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Abstract

Background: Healthy young adults typically exhibit a progressive 'top-down' reorientation of body segments (i.e., head, trunk, then pelvis) during turning. In contrast, this behaviour is less evident in older adults at risk of falling, who often reduce angular displacement between body segments during turns. The potential functional and psychological contributors to this so-called 'en-bloc' turning strategy are not yet understood.

Research question: Are there associations between concern about falling and variables representing en-bloc turning (i.e., increased coupling between body segments)?

Methods: We assessed 21 older adults while turning during an adaptive walking task. We collected data from markers forming the head, trunk, and pelvis segments, while gait velocity throughout the turn was calculated from a sternum marker. We correlated several variables with concern about falling alone, as well as while controlling for functional balance ability.

Results: Correlation analyses revealed that concern about falling was related to en-bloc turning strategies and slower gait velocity throughout the turn, when analysed independently of functional balance. When controlling for balance ability, en-bloc turning strategies between the head and trunk, as well as the head and pelvis, remained significantly associated with concern about falling.

Significance: Findings offer an insight into the potential role that psychological characteristics may have in determining older adults' turning behaviour and associated risk of falling.

Keywords

Falls efficacy; fear of falling; en-bloc; fall-risk; segmental coupling.

1. Introduction

Falls by older adults commonly occur during turning [1]. Such falls may arise, in part, due to rigid 'en-bloc' turning strategies, which could reduce reactive capabilities to perturbation [2]. We examine the contributions of functional balance and psychological factors when using such strategies.

The mechanics of turning typically follow a progressive top-down 'unfolding' pattern; beginning with the head, with subsequent rotational adaptations to the trunk then feet [3,4]. When turning 360° on the spot, older adults who subsequently fall display smaller angular differences from head to trunk and trunk to pelvis [2]. It remains unclear if this en-bloc strategy is associated with physiological constraints limiting decoupling between body segments (i.e., functional balance ability) or perceived balance ability (i.e., concern about falling).

Psychological factors, namely concern about falling, contribute to the use of cautious balance strategies [5]. It is reported that lower levels of balance confidence are correlated with cautious turning behaviour [4]. While researchers propose a link between concern about falling and en-bloc turning in older adults [6], the association has not been examined empirically. Initially, we explored how concerns about falling relate to turning behaviour, *independent* of functional balance. We hypothesised that en-bloc turning strategies are associated with greater concerns about falling. These associations were predicted to remain when controlling for functional balance.

2. Methods

2.1. Participants

Altogether, 21 older adults (5 M/16 F; 73.95 ± 7.05 years) participated. Participants with neurological impairment, musculoskeletal diagnoses, or prescribed medication for anxiety or dizziness were excluded. Informed consent and ethical approval were obtained. See Table 1 for participant characteristics.

TABLE 1

2.2. Apparatus

We collected three-dimensional coordinates from reflective markers located on each temple (head), the acromio-clavicular joint of each shoulder (trunk), the xiphoid process of the sternum, and the anterior superior iliac spine (ASIS) of each hip (pelvis) (Fig. 1a) using an eight-camera Motion Analysis system (Santa Rosa, California, USA) sampling at 150 Hz.

2.3. Procedure

Participants walked along two nonlinear paths (Fig. 1b) comprising 11 white wooden blocks, with all other blocks painted black in a 6 × 5 grid. Each wooden block measured 0.4m × 0.4m, with a height of 0.3m. Participants walked (and turned) at a self-selected speed along the white path without contacting the black blocks. Two blocks per pattern were marked with crosses that acted as stepping targets to normalise foot placement with reference to the intended walking path. Only turns related to the first of these stepping targets were analysed (Fig. 1b).

Participants walked from behind a screen, up a ramp (1.2m in length), along the white path and down a corresponding ramp at the walkway end. A total of 12 trials (4 blocks of 3 walks) were completed. Walkway patterns were randomized.

FIGURE 1

2.4. Data Processing

We applied a low-pass (Butterworth) filter with a cut-off frequency of 5 Hz to all kinematic data. We analysed data between 0.55m prior to, and 0.4m to the lateral side (dependent on turn direction) of, the intersection point (Fig. 1b). The angular displacement profiles of each body segment (head, trunk, and pelvis) in the yaw plane were calculated, relative to the horizontal axis (Fig. 1b). First- (velocity), second- (acceleration) and third- (jerk) derivatives of the angular data were calculated to define turn onset/offset. As per previous research [7], turn onset was defined as the point of a zero-crossing in the jerk profile and a corresponding negative to positive reversal in the acceleration profile prior to a continuous and sustained angular displacement above zero degrees. Turn offset was the point the angular velocity profile returned to, and remained below, zero. We removed trials containing instances of 'spin turns' [8], which were identified by visually inspecting kinematic data.

2.5. Measures

2.5.1. Maximum angular difference between segments

The absolute maximum difference (degrees) when one segment's angular trace was subtracted from another was calculated from head to trunk, trunk to pelvis, and head to pelvis.

2.5.2. Gait velocity through the turn

We calculated the instantaneous velocity (m/sec) of the sternum from the first derivative of the sternum marker. The mean velocity (m/sec) was calculated between turn onset/offset.

2.5.3. Concern about falling and functional balance

We employed the Falls Efficacy Scale-International (FES-I) [9] to assess concern about falling and the Berg Balance Scale (BBS) [10] to evaluate functional balance.

2.6 Statistical Analysis

We conducted correlation analyses to determine the relationship between concern about falling (FES-I) and turning measures. As the maximum angular difference between head and trunk segments violated parametric assumptions, Spearman's correlational analyses were employed to examine associations with this variable. Pearson's correlations were conducted for all other variables. Partial correlation analyses were conducted to assess associations between FES-I and turning measures, when controlling for BBS. Non-parametric correlations were used as BBS scores violated parametric assumptions. We report one-tailed *p*-values.

3. Results

Higher levels of concern about falling (FES-I) were associated with reduced maximum angular difference between the head and trunk ($rs = -.45$, $p = .02$) and head and pelvis ($r = -.65$, $p = .001$). Higher levels of concern were associated with lower velocity through the turn ($r = -.63$, $p = .001$). When controlling for BBS, there remained significant associations between FES-I and maximum angular difference for the head and trunk ($rs = -.38$, $p = .049$) and head and pelvis ($rs = -.39$, $p = .043$). We present the results in Table 2.

TABLE 2

4. Discussion

We examined the relationships between concern about falling, functional balance, and turning characteristics in older adults performing an adaptive walking task. The overall turn velocity was not associated with concern about falling, when controlling for functional balance, while decoupling between the head and trunk/pelvis was significantly correlated. The absence of any significant relationship between concern about falling and trunk-pelvis decoupling indicates that head-pelvis decoupling is largely independent of the decoupling between head and trunk in concerned participants. Such rigidity between upper-body segments indicates self-preservation behaviours to minimise instability. Our findings support interpretations linking turning caution with reduced balance confidence in older adults [4].

Concern about falling is associated with increases in self-reported conscious processing of gait [11]. The concept of freezing degrees of freedom, commonly observed during postural threat in older adults, is thought to arise through a re-investment in conscious control [12]. Concern about falling leads to a decrease in fixations and an increase in fixation durations during adaptive gait, implying that these behaviours help to stabilise the head and visual scene [12]. Similarly, older adults when concerned adopt a 'head stabilisation' strategy during walking, reducing the amplitude of head oscillations [13]. We suggest current findings indicate that these stabilisation strategies can be extended to the concept of head-trunk decoupling during self-paced turning.

In non-concerned individuals, increased angular displacement between head and trunk permits a decoupling of the egocentric frame of reference for both segments (i.e., the head, and corresponding visual input, assumes a new direction, while the trunk and pelvis remain aligned in the previous heading direction) [14,15]. Our results suggest that en-bloc coupling between head and trunk may represent an attempt to reduce these demands in older adults fearful of falling. Further work is necessary to scrutinise the causal nature of these relationships and the impact of changes in attentional and cognitive factors (e.g., conscious movement processing) on gait stability and fall-risk.

4.1 Limitations

While the pre-defined path used in the present research potentially constrained participants' movement, it was deemed appropriate to maintain experimental control. The paths were also designed to provide an indication of real-world pre-defined turning (e.g., turning to enter a doorway from a hall). Also, differences in body segment co-ordination could have been calculated by an alternative method (e.g., delay in onset of reorientation [16]). Furthermore, spin turns were identified and removed by visually inspecting kinematic data, rather than through computational means.

4.2 Conclusions

This research demonstrates associations between concern about falling and en-bloc turning strategies in older adults when controlling for functional balance, thereby, offering insight into the role psychological factors may play in the risk of falling in older adults. Future work should look to evaluate the associations reported here in a larger sample, as well as during experimentally-manipulated conditions of fear/concern about falling.

Declaration of Competing Interest

None.

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