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OLDER ADULT FRONTAL PLANE ANGULAR MOMENTUM AND LATERAL DISTANCE DURING 90 DEGREE TURNS WHILE WALKING

Zahava M Hirsch (1), Mitchell Tillman (1), Jun M Liu (1), Janine Molino (2,3), Antonia M Zaferiou (1)

(1) Department of Biomedical Engineering, Stevens Institute of Technology, Hoboken, NJ, USA
(2) Department of Orthopedics, Warren Alpert Medical School of Brown University, Providence RI, USA
(3) Biostatistics, Epidemiology, Research Design and Informatics (BERDI), Rhode Island Hospital, Providence, RI, USA

INTRODUCTION

Falls are a leading cause of fatal and non-fatal injuries in older adults in the U.S[1]. Up to half of all walking steps taken daily are part of turns[2], and falls during turns were found to be 7.9 times more likely to result in a hip fracture[3]. This study focuses on two frontal plane balance metrics, as the ability to control balance stability in the frontal plane is important when it comes to fall mitigation[4]. The first is frontal plane angular momentum (Hf), the measure of the rotational motion of the body around the whole-body center of mass. Older adults tend to have larger Hf ranges from larger extrema values, during straight-line gait than do younger adults[5,6]. Larger Hf range has been associated with less ability to control balance and a greater risk of falls[7,8]. Hf range has not yet been explored in older adults during turns. The second metric is lateral distance (LD), the frontal plane distance between the whole-body center of mass location to the closest lateral edge of the base of support[9]. Previous research with younger adults found that LD minima tend to be smaller during turns as compared to straight-line gait[10]. This indicates that turning introduces more complex balance states; however, LD during turns has not yet been explored with older adults.

Turning takes place in a variety of contexts in day-to-day life. This study looks at 90˚ turns in two contexts: pre-planned turns, where one can prepare in advance for the turn, and late-cued turns, where there is limited preparation leading up to the turn. Late-cued turns can pose increased challenges and risk of falling[11]. Based on previous research with young adults, we hypothesize that with Hf, older adults will have 1) larger range of Hf during both pre-planned and late-cued turns as compared to straight-line gait, and 2) larger range of Hf during late-cued turns as compared to pre-planned turns. With LD, we hypothesize that older adults will have 3) smaller minima of LD during pre-planned and late-cued turns as compared to straight-line gait, and 4) smaller minima of LD during pre-planned turns as compared to late-cued turns.

METHODS

16 healthy older adults (14 female; age 73 ± 4.93 years; mass 70.8 ± 11.5 kg; height 1.63 ± .078 m) provided informed consent in accordance with the IRB. Participants passed clinical and cognitive assessments. A 13-segment whole-body kinematic model[12] was built using optical motion capture data (250 fps; OptiTrack, USA). A grocery store aisle intersection was simulated with a taped T-shaped walkway that was 0.915 m wide, including a 10 m straight-way with a 90˚ turn in the center leading to a 5 m aisle. Three tasks were performed 10-14 times in an order of increased difficulty as a safety precaution. First, participants walked straight for 10 m. Next, they performed 90˚ pre-planned left turns. Finally, they performed 90˚ late-cued left turns visually cued by a display screen at the end of the 5 m aisle (mixed with 50% chance of a catch trial, in which no turn was performed). Of the 16 participants, eight did not complete late-cued turns due to lack of time. A physical therapist followed closely behind the participants during each task for standby assistance. Hf about the center of mass was normalized to a dimensionless form[5]. LD was calculated as the distance from the center of mass to the closest lateral edge of the base of support (mediolateral was defined by the frontal plane of the pelvis). LD is negative when the center of mass passes laterally to the lateral edge of the foot. Hf range and LD minima were found during steady-state straight-line gait, and during the turn phases defined by a pelvis rotation threshold. Differences in HF range and LD minima across straight-line gait and turning conditions were examined using linear mixed models that included random intercepts for study participants, random slopes for trial number nested within study task and study participants, and fixed effects for study task. An adjusted p-value < 0.05 was used to determine statistical significance.

RESULTS

Hf range: Group level analysis show that Hf range was smaller during straight-line gait than pre-planned or late-cued turns; but there

was no significant difference between Hf range during pre-planned vs late-cued turns [**Fig. 1A**]. Participant-specific analyses revealed that not all participants followed the group-level statistical findings, with some demonstrating the opposite behavior from the group-level findings [**Fig. 2A**]. LD minima: Group level analysis show that LD minima were larger during straight-line gait than both pre-planned and late-cued turns; and larger during late-cued turns than pre-planned turns [**Fig. 1B**]. Participant-specific analysis revealed that not all participants followed the group trend, but no participant statistically demonstrated the opposite behavior [**Fig. 2B**].

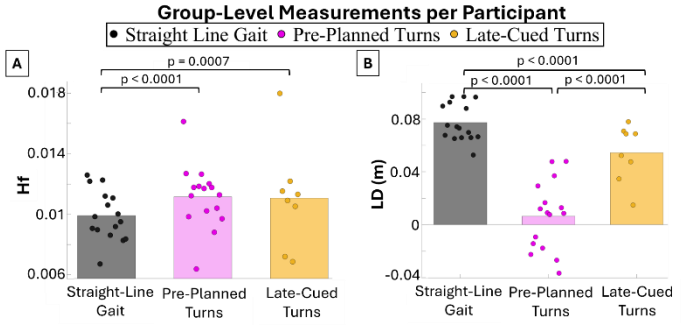

Figure 1: Group-level **A)** Hf range and **B)** LD minima. Each participant's averaged Hf range and LD min value across trials per task indicated by dots. Group-level average per task indicated by bars.

DISCUSSION

Hf range findings: Our hypotheses were partially supported, as the group trend demonstrated smaller Hf range during straight-line gait than pre-planned or late-cued turns. However, there was no difference in Hf range between pre-planned and late-cued turns, which did not support our hypothesis. Most older adults followed these group trends. However, some older adults used smaller Hf range during late-cued turns than straight-line gait (participants three and seven) or pre-planned turns (participant eight), which was an unexpected result based on what was observed with younger adults performing the same tasks[10]. Additionally, participant 13 used a smaller Hf range during pre-planned turns than straight-line gait. Larger Hf range has been associated with less ability to control balance and a greater risk of falls. However, most prior research looked at older adult balance during straight-line gait. In contrast, these results suggest that larger Hf range during turns may indicate a greater *ability* to successfully navigate more complex balance tasks such as unexpected turns, while smaller Hf range may indicate a protective strategy with older adults during these tasks. LD minima findings: Our hypotheses were supported, as the group trend demonstrated larger LD minima during straight-line gait, followed by late-cued turns, and the smallest (most negative) LD minima during pre-planned turns. All eight participants who performed late-cued turns had at least one negative LD minima during their pre-planned turns. However, only five of these participants had instances of negative LD minima during late-cued turns, and of these, four had fewer instances of negative LD during late-cued turns than pre-planned turns. More challenging turns may lead to more protective and varied stepping and balance strategies, resulting in more positive LD minima.

These results suggest a more careful interpretation of Hf range and LD minima when it comes to assessing balance control *abilities*. Trends that have been explained as indicative of poor balance control during simpler tasks could instead be indicating viable balance strategies used by both healthy young and healthy older adults during turns.

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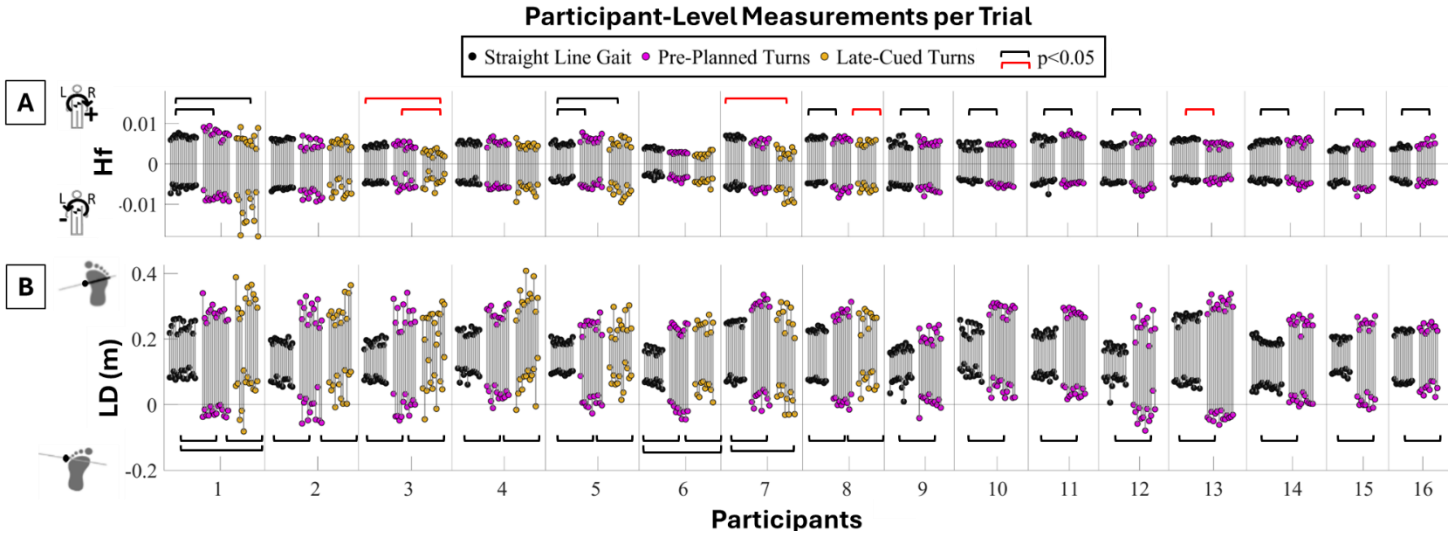

Figure 2: Participant-level statistical results. Data points represent min, max and range for A) Hf and B) LD for all trials and participants. Statistical analysis for Hf indicates changes in range, statistical significance for LD indicates changes in minima. Black bars indicate significance that align with the group trend, red bars indicate significance that goes against the group trend.