages may include a higher motivation for astronauts to perform their exercise assignments due to the stimulation of the virtual reality system.

There were some limitations imposed by the experimental set up. First, in order to track the subjects' eye movements, a head mounted device was placed in front of the right eye. This meant that subjects could only look at the visual display with their left eye, and this may have altered their depth perception. Second, the display was projected on to a flat screen. While subjects were instructed to look at the center of the display, there may have been some cues that subjects obtained if they inadvertently looked at the edge of the screen. Finally, there were limitations imposed by the fact that only the treadmill belt speeds could be controlled (and not their height). Future split-belt treadmill designs may incorporate belts that can move vertically, giving subjects the sensation that they are not only running around a corner, but also up or down an incline.

Despite these limitations, the combination of a visual display and differential belt speeds yielded gaze velocities that were significantly greater than those obtained when subjects simply ran on a treadmill with no display and with identical belt speeds. This is encouraging for planners of exercise countermeasures since it suggests the vestibular system can be perturbed with relatively simple technology.

REFERENCES

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