Increased double support variability in elderly female fallers with vestibular asymmetry

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Abstract

There is a broad consensus on the coupling of deteriorating gait and vestibular asymmetry, which has proved predictive of falls in the elderly. To date, research on this coupling remains inconclusive and has not focused specifically on fallers. In the present study, differences in gait variability were examined in a population of elderly females with fall-related wrist fractures, divided into samples with positive ($N = 28$, 73 ± 9 years) and negative head-shaking tests ($N = 6$, 67 ± 9 years). Swing, stance, and double support time variability were measured in preferred speed walking using GAITRite® and statistically evaluated in multivariate analysis of covariance with age as covariate. Results showed overall greater gait variability for the positive nystagmus group ($p = 0.03$) despite non-significant adjustment of the covariate ($p = 0.18$). In post-hoc analysis, the effect on variability in double support time emerged as a significant and large contributor to this difference ($p = 0.009$, $\eta_p^2 = 0.20$). Conversely, the ability of swing and stance time variability to discriminate between groups was both non-significant and small ($p = 0.25$, $\eta_p^2 = 0.04$ and $p = 0.34$, $\eta_p^2 = 0.03$ respectively). We believe that the increased variability might stem from a strategic use of double support to re-stabilize from balance perturbations during gait. To some extent, these results diverge from previous findings and need to be reassessed in future studies.

Keywords: Vestibular asymmetry, double support, head-shaking nystagmus, gait analysis, gait variability

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1. Introduction

Dizziness is common in the elderly [1] and is correlated to an increased risk of falling [2] in proportion to its severity [3] and though there is a broad consensus on its coupling to deteriorating gait the mechanism is not yet fully known. Although the causes for dizziness vary, vestibular asymmetry is a major contributor and has been selectively reported in both fallers [4, 5] and healthy people [6].

The scientific body on the effects of vestibular asymmetry on gait has been arguably scant and findings have diverged about the various aspects of the issue – one confounding issue being the wide variability in gait patterns and parameters. In spite of this, some insight have been given in research on gait variability. Indeed, evidence of alterations in both stance time (StT) and swing time (SwT) variability have been displayed in those with spinocerebellar degeneration [7], olivopontocerebellar atrophy [8] vestibular schwannomas [9], acoustic neuromas [10], both peripheral and central lesions [11] as well as vertigo [12]. Likewise, these results have been reproduced for double support time (DST) variability in some studies [8, 10–12], yet contrastingly not elsewhere [7]. The case for variability as a parameter in gait analysis is not in fact novel – recognition of its adequacy has before been given in studies on both aging [13] and fall-risk [14].

To date, methods in the present field of research have often involved comparisons to otherwise healthy individuals where there is cause to believe that confounding factors may be present. Hence, we intended to effectively discriminate between the effects of vestibular asymmetry and other confounding variables by drawing our sample from a population of fallers.

The aim of this study was to assess variability in DST, SwT and StT in female elderly fallers with and without vestibular asymmetry.

2. Method

2.1. Participants

The study was conducted out of a primary care setting in Sweden as part of a larger study on vestibular rehabilitation [15]. The sampling process is presented in Figure 1. We recruited a sample of people who had recently suffered fall-related wrist fractures if they were older than 50 years of age, and by the recruiter deemed capable of undertaking the intervention regimen. In total, 84 people were enrolled.

A large number of these ($N = 40$) did not participate in gait measurements due to a technical failure of the walkway unit. In the head-shaking tests, five participants were excluded: One, who opted out; one, who suffered neck pain at the time; two, for whom test results could not be unequivocally determined; and one more, owing to a technical mishap. Moreover, one person's gait data failed to export properly, also prompting exclusion. Finally, past reports of gender–age interactions on gait parameters [16] warranted omission of males ($N = 4$). The remaining participants ($N = 34$) were divided into two groups based on the results of the head-shaking test: positive (HSP, $N = 28$) or negative (HSN, $N = 6$) for nystagmus.

The weight of the HSP group ($mean = 67 \pm 8$ kg) was similar to that of the HSN group ($mean = 66 \pm 10$ kg). In terms of age, however, the HSP group was somewhat older ($mean = 73 \pm 9$ years) and shorter ($mean = 163 \pm 6$ cm) than the HSN group ($mean = 67 \pm 9$ years and $mean = 167 \pm 9$ cm respectively).

2.2. Vestibular asymmetry

The head-shaking test has been used widely in the diagnosis of vestibular asymmetry, yet has faced some criticism for poor sensitivity. Dros et al. pooled estimates for the test, reporting 45 % sensitivity and 82 % specificity for peripheral and central vestibular dysfunction [17]. Nevertheless, the test has shown success in predicting falls in cases with unilateral peripheral vestibulopathy [18] and multi-sensory dizziness [19].

The test was conducted in the supine position by rotating the head in the transverse plane at 2 Hz for approximately 15 s, using frenzel goggles to record the result. An experienced clinical physician – blinded to the patients' diagnoses – conducted and assessed the results, which were considered positive if nystagmus for at least three fast phase beats could be detected, as well as their direction determined. Both horizontal and vertical nystagmus was included.

2.3. Gait analysis

The GAITRite® system was utilized to collect gait analysis data. GAITRite® is designed to measure a wide range of gait variables and has shown strong concurrent validity [20, 21] and test–retest reliability [20–22]. Resulting from the aforementioned mid-stage failure of the first walkway, two separate units were used. These differed somewhat in regards to their respective active areas: 4.88 m and 6.10 m. Accordingly, two different versions of the GAITRite Gold® software were also used: 3.8 and 4.5 respectively.

The patients were instructed to begin their walk 2 m prior to, and continue on 2 m past the walkway at their preferred speed. They were barefooted and none required walking aids. Depending on walkway length, two or at most three passes were required to ensure sufficient stride counts. Three parameters were extracted from the GAITRite data: DST, StT and SwT variability. These measures, in line with similar studies [8–12, 23], were converted into coefficients of variation (CV) in order to repress statistical between–subjects noise.

2.4. Statistical analysis

A one-way independent multivariate analysis of covariance (MANCOVA) was conducted on the three dependent variables (DVs), with group membership (HSN or HSP) chosen as independent variable. Similarly to a previous design by Angunsri et al. [7], age was used as a covariate – its effect on gait having been established before [23–25] and shown to correlate with gait variability [26] independently of height and weight [13, 16].

In post-hoc analysis of the MANCOVA, a Roy–Bargman step-down procedure [27] was adopted in order to investigate univariate effects whilst maintaining control over Type I error rate. In lieu of theoretical grounds upon which to assign priority of DVs, the order of the step-down model was derived from the relative contribution, in terms of variance, of each DV. Following suggestions by Wilkinson [28], this was accomplished by assessing model variance through successive MANCOVAs in which DVs were excluded one by one. Bonferroni corrections were made to each and every level of step-down and univariate analyses to accommodate for the family-wise error rate, set at $\alpha = 0.05$ for statistical significance.

In order to ensure that the people were excluded from the gait tests did not markedly differ from those who were not, we compared those two groups on age, gender, height, and weight; there were no significant differences ($p > 0.05$) between the groups.

In light of reports of between-leg differences in those with vestibular asymmetry [9], a preliminary analysis was conducted selectively for those with side-beating nystagmus within the HSP group. In this analysis, gait data of left and right legs were allocated to either of two groups, namely *affected* or *control*, corresponding to direction of the nystagmus. No significant differences were found between these two groups and subsequently means of both legs were used throughout. Moreover, owing to the usage of two separate walkways, another analysis was carried out between gait data from the second and first units including only the people with positive head-shaking tests, again showing no significant difference.

Statistical analyses were conducted in SPSS (22.0.0.0) and R (3.0.3).

2.5. Ethical considerations

Written informed consent was attained for all participants and the study was approved by the Regional Ethical Review Board in Lund (no. 585/2008).

3. Results

Multivariate analysis showed a significant difference between the HSP and HSN groups on the combined DVs: DST, SwT and StT variability $F(3, 29) = 3.41$, $p = 0.03$, suggesting that the HSP group did in fact display greater gait variability than the HSN group. The effect of the covariate, age, on the composite of DVs, did however not significantly adjust marginals means $F(3, 29) = 1.78$, $p = 0.18$.

Separately for the result of the head-shaking test (positive or negative) and the covariate (age), post-hoc univariate and Roy–Bargmann step-down analyses were conducted on the three DVs. Priority in step-down analyses was given to DST, followed by SwT and StT variability. See Table 1 for these results and Figure 2 for their corresponding marginal means adjusted for age.

The covariate showed a non-significant and negligible adjustment effect on DST variability $F(1, 31) = 0.04$, $p = 0.84$, $\eta_p^2 = 0.00$ but, in contrast, significantly and moderately adjusted for variability in SwT $F(1, 30) = 4.60$, $p =$

0.04, $\eta_p^2 = 0.13$. Covariate adjustment for StT variability was non-significant $F(1, 29) = 0.74$, $p = 0.40$ and small $\eta_p^2 = 0.03$.

Variability in DST was greater for the HSP group ($mean = 0.091$, $SE = 0.004$) compared to the HSN group ($mean = 0.061$, $SE = 0.010$). In addition to being significant $F(1, 31) = 7.85$, $p = 0.009$, this difference also represented a medium to large effect $\eta_p^2 = 0.20$. SwT variability for the HSP group ($mean = 0.044$, $SE = 0.003$) was comparable to that of the HSN group ($mean = 0.047$, $SE = 0.004$) and differed neither significantly $F(1, 30) = 1.38$, $p = 0.25$ nor in terms of effect size $\eta_p^2 = 0.04$. Similarly for StT variability, adjusted means varied only marginally between the HSP ($mean = 0.037$, $SE = 0.002$) and HSN group ($mean = 0.033$, $SE = 0.006$). Moreover, this difference proved non-significant $F(1, 29) = 0.93$, $p = 0.34$ and small in terms of effect-size $\eta_p^2 = 0.03$.

In summary, overall gait variability was greater in females with head-shaking nystagmus compared to those without. Double support time (DST) variability contributed both significantly and considerably to this difference, whilst the ability of both stance time (StT) and swing time (SwT) variability to distinguish between groups was non-significant and negligible.

4. Discussion

There was an overall increase in gait variability in those with positive head-shaking tests, which adheres to the wide consensus that vestibular asymmetry alters gait patterns. DST variability emerged as a significant and large contributor to this difference. However, there was no significant difference in StT or SwT variability between the groups. Taken together, we present divergent findings primarily concerning SwT, which has previously been reported to have good sensitivity to indicate vestibular hypofunction [12].

In regards to the interpretation of the results, Callisaya et al. have suggested that double support might be used by those with poor balance to compensate for deviations in center of mass [13]. In a similar vein Wuehr et al. proposed, in their study on neuropathology, that double support might be used as a way of re-stabilizing [29]. Certainly, the double support phase comes with the added benefit of input from proprioceptors and mechanoreceptors of, not just one, but two feet. However, assuming that variability in double support represents a method to stabilize exceeds the extent of the findings of this study. We can only conclude a variation in gait strategy. Nevertheless, it is known that patients with vestibular loss compensate with their remaining sensory input [30], and it would be interesting to see if that compensation might bear semblance to the increased variability in double support that we have found in this study.

The results of this study need to be reassessed in future research, particularly since they deviate somewhat from earlier findings. One option would be to study gait variability in a repeated measures design for patients before and after undertaking treatment for vestibular asymmetry. Such a study might benefit from also looking at gait parameters in terms of absolutes, which too remain to be thoroughly researched in fallers with and without vestibular asymmetry.

4.1. Strengths and limitations

This study was constrained to a sample of elderly female fallers with wrist fractures, who differed only on the condition of having vestibular asymmetry or not. Participants were recruited in a clinical setting after having suffered falls and did not present any concerns for selection bias. It should thus be relatively safe to assume homogeneity in the sample and, consequently, reduced noise. A possible caveat, however, is whether any underlying causes for vestibular dysfunction were present, which in turn could make any inferences unreliable.

The distribution of positive and negative head-shaking tests in our study group closely matched that of another similar study [5], reinforcing the argument that our sample was in fact representative of the population. Moreover, considerable care was taken in scrutinizing the data for its associated statistical assumptions in order to facilitate generalizability. In spite of this, consideration should be taken to the specificity of the studied population, that is, female elderly fallers. On account of this, the extent to which the present findings can be extended remains to be expanded upon.

In addition to sample sizes being unequal, the negative head-shaking test group was particularly small ($N = 6$). While worthy of concern in a statistical context, the high specificity of the head-shaking test [17] offers some assurance in regards to the integrity of the sample. On the other end, however, the low sensitivity of the test might warrant more concern to the effect that possible false positives contamination of the positive head-shaking group might have occurred.

4.2. Conclusions

Elderly female fallers with wrist fractures who tested positive for vestibular asymmetry exhibited greater gait variability in preferred speed walking compared to those who tested negative. Out of the examined gait parameters, only the effect on double support time variability proved significant, explaining a medium to large portion of between–groups variance. The effects on variability in swing and stance time, on the other hand, did not significantly nor substantially differentiate between groups. We suggest that the increased variability might stem from a strategic use of double support to re-stabilize from balance perturbations during the gait cycle.

4.3. Conflict of interest statement

To the best of our knowledge, no conflict of interest influenced the work on this paper.

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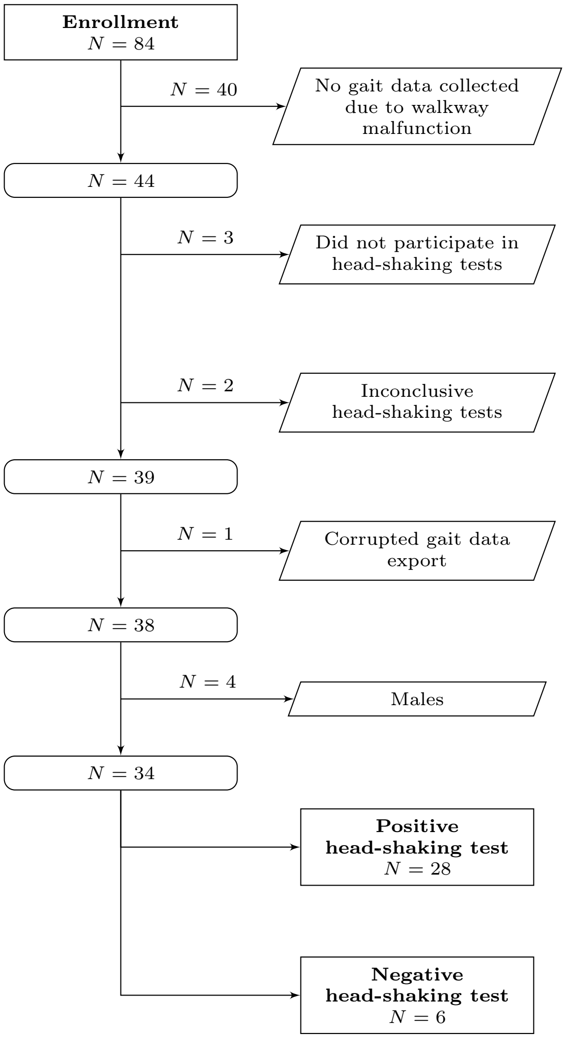

Figure 1: Flowchart over the selection process from the initial 84 female fallers to the final 28 subjects with positive head-shaking tests and 6 subjects with negative head-shaking tests.

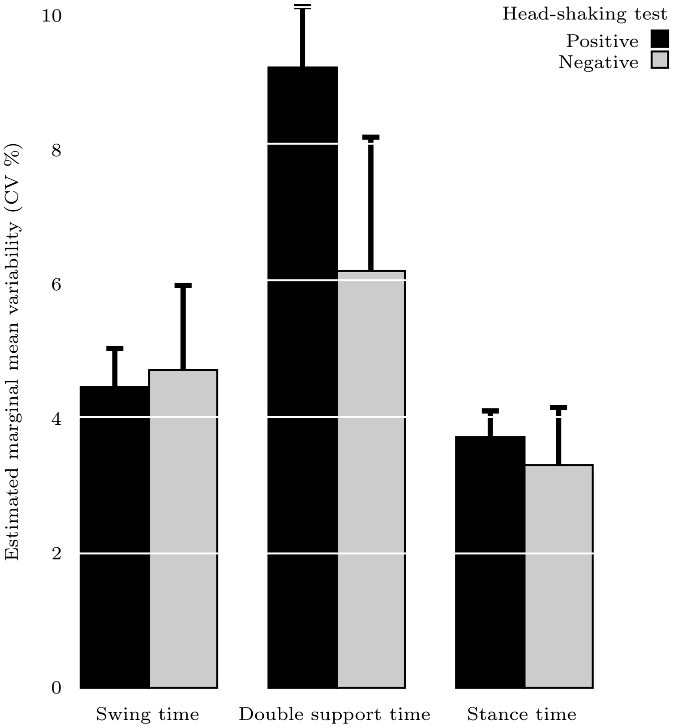

Figure 2: Estimates of marginal mean variability, expressed as the coefficient of variation in percent (CV %) for the three dependent variables. Values are adjusted for the covariate ($age = 72$ years). Error bars represent 95 % confidence intervals. Black bars represent the positive head-shaking test group and gray bars represent the negative head-shaking test group.

Table 1: Univariate and Roy-Bargmann step-down F-tests of the dependent variables (double support, swing and stance time) are presented for the covariate (age) and the result of the head-shaking test, positive or negative.

								95 % C
Idependent variable	Dependent variable	Univariate F	df	Step-down F	df	α	η_p^2	Lower
Head-shaking test result	Double support time CV	7.85[a]	1/31	7.85[**]	1/31	0.02	0.20	0.0001
	Swing time CV	0.14	1/31	1.38	1/30	0.02	0.04	0.0000
	Stance time CV	0.80	1/31	0.93	1/29	0.01	0.03	0.0000
Age (covariate)	Double support time CV	0.04	1/31	0.04	1/31	0.02	0.00	0.0000
	Swing time CV	4.55[b]	1/31	4.60[*]	1/30	0.02	0.13	0.0000
	Stance time CV	0.00	1/31	0.74	1/29	0.01	0.03	0.0000

[a] Significance level cannot be evaluated but would reach $p = 0.009$ in univariate context

[b] Significance level cannot be evaluated but would reach $p = 0.04$ in univariate context

[*] $p = 0.04$

[**] $p = 0.009$