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Varying the Speed of Perceived Self-Motion Affects Postural Control During Locomotion

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Abstract. Virtual reality environments have been used to show the importance of perception of self-motion in controlling posture and gait. In this study, the authors used a virtual reality environment to investigate whether varying optical flow speed had any effect on postural control during locomotion. Healthy young adult participants walked under two conditions, with optical flow matching their preferred walking speed, and with a randomly varying optic flow speed compared to their preferred walking speed. Exposure to the varying optic flow increased the variability in their postural control as measured by area of COP when compared with the matched speed condition. If perception of self-motion becomes less predictable, postural control during locomotion becomes more variable and possibly riskier.

Keywords. Virtual reality, optical flow, postural control, center-of-pressure, variability

Introduction

Falls among the elderly often lead to impairments that preclude their activities of daily living while also imposing a significant economic burden on society. [1] Therefore, the ability to predict and prevent falls is critically important. Previous attempts at correlating gait variability with fall risk have not proven conclusive. [2] This may be because gait parameters do not appropriately assess postural control during locomotion. However, center of pressure (COP) has been used with moderate success to assess *standing* postural control. Yet, falls tend to happen while walking and not during static standing. [3] Thus, it's possible that a connection between *walking* COP and falls does exist. [4] Accordingly, it's reasonable to hypothesize that diminished balance while walking could be a strong predictor of falls and that assessing COP variability during gait may be essential in establishing this correlation. Further, optical flow (OF) manipulations using virtual reality (VR) environments have already been shown to affect measures of *gait variability*. [5-8] However, how such VR manipulations affect *postural variability* during gait remains to be investigated. Besides, walking in VR environments affects our perception of self-motion. [9,10] When OF is randomized, the perception of self-motion becomes unpredictable. Thus, how postural control would be affected in an unpredictable visual environment is a further objective of our study. Therefore, the purpose of this study is to determine the effect of unpredictable perception of self-motion on postural control variability and lay the foundation for how such effects may relate to increased fall risk.

1. Methods & Materials

1.1. Participants

Ten healthy young adults (five males and five females; aged 25±5 years) were recruited for this study. This study was approved by the local Institutional Review Board and all participants provided a written consent.

1.2. Experimental Protocol

Participants walked on an instrumented treadmill with embedded force plates (Bertec Corp., Columbus, OH) immersed in a VR environment. The VR environment was customized; written in Vizard software (World Viz, Santa Barabara, CA). This VR environment was projected using a commercial system (Optoma TX 774, Optoma Technology Inc., Milpitas, CA) onto three 99 × 68 inch screens (Stewart Filmscreen Corp., Torrance, CA). The center screen was positioned 1.5m away from the participant. This created a vertical and horizontal field of view, 59.39° and 79.42°, respectively. The VR environment visually consisted of a continuously moving corridor. This VR set-up has been previously used. [7,8,10] While the participants were walking on the treadmill, ground reaction force data was recorded at 300Hz. The participants began by walking for five minutes on the treadmill to assess their preferred walking speed (PWS). After the PWS was recorded, all the participants walked on the treadmill using their PWS for two minutes in the two following conditions: 1) OF with consistently varying random speed between 80% and 120% of PWS; and 2) the OF speed matched with the participants' PWS.

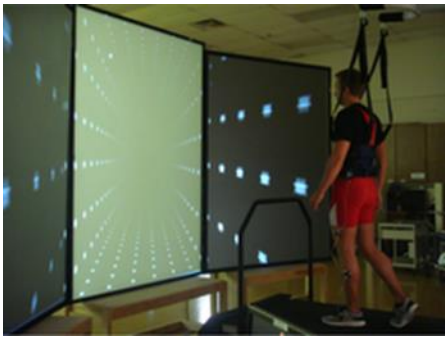

Figure 1. A participant walking on the treadmill while being immersed in the virtual environment

1.3. Data Collection and Analysis

The ground reaction force data was used to calculate COP using Matlab r2009a (Mathworks Inc., Natick, MA). Following this, the coefficient of variation (CV) for COP was used to analyze postural control variability. A COP area profile was defined using 4 points: right heel strike (RHS), left heel strike (LHS), right toe-off (RTO), and left toe-off (LTO). The COP profile starts with each step's heel strike and continues during the single-support phase (SSP) until the moment right before toe-off as the next step's heel strike commences which initiates the double-support phase (DSP). At this point, the COP signal crosses over once the initial toe-off is completed and the signal continues in a similar manner until the crossover of the next step's SSP begins. This allows the recording of a continuous COP signal for each gait cycle, which is then used to calculate two area triangles. Each triangle consists of the heel-strike and toe-off of each side and the intersection point between the two triangles. We then aggregated these triangles to find the net area of COP. A paired t-test was performed using SPSS software (18.0, IBM Corporation, Somers, NY) to assess the condition effects on COP. The significance level was set at 0.05.

2. Results

The results showed that the area of COP in the condition with random OF speed (OFr) significantly increased in variability when compared to the condition with matched OF speed (OFm) to the PWS; this conclusion is based on the difference between the standard deviations of COP area between the two conditions ($p = 0.002$, figure 2). This effect was not seen upon analyzing only the mean. The difference between the CV of COP area between the two conditions was used to confirm the conclusion ($p = 0.0002$, figure 3). COP profiles of both legs in one participant are displayed similar to a butterfly pattern previously used. [11] These representations (figures 4 and 5), illustrate the significant change in area of COP when OFm is compared to OFr.

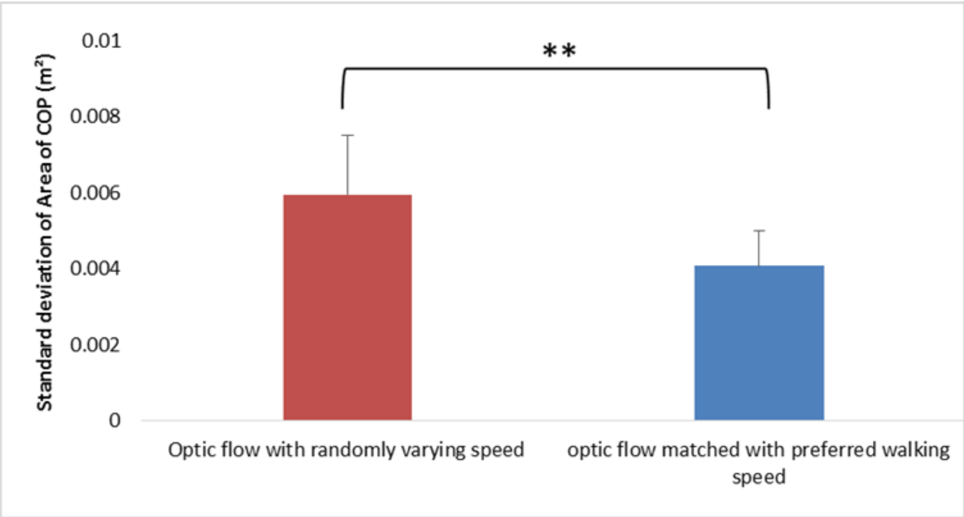

Figure 2. The participants walking with OFr showed an increase in posture control variability compared to walking with OFm as confirmed by standard deviation of COP area.

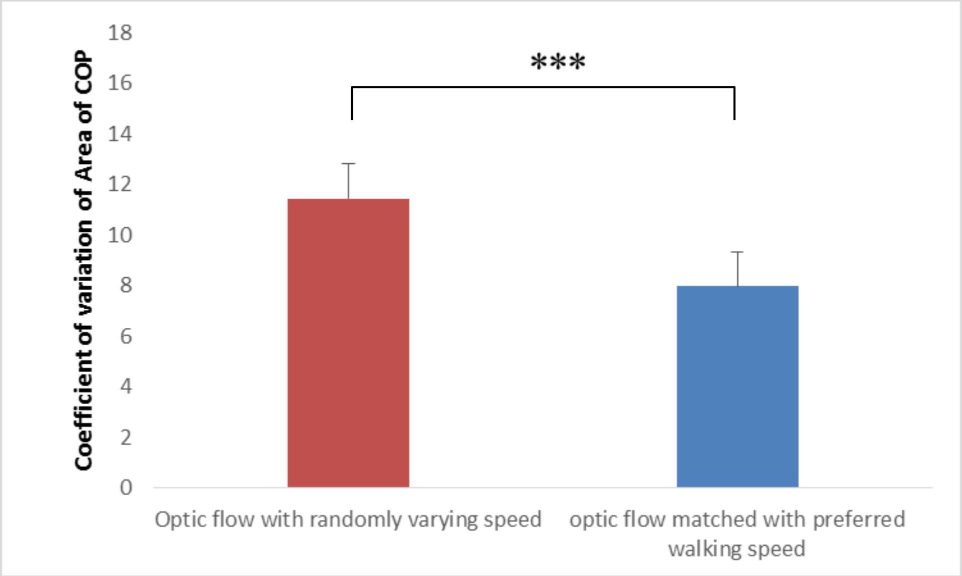

Figure 3. The participants walking with OFr showed an increase in postural control variability compared to walking with OFm as confirmed by coefficient of variation of COP area.

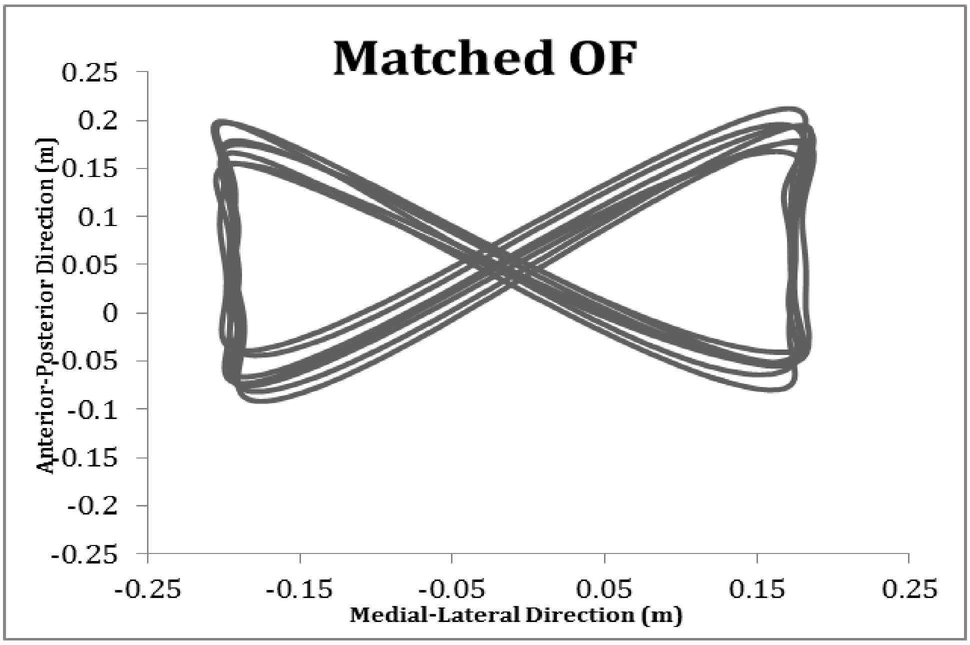

Figure 4. The COP profile in seven gait cycles for one participant performing the OFm trial.

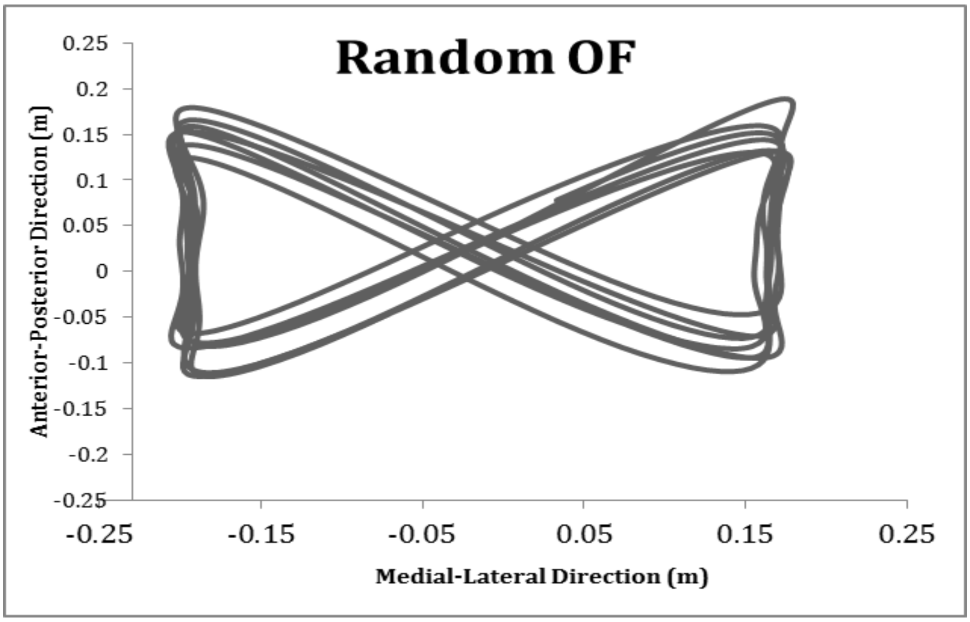

Figure 5. The COP profile in seven gait cycles for one participant performing the OFr trial.

3. Discussion

In this study our objective was to determine how OF manipulations, especially random OF speed, would affect postural variability during walking. We found that in comparison to the condition with OF speed matched with preferred walking speed, there was an increase in COP variability when the OF speed became random. This suggests that when the perception of self-motion becomes unpredictable, postural control is significantly affected and may increase the risk of falls. A situation may not only be encountered by individuals who are in such environments (like walking in a moving vehicle, e.g. ship, bus) but also by people who have perceptual deficits. It has been previously established that modulation of OF can change locomotor performance by reducing gait variability. [5-8,10] Findings from our current study demonstrate the kind of postural control changes which accompany such modulations. Specifically, we found that when perception of self-motion becomes unpredictable, as in cases of random OF speed, postural control variability increases which suggests an impairment of balance during locomotion. This study strengthens the importance of examining postural control during locomotion, and illustrates how perceptually enhanced environments like VR can help aid in such investigations.

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