Vestibular asymmetry increases double support time variability in a counter-balanced study on elderly fallers

Johan Larsson[a,1,*], Michael Miller[b], Eva Ekvall Hansson[a,b]

[a]*Department of Clinical Sciences, Family Medicine, Lund University, Jan Waldenströms gata 35, 205 02 Malmö, Sweden*
[b]*Department of Health Sciences, Lund University, P.O. Box 157, 221 00 Lund, Sweden*

Abstract

Vestibular asymmetry is a common cause of dizziness in the elderly, for whom it precipitates the risk of falling. Previous studies have shown that those with vestibular asymmetry displayed an altered variability in double support time (DST) compared to controls. However, swing time (SwT) variability findings are conflicting. In this study, we investigated if vestibular asymmetry might be causally connected to increased DST variability. We studied a group of eight elderly fallers with wrist fractures across three months, during which time four of them regained vestibular symmetry while four others developed an asymmetry. We evaluated the variability of DST and SwT, both when the participants suffered from vestibular asymmetry and when they did not. On average, variability in DST was significantly greater by 2.38 %CV (coefficient of variation) when participants scored positive for vestibular asymmetry compared to when not, $t(5) = 4.39$, $p = 0.01$, $\xi = 1.67$. In contrast, SwT variability differed non-significantly by 0.44 %CV when participants had tested positive versus negative for vestibular asymmetry, $t(5) = -0.87$, $p = 0.39$, $\xi = -0.29$. As a possible rationale for our results, we propose that increased DST variability may be the result of a re-stabilization strategy. Further research on DST variability and its correlation to the duration of vestibular asymmetry is recommended.

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

---

Acknowledgments

The authors would like to thank Måns Magnusson for conducting the head-shaking tests.

*Corresponding author. Tel.: +46 730 353836
Email address: `johanlarsson@outlook.com` (Johan Larsson)
[1]Permanent address: S:t Petri Kyrkogata 13A, 222 21 Lund, Sweden

1. Background

The prevalence of dizziness increases with age; indeed, for those past 65, it is more common than not [1]. One major cause is vestibular asymmetry: an asynchronous firing of the vestibulo–ocular organs, which in turn is the consequence of a variety of diseases, such as vestibular neuronitis and Ménière's disease. The detrimental effects of vestibular asymmetry is many times severe—for the elderly, it precipitates the risk of falling [2].

Since falls occur predominantly during locomotion, many studies have aimed to establish how the gait of those with vestibular asymmetry compares to that of people with healthy vestibular function. That research, however, has frequently been marred on account of the confounders often present in people with vestibular diseases. In a previous study, we approached that limitation by investigating the gait of a relatively homogeneous sample of elderly female fallers with wrist fractures, finding increased double support time (DST), but not swing time (SwT), variability in those with vestibular asymmetry [3]. Increases in DST variability has been reported before, but has as such then coincided with greater variability also in SwT [4, 5], or been found selectively in SwT [6].

In the present study, we sought to investigate if vestibular asymmetry might be causally connected to increased DST variability. This required the experimental induction (or deduction) of vestibular asymmetry in our participants, which we achieved by studying a cohort across three months, during which time some regained vestibular symmetry while others developed an asymmetry. As far as we can tell, this is the first attempt to evaluate the effects of vestibular asymmetry within participants; moreover, we aimed to establish if our previous results could be significantly reflected in an altered study design. We hypothesized that variability in DST, but not SwT, would increase when participants suffered from vestibular asymmetry compared to when they did not.

2. Method

2.1. Participants

The study was conducted as part of a larger study on vestibular rehabilitation [7]. The sampling process is described in Figure 1. Eighty-five individuals, aged 50 or older, were recruited from a hospital ward in southern Sweden after having suffered radiologically confirmed fall-related wrist fractures. After being forwarded to a primary care clinic, they were randomly allocated to a control (n = 44) or intervention (n = 41) group, and respectively undertook either conventional care or a vestibular rehabilitation regimen (as detailed here [7]). Head-shaking tests (HST) and gait analysis were conducted at baseline and three months later at follow-up.

Fourteen persons opted to drop out from the intervention, as did three controls. Additionally, 34 participants were excluded because the walkway unit malfunctioned. Moreover, two who declined the HST and one for whom the test was inconclusive were omitted. For the remaining participants, the results of the HSTs were compared between baseline and follow-up. Those with identical results were excluded (n = 23).

Eight persons remained, four with a positive to negative change, and four with a negative to positive change on the HST. In the former group, three came from the intervention group and one from the control group, while in the latter group all of the participants came from the control group.

2.2. *Vestibular asymmetry*

Vestibular asymmetry was diagnosed with the HST, which in pooled analyses has shown good specificity (82 %) but lackluster sensitivity (45 %) [8]. Nevertheless, the test has previously proved predictive of falls in people with multi-factorial dizziness [2].

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 tape the results. An experienced physician—blinded to the patients' diagnoses—conducted and assessed the tests, which were considered positive if nystagmus could be detected and its direction determined.

2.3. *Gait analysis*

A GAITRite® walkway (CIR systems Inc., New Jersey, USA) with an active area of 4.88 m was used to collect gait data. Patients were instructed to start walking at their preferred speed 2 m before, and continue 2 m past the walkway, doing so in two or three passes. The variability of DST and SwT was expressed as the coefficient of variation in percent (%CV) in line with similar studies [4–6]. Following preliminary analysis we opted to use the means of the both legs.

2.4. *Subject characteristics*

Participant characteristics are presented in Table 1. Vibration tests revealed sensation deficits for two individuals (see Table 1).

2.5. *Statistical analysis*

Statistical significance was assessed by bootstrapped versions of Yuen's paired samples *t*-test [9]. Effect sizes are provided in Wilcox's explanatory measure of effect size, ξ—a robust analog to δ (Cohen's d). Bonferroni-corrections were applied to maintain a family-wise error rate at $\alpha = 0.05$. All analysis was conducted in R (3.1.3).

2.6. *Ethical considerations*

The study was approved by the Regional Ethics Review Board in Lund, Sweden (no. 585/2008). All participants gave written consent.

3. Results

Bonferroni-corrected 97.5 % confidence intervals, computed by the bootstrap-t method [9], are given inside brackets. Plots for the average variability for all the participants and conditions are given in Figure 2.

On average, variability in DST was significantly greater by 2.38 (0.61; 4.15) %CV when participants scored positive for vestibular asymmetry compared to when not, $t(5) = 4.39$, $p = 0.01$, $\xi = 1.67$.

In contrast, SwT variability differed non-significantly by −0.44 (−3.54; 2.66) %CV when participants had tested positive versus negative in the HST, $t(5) = -0.87$, $p = 0.39$, $\xi = -0.29$.

4. Discussion

Vestibular asymmetry lead to significant and, based on effect-sizes, large increases in DST variability. Contrastingly, we were not able to show any significant change in SwT.

These results support and reinforce those of our previous study [3]. In that study we were surprised to find an increase only in double support, given that these phases (swing and double support) are intertwined—velocity in the swing phase, for instance, inevitably carries over into the double support phase.

One possible explanation, however, may be that double-support is used as a re-stabilizing period [3, 10]. Indeed, people have been shown to adjust their gait, stride-to-stride, in order to maintain their chosen gait speed [11]. Furthermore, it is known that persons with vestibular disorders rely more on cutaneous sole proprioception [12] which is increased during DST. Taken together with the benefit of a wider base of support, this provides a rationale for the increase specifically in DST variability.

A limitation might be that at follow-up, one person's HST indicated perverted (downbeat) nystagmus, possibly suggesting a central disorder [13]. Perverted nystagmus also correlates with altered gait [14], though whether it does so differently from regular nystagmus is hitherto unknown. The groups were unevenly composed of participants from the intervention and the control group, which, together with the substantial attrition, might have introduced selection bias.

Our sample size was small ($n = 8$), which impairs our statistical analysis. The t-test, however, was designed for small sample sizes and has proved adequate in yet smaller samples than in our study [15]. Finally, we did not control for any possible confounders, refraining from doing so to avoid overfitting and losing statistical power.

In conclusion, we have been able to demonstrate that vestibular asymmetry leads to increased DST variability. Further research on DST variability and its correlation to the duration of vestibular asymmetry is recommended.

5. References

[1] S. A. de Moraes, W. J. d. S. Soares, E. Ferriolli, M. R. Perracini, Prevalence and correlates of dizziness in community-dwelling older people: a cross sectional

population based study, BMC Geriatr 13 (4) (2013) 1–9. doi:10.1186/1471-2318-13-4.
URL http://www.biomedcentral.com/1471-2318/13/4

[2] E. Ekvall Hansson, M. n. Magnusson, Vestibular asymmetry predicts falls among elderly patients with multi-sensory dizziness, BMC Geriatr 13 (1) (2013) 1–6. doi:10.1186/1471-2318-13-77.
URL http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3724742/

[3] J. Larsson, E. Ekvall Hansson, M. Miller, Increased double support variability in elderly female fallers with vestibular asymmetry, Gait Posture 41 (3) (2015) 820–824. doi:10.1016/j.gaitpost.2015.02.019.
URL http://linkinghub.elsevier.com/retrieve/pii/S0966636215000673

[4] K. Ishikawa, Z. W. Cao, Y. Wang, W. H. Wong, T. Tanaka, S. Miyazaki, I. Toyoshima, Dynamic locomotor function in normals and patients with vertigo, Acta Otolaryngol (Stockh) 121 (2) (2001) 241–244. doi:10.1080/000164801300043668.
URL http://informahealthcare.com/doi/abs/10.1080/000164801300043668

[5] K. Ishikawa, Y. Wang, W. H. Wong, Y. Shibata, Y. Itasaka, Gait instability in patients with acoustic neuroma, Acta Otolaryngol (Stockh) 124 (4) (2004) 486–489. doi:10.1080/00016480310000566.
URL http://www.ncbi.nlm.nih.gov/pubmed/15224880

[6] M. Yin, K. Ishikawa, E. Omi, T. Saito, Y. Itasaka, N. Angunsuri, Small vestibular schwannomas can cause gait instability, Gait Posture 34 (1) (2011) 25–28. doi:10.1016/j.gaitpost.2011.02.026.
URL http://www.gaitposture.com/article/S0966-6362(11)00076-2/abstract

[7] E. Ekvall Hansson, L. E. Dahlberg, M. n. Magnusson, Vestibular Rehabilitation Affects Vestibular Asymmetry among Patients with Fall-Related Wrist Fractures - A Randomized Controlled Trial, Gerontology 1 (1) (2014) 5p. doi:10.1159/000366556.
URL http://www.karger.com.ludwig.lub.lu.se/Article/FullText/366556

[8] J. Dros, O. R. Maarsingh, H. E. van der Horst, P. J. Bindels, G. Ter Riet, H. C. van Weert, Tests used to evaluate dizziness in primary care, CMAJ 182 (13) (2010) E621—-E631. doi:10.1503/cmaj.080910.
URL http://www.ncbi.nlm.nih.gov/pubmed/20643840

[9] R. R. Wilcox, Introduction to Robust Estimation and Hypothesis Testing, 3rd Edition, Statistical modeling and decision science, Academic Press, 2012.

[10] M. Wuehr, R. Schniepp, C. Schlick, S. Huth, C. Pradhan, M. Dieterich, T. Brandt, K. Jahn, Sensory loss and walking speed related factors for gait alterations in patients with peripheral neuropathy, Gait Posture 39 (3) (2014) 852–858. doi:10.1016/j.gaitpost.2013.11.013.
URL http://www.gaitposture.com/article/S0966-6362(13)00685-1/abstract

[11] J. B. Dingwell, J. P. Cusumano, Identifying Stride-To-Stride Control Strategies in Human Treadmill Walking, PLoS One 10 (4) (2015) e0124879. doi:10.1371/journal.pone.0124879.
URL http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0124879

[12] F. B. Horak, Postural compensation for vestibular loss and implications for rehabilitation, Restor. Neurol. Neurosci. 28 (1) (2010) 57–68. doi:10.3233/RNN-2010-0515.
URL http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2965039/

[13] J. N. Wagner, M. Glaser, T. Brandt, M. Strupp, Downbeat nystagmus: aetiology and comorbidity in 117 patients, J. Neurol. Neurosurg. Psychiatry (6) (2008) 672–677. doi:10.1136/jnnp.2007.126284.
URL http://jnnp.bmj.com/content/79/6/672.long

[14] R. Schniepp, M. Wuehr, S. Huth, C. Pradhan, C. Schlick, T. Brandt, K. Jahn, The gait disorder in downbeat nystagmus syndrome, PLoS One 9 (8) (2014) e105463. doi:10.1371/journal.pone.0105463.
URL http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0105463

[15] J. de Winter, Using the student's t-test with extremely small sample sizes, Practical Assessment, Research and Evaluation 18 (10) (2013) 1–12.
URL http://pareonline.net/getvn.asp?v=18\&n=10

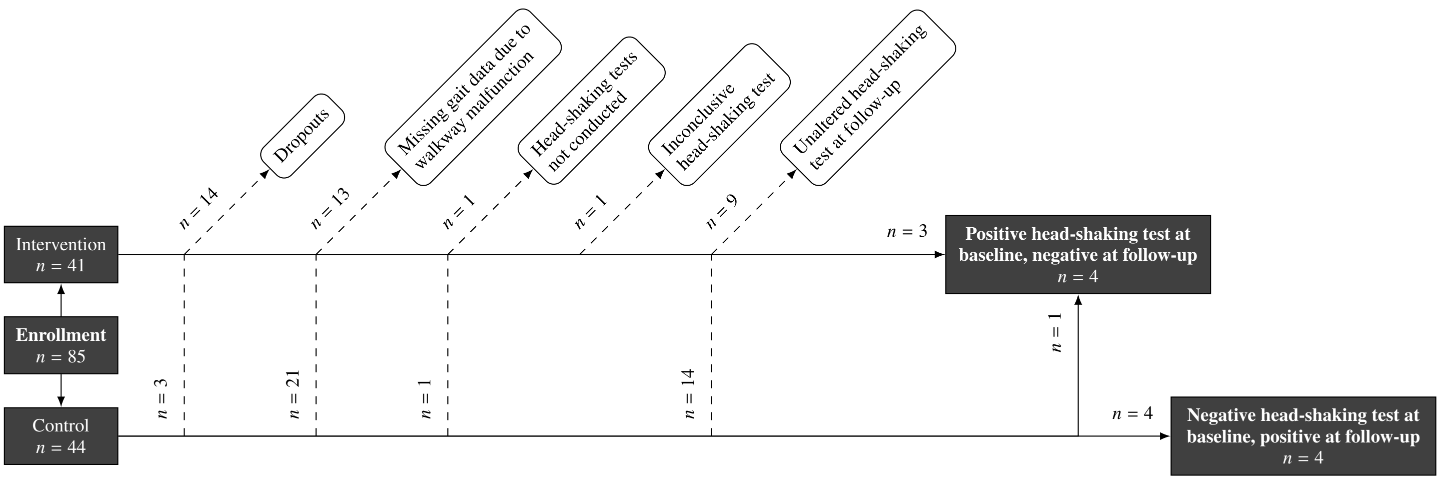

Figure 1: The selection process from initial enrollment until final inclusion of study participants (n = 8), for whom the result of the head-shaking test varied between baseline and follow-up measurements from either positive to negative or vice versa.

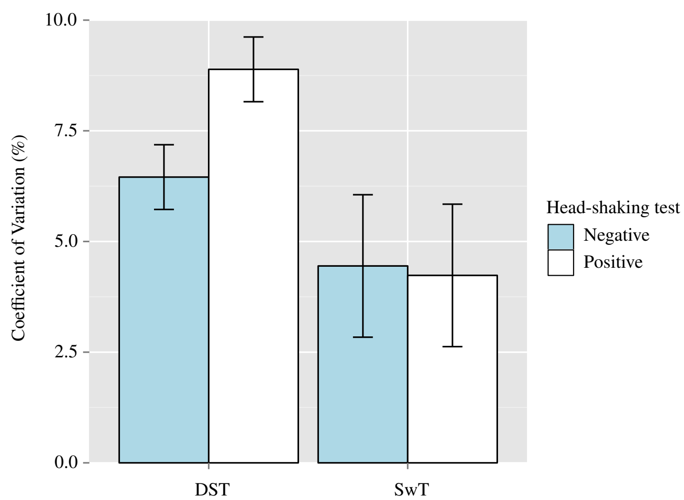

Figure 2: Trimmed means of the coefficient of variation in percent for double support time (DST) and swing time (SwT) variability by results of the head-shaking test. Error bars have been computed on normalized scores, representing bootstrapped 97.5 % confidence intervals.

Table 1: Characteristics of the participants, including which group they were assigned to as well as their results on the head-shaking test.

Sex	Age	Height (cm)	Weight (kg)	Group[a]	Head-shaking test[b] Baseline	Head-shaking test[b] Follow-up
Female	54	179	75	C	N	Right
Female	62	174	80	C	N	Down
Female	67	160	67	C	N	Right
Female	67	162	70	C	N[1]	Right
Female	58	166	77	C	Right	N
Female	71	164	76	I	Right	N
Female	80	165	74	I	Left	N
Male	89	170	70	I	Right[1]	N[2]
Mean	69	167	74			
SD	12	6	4			

[a]C = control group, I = intervention group
[b]N = negative test; else the direction of positive nystagmus
[1] At the time of the test the respective participant lacked sensation for vibration from the lateral malleol / [2] tibial tuberosity and caudally.