# COORDINATION OF LOWER LIMB JOINTS DURING LOCOMOTION:THE EFFECTS OF VESTIBULO-OCULAR REFLEX ADAPTATION

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## INTRODUCTION

Controlling locomotion while maintaining a stable gaze requires precise coordination between several, interdependent full-body sensorimotor subsystems (Bloomberg and Mulavara, 2003; McDonald, et al., 1997). The overall goal of this study is to determine how this full-body gaze stabilization system responds to adaptive changes in vestibulo-ocular reflex (VOR) function.

Locomotion involves cyclical physical interactions (impacts) with the environment. Hence, focusing on a target and maintaining visual acuity during this activity may require mechanisms to manage the energy flow, so it does not disrupt the visual and vestibular sensory information processing that stabilizes gaze. It has been shown that increasing the difficulty of a gaze task (reading numbers on a screen as opposed to simply focusing on a central dot pattern) resulted in an increase in the amount of knee flexion movement during the critical phase immediately following the heel strike event (Mulavara and Bloomberg, 2003). The increase in knee flexion during the stance phase of the gait cycle has been suggested to function as a shock absorbing mechanism associated with the rapid weight transfer from the trailing to the leading leg during walking.

To understand this full-body coordination, the relative contributions of each component and the resulting effects should be assessed. In this study, we hypothesized that VOR adaptation would result in a reorganization of the lower limb joint coordination during treadmill walking in a manner to facilitate the gaze stabilization task and preserve locomotor function.

## METHODS

Fifteen subjects participated in this study, which was approved by the NASA Committee for the Protection of Human Subjects. Footswitch data (Motion Lab Systems, Baton Rouge, LA), collected at 1000Hz, were used for calculating gait timing events. Retroreflective markers were affixed to the right lower limb in a configuration such that each segment's 3-D motion could be determined. Marker motion was collected at 60 Hz using six Hi-Res Falcon cameras (Motion Analysis, Santa Rosa, CA) set up in a split-volume configuration.

In this protocol, five walking trials were recorded before VOR adaptation as a "normal" baseline. For each 90 second trial, the subjects walked on a treadmill at 6.4 km/hr while reading 5-digit numbers on a computer screen placed 2 m from his/her eyes. Data were recorded for a 20-second epoch in the middle of each trial. The VOR adaptation consisted of the subject sitting and watching a movie while wearing minimizing lenses (0.5x mag.). The movie was projected onto a large screen (2.5 x 2.5 meters) positioned 2 meters in front of the subject. During the 30-minute viewing time, the subject was instructed to move his/her head slowly in pitch to incite the adaptation. Immediately after the adaptation period, five more walking/reading trials were recorded in the same manner as before adaptation.

Marker motion data were tracked using EVa system software (Motion Analysis, Santa Rosa, CA). Motion of the lower limb joints was determined using the convention detailed by Verstraete (1992). The following parameters were computed for each of the 20 gait cycles analyzed in each trial: the maximum, minimum, average and range of the joint angles. These parameters were used as input to a repeated-measures ANOVA (STATA 6, College Station, TX) with a significance level of $p<0.05$.

## RESULTS AND DISCUSSION

The repeated-measures ANOVA showed that in the first walking trial after VOR adaptation, subjects significantly increased their average knee flexion ($p<0.001$; Figure 1). Average ankle angle tended to decrease (i.e., increased dorsiflexion) in the first trial post-adaptation, but did not quite attain statistical significance ($p=0.064$).

This coordinated increase in average knee flexion and decrease in average ankle angle appears to be part of a compensatory strategy by the lower limbs to stabilize gaze in response to modified VOR. Hence our subjects may have experienced gaze instability immediately after the adaptation period, and they evoked a strategic response to minimize perturbations to the head with increased knee flexion.

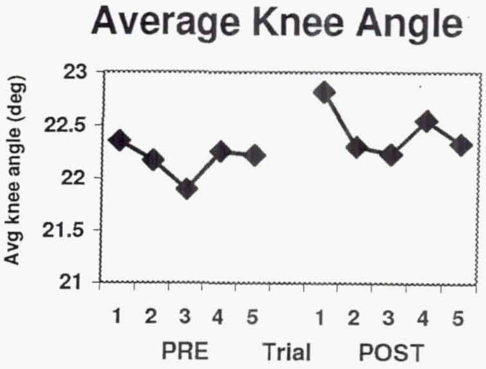

**Figure 1:** Representative average knee angle data for one representative subject before and after VOR adaptation.

## SUMMARY

The adaptive modification of the VOR resulted in a reorganization of knee and ankle joint coordination during treadmill walking, specifically increased knee flexion. Hence the subjects were able to adopt a modified strategy for full-body coordination to maintain stable gaze.

## REFERENCES

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