Stair fall risk profiling using a novel multivariate approach

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Summary

Stair falls are a major problem for older people. The present study: a) applied a novel multivariate approach to characterize the overall stair behaviour while ascending and descending stairs and b) investigated whether the selected stepping behaviour was maintained irrespective of step dimensions. K-means clustering was used to characterize the overall behaviour of 70 older (>65 y) and 25 younger adults based on biomechanically risky and conservative strategies. Age and fall history were not unique factors of the clusters, highlighting the limitations of conventional comparisons. Moreover, changing the staircase to 'easier' step dimensions tended to have no effect on the selected stepping behaviour. Further research should implement this multivariate method using a longitudinal approach to identify the behaviours that can differentiate those who will experience a stair fall from those who will not.

Introduction

Stair negotiation is amongst the most challenging daily tasks for older adults, often resulting in falls [1]. Stair fall risk has typically been assessed by quantifying mean differences between subject groups for single biomechanical parameters indicative of risk. This approach overlooks that certain individuals within a group may also display more conservative strategies, which could compensate for the risky behaviours. Moreover, it remains unknown whether the conclusions that would be drawn regarding stair fall risk from the step dimensions examined, would still apply if the demand of the stair-negotiating task changes by implementing different step dimensions. The aim of this study was to characterise the stair negotiation behaviour based on multiple factors that include biomechanically risky and conservative strategies using a clustering approach. Furthermore, we investigated whether the identified clusters maintained their stepping strategy when the task difficulty changes by means of step dimensions.

Methods

Twenty-five younger (24.5±3.3 y) and 70 older adults (71.1±4.1 y), with (27) and without (43) a history of falling, ascended and descended a custom-built instrumented (four force plates embedded in the lower steps) seven-step staircase (staircase 1: rise 200 mm, going 250 mm) at their self-selected pace in a step-over manner without using the handrails. The older adults additionally ascended and descended the staircase set in an 'easier' configuration (staircase 2: rise 150 mm, going 280 mm) in a similar manner. Measured biomechanical parameters for both staircases included: 1) foot clearance, reflecting trip-induced fall risk; 2) foot contact area and 3)

required coefficient of friction, both reflecting slip-induced fall risk; 4) centre of mass angular acceleration (only for stair descent), reflecting the ability to control the body against gravity as it descends; 5) cadence, an increased speed could negatively modify the parameters mentioned before; 6) variance of the above parameters, more variance can indicate a person's inability to maintain a safe movement pattern. K-means clustering was performed to group individuals based on the overall biomechanical stair behaviour on each staircase for ascent and descent separately. The cluster profiles were calculated to examine differences between the compositions of the clusters. To correlate membership between the clusters for the two stair configurations a Cramer V index was calculated.

Results and Discussion

For staircase 1: five clusters during stair ascent and four clusters during descent were identified, all containing a mix of younger adults, older non-fallers and previous fallers. For the 'easier' staircase 2: three clusters were identified during stair ascent and descent, all containing older non-fallers and previous fallers. This important finding cannot be captured by conventional comparative approaches, which differentiate subject groups based on age and fall-history and compare mean values. The cluster profiles revealed that clusters differed from the overall mean by showing: a) solely risky strategies; b) solely conservative strategies; c) a combination of risky and conservative strategies or d) no particularly risky or conservative strategies. The change to 'easier' step dimensions did not alter membership of the different clusters, indicated by a moderate to strong relationship for ascent (Cramer V: 0.364) and descent (Cramer V: 0.332).

Conclusions

The clusters were not unique to old age and a previous fall, highlighting the limited predictive power of conventional comparisons of individual parameters. Furthermore, the stair negotiation strategies of the different clusters in stair ascent and descent were maintained irrespective of step dimensions. This could indicate that 1) manipulating the demand of the task within the range of step dimensions studied does not affect the underpinning mechanism of a potential stair fall and 2) detection of at risk individuals is possible using stairs within the range of the dimensions studied. The next step is to grade the cluster profiles in terms of stair fall risk. To reach this important milestone, we are currently linking the clusters with stair falls documented over a follow-up period.

References

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