ROLE OF PROPRIOCEPTION AND FOOT SOMATOSENSATION IN DETECTING SLIPPING ACCIDENTS

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INTRODUCTION

Falls are a serious occupational and public health problem. Factors that contribute to the initiation and outcome of the slip include environmental (flooring, liquid contaminants, lighting) and person-specific (walking style, anticipation, slip detection and slip response). Generating a timely and effective response to a slip is critical to achieving recovery from the slip [1]. Prior to generating a postural response, the body must first detect that a slip is occurring. Previous research has indicated that degradation in the sensory system due to aging may increase slip risk [2]. The precise sensory systems responsible for detecting slipping, however, are unknown. The purpose of this project is to examine the role of sensory flow from foot somatosensation and lower-body proprioception to detecting slipping events.

METHODS

Data from 17 younger (aged 20-35) and 13 older adults (aged 50-65) was collected and analyzed. All subjects were consented prior to their participation and this research was approved by the University of Pittsburgh Institutional Review Board. Subjects donned a protective harness during all trials. Subjects were informed that the floor would be dry and then completed three dry trials followed by an unexpected slip trial. The unexpected slip was induced by applying a diluted glycerol fluid contaminant onto a force plate. Subjects had a set of 79 reflective markers during testing, which were recorded by motion capture cameras and allowed for the calculation of ankle, knee and hip angles. Slipping trials were categorized by slip severity using the maximum slipping velocity of the heel measured shortly after heel strike, with a threshold of 1.0 $m*s^{-1}$ [3]. Subjects walked across 2 force plates that measured ground reaction forces.

The primary variables of interest were the joint angles both ipsilateral and contralateral to the slip and the normal ground reaction force. The time that a joint angle during a slip deviated from normal walking conditions was determined, and interpreted as the initial time that a slip could be detected by the proprioceptors in that joint. The normal force deviations were interpreted as the time that foot pad somatosensation could detect a slip. The deviation time was calculated between the slip trial and the preceding dry trial. Thresholds for detection were set at 20% of the maximum for normal force, 10% of the range of motion during gait for hip and knee angles and 20% of the range of motion during stance for ankle angles. Deviation times (TimeDev) were calculated as the time after heel strike that the deviation exceeded these thresholds (Fig. 1). Occurrences when the deviation exceeded the threshold at the time of heel contact (pre-deviation; 3/210 occurrences) and when the deviation never exceeded the threshold during the first 450 ms after heel contact (no deviation; 12/210 occurrences) were excluded from the analysis.

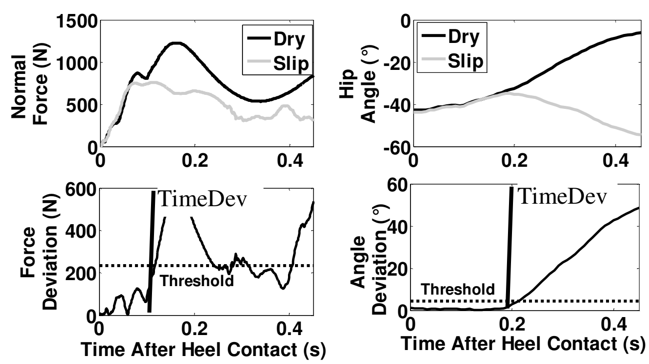

Fig. 1: Normal force (left) and hip angle (right) for a representative subject. The deviation graphs (bottom) indicate when the threshold was exceeded.

An ANOVA analysis was performed with TimeDev as the dependent variable, the sensory system in which the deviation occurred (i.e. joints and foot pad) as a fixed-factor independent variable and subject as a random-independent variable. For each subject, the sensory system that first deviated from baseline conditions was identified (i.e. the sensory system likely responsible for detecting the slip) and the time that the first deviation occurred across all of the sensory systems was identified ($TimeDev_{Initial}$). An ANOVA analysis was performed with $TimeDev_{Initial}$ as the dependent variable, subject as a random independent variable and age group, slip severity and their interaction as fixed-factor independent variables.

RESULTS AND DISCUSSION

Deviation time (TimeDev) differed across the sensory systems ($p<0.001$). Post-hoc (Tukey) analyses reveal that the normal force deviated prior to any of the joint angle measures (Fig. 2) ($p<0.001$). Therefore, foot somatosensation is the first opportunity for detecting a slip.

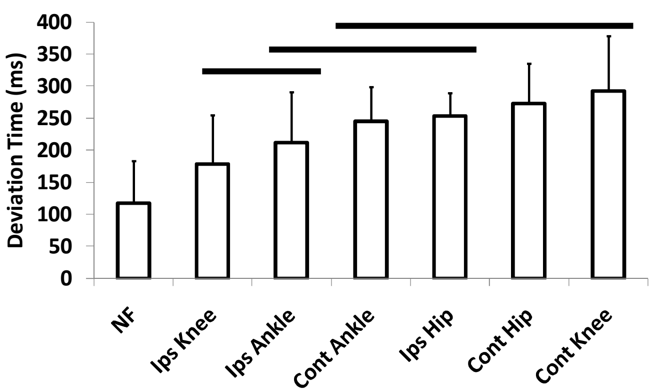

Figure 2: Average deviation times (with standard deviations) for normal force (NF), ipsilateral joint angles (Ips) and contralateral joint angles (Cont). Bars represent non-significant differences ($p<0.05$).

Inspection of the data revealed that 22 subjects experienced initial deviations in foot somatosensation; 4 subjects experienced initial deviations in the knee angle ipsilateral to the slip; 2 subjects experienced deviations in the ankle angle ipsilateral to the slip; 1 subject experienced deviations in the knee and another in the ankle contralateral to the slip.

Neither slip severity, age group or their interaction significantly contribute to the time in which the first system initially deviated from baseline conditions ($TimeDev_{Initial}$). Therefore, the timing in which the flow of sensory information first deviates is not dependent on slip severity or the age of the person.

While this study strongly indicates that foot somatosensation may be critical to the detection of slips, there are other contributing factors that could affect the detection of slipping accidents. This study did not examine other sensory systems that may also play a role in detecting slipping accidents such as the vestibular system. In addition, this study did not examine sensitivity among different sensory systems, which could have been used to define the thresholds for slip detection.

This research may be critical to identifying working conditions and pathologies that affect a person's ability to properly detect and respond to a slipping accident. In particular, cold working conditions may reduce foot somatosensation sensitivity or diseases such as diabetes are known to in some cases degrade foot sensations. Future research intends to focus on the affects of reduced foot somatosensation on the ability to properly respond to slipping accidents.

CONCLUSIONS

In this abstract, foot somatosensation was identified as being potentially critical to the process of detecting and responding to slipping accidents. Person's who have a limited ability to sense foot pressures may have a limited ability to detect a slip and generate an effective postural response.

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