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

Susan E. D'Andrea Ph.D.*, Michael W. Kahelin B.S.
Department of Biomedical Engineering, The Cleveland Clinic Foundation, Cleveland, OH

Jay G. Horowitz Ph.D., Philip A. O'Connor M.S.
NASA Glenn Research Center, Cleveland, OH

INTRODUCTION

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 concept behind the current study is that by challenging the neurovestibular system while walking or

FIGURE 1: Dual Track Treadmill

running, a treadmill 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. The overall goal of this research is to design, develop, build and test a dual track treadmill, which utilizes virtual reality, VR, displays (Figure 1).
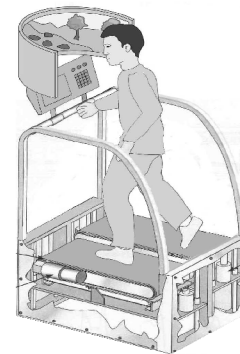
PILOT STUDIES

Pilot studies were performed to evaluate the potential of the system to stimulate the neurovestibular system. Twenty subjects were tested running on a dual-track treadmill in simulated curve walking scenes. Subjects also participated in an extended trial consisting of walking 30 minutes in one randomly assigned condition. Before and immediately following testing, subjects ran a timed obstacle course. Results revealed that the combination of visual and proprioceptive stimuli provided by the VR system and the movement of the treadmill respectively, will significantly increase the stimulus to the neurovestibular system.

TREADMILL DESIGN

The proposed treadmill has been designed to function with two belts and four actuators to both elevate and incline the tracks independently (Figure 2). Along with dual speed control, this arrangement will enable the system to replicate motion found during ascending and descending hills, going over rough terrain, turning corners and climbing stairs. Working in conjunction with the VR display, the treadmill system will provide an immersive environment for testing effects on the neurovestibular system.

The system's motion is governed by six independently controlled axes: two AC motor-driven treads and four servo-driven linear actuators. The system can be simplified as a hierarchical structure composed of three levels and ten components (Figure 3). The highest level of the hierarchy is the main user interface which governs all functions of the system, including manual control, programmed control, and path generation. It is also responsible for synchronizing the system's motion with its visual display. The user interface level communicates directly with the motor controller and visualization application. The visualization application, created by NASA, uses a "morphing hallway" algorithm to create a visual environment that simulates motion in three dimensions, as well as a variety of terrains including stairs. This application outputs the visual effects to a display unit. The motor controller is responsible for the motion of the motors. This component is linked to the user interface via component object model (COM) interface. The controller is responsible for the PID control of the servomotors and the translation of the user interface's mnemonic code to machine code. The lowest level of the hierarchy represents the hardware of the system. This level is responsible for providing the physical stimulation to the subject. It is composed of the visual display and the actuation devices working through the treadmill frame.
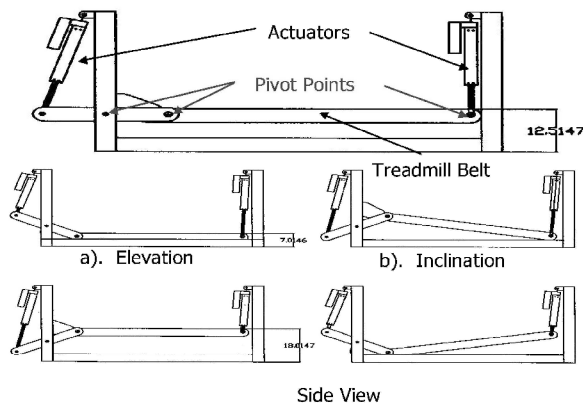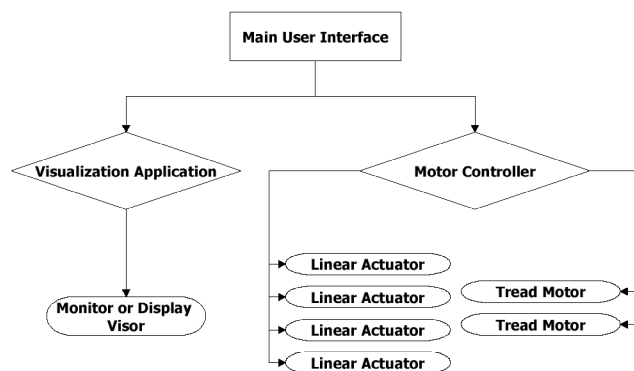
Figure 2: Treadmill Schematic

Figure 3: System Overview

Biomechanical testing will concentrate on establishing the extent to which the treadmill will stimulate the neurovestibular system. This will include motion analysis, electromyography, accelerometry and pupil tracking data. It is expected that these biomechanical parameters indicating neurovestibular response will differ significantly while walking and running on a standard treadmill from those recorded using the novel virtual reality dual track system.

REFERENCES

1. Bloomberg, *et al.*, 1997. Journal of Vestibular Research, Vol. 7, Nos 2/3, pp 161-177.
2. Oman, C.M *et al.*, 1996. Journal of Applied Physiology, Vol. 81, No. 1, pp. 69-81.

ACKNOWLEDGEMENTS

*Susan E. D'Andrea, Ph.D.   Phone: 216.444..5347
Department of Biomedical Engineering/ND20   Fax: 216.444.9198
The Cleveland Clinic Foundation   Email: dandreas@bme.ri.ccf.org
9500 Euclid Avenue
Cleveland, OH 44195