The Influence of Virtual Curved Paths on Gait Symmetry for Older Adults

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Summary

This study examined the impact of visual curved paths in low-immersion virtual reality (VR) on gait symmetry in older adults. During walking tasks, a significant inward shift of the centre of mass was observed on highly curved paths, which suggests that visual cues may potentially influence gait symmetry by altering weight distribution.

Introduction

Gait disorders, such as asymmetrical gait patterns, commonly affect individuals with neurological and musculoskeletal conditions, with older adults being a key demographic. Treadmill-based virtual reality (VR) shows promise for gait rehabilitation by providing real-time visual cues to guide movement, however, designing cues that promote gait symmetry remains challenging. In daily activities, curved paths influence step length, swing time, and centre of mass [1], suggesting that similar visual stimuli in VR may elicit comparable adaptations. Previous studies have focused on straight optic flow effects on overall gait performance (e.g., speed) rather than the impact of sustained curved paths on gait symmetry [2]. Moreover, many studies rely on high-immersion systems with advanced treadmills such as split-belt and self-paced treadmill, limiting clinical feasibility [2, 3]. This pilot study aimed to investigate whether simulating different levels of curved paths in low-immersion VR with a fixed-speed and single-belt treadmill can affect gait symmetry and related parameters in older adults, offering a more accessible approach for clinical use.

Methods

Twenty-two healthy older adults (9 male/13 female, median age 71.5 (65-82) years) were recruited. After informed consent, participants completed treadmill familiarization to set a comfortable speed which was kept constant throughout the experiment. Participants performed walking tasks using a portable fixed-speed and single-belt treadmill (Ape Style FX1500, New Zealand) and a 55-inch screen displaying 4 different virtual conditions: straight path (S), curved paths with high curvature (C_{high}, 1/7 m^{-1}), mid curvature (C_{mid}, 1/14m^{-1}), and low curvature (C_{low}, 1/14m^{-1}). The virtual paths were created in Unity 3D, with Kinect Azure tracking motion to match optic flow to treadmill speed. Kinematic data during walking were captured using OpenCap (Stanford, USA) at 60 Hz. The 40s-data excluding acceleration and deceleration phases were used for analysis. The step length ratio (SLR), swing time ratio (SWR), and relative Centre of Mass (i.e., medial-lateral distance from Centre of Mass to middle of ankle joints at mid stance of inner leg (COM_{in}) and outer leg (COM_{out})) were calculated. The ratio was calculated by dividing the inner leg parameter by the outer leg parameter. A one-way repeated measure ANOVA (with Greenhouse-Geisser correction) was used to investigate how the curvature level affects gait parameters and Post-hoc analysis (paired-t-test) with Bonferroni-Holm adjustment was conducted to compare difference between each path conditions.

Results and Discussion

There was a significant main effect of relative COM position (COM_{in}) ($F_{3,63} = 7.69$, $p = 0.004$). The relative COM position at left foot mid stance shifted most inward (i.e., the lowest values) on the most curved path (C_{high}), differing significantly from both the less curved path C_{low} ($p = 0.017$) and Straight path ($p = 0.030$). The significant inward shift of the COM with increasing curvature suggests that visual curved path stimuli could affect lateral weight distribution, similar to real-word curve-ahead walking.

Table 1: The gait parameters in different virtual path conditions

Path	C_{high}	C_{mid}	C_{low}	S
SLR	1.01(0.06)	1.02(0.06)	1.02(0.05)	1.03(0.05)
SWR	1.00(0.02)	1.00(0.02)	1.00(0.02)	1.01(0.02)
COM_{in} (cm)	2.63 (0.75)	2.70 (0.80)	2.76 (0.70)	2.74 (0.61)
COM_{out} (cm)	-1.95 (0.75) *, †	-1.87 (0.67) *, †	-1.69 (0.62)	-1.52 (0.58)

Conclusions

This study shows that visual curved path stimuli in low-immersion VR with a fixed-speed and single-belt treadmill shifts the medial-lateral COM inward on highly curved paths. There were no significant changes in step length and swing time ratios.

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References

[1] Courtine G and Schieppati M. (2003). *Eur J Neurosci*, 18: 177-190.
[2] Salinas M.M. et al. (2017). *Gait Posture*, 57: 15-20.
[3] Leeder T et al. (2019). *Aging Clin Exp Res*, 31(8): 1077-1086