ASYMMETRIC VESTIBULAR FUNCTION IN THE ELDERLY MIGHT BE A SIGNIFICANT CONTRIBUTOR TO HIP FRACTURES

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The aim of this study was to assess postural control, vestibular symmetry and health status in otherwise healthy hip fracture subjects and compare these factors with controls. The fracture subjects were recruited from 113 consecutive patients operated 12–33 months earlier. Nineteen of those were otherwise healthy and fulfilled the inclusion criteria. They were assessed and compared with 28 age- and sex-matched controls. Nystagmus after head shake was checked for by video-nystagmoscopy (charged couple device cameras). Vibration sensation was tested with a tuning fork, medical history and posturography of vibration-induced sway were studied. The subjects had a significantly higher frequency of head shake nystagmus ($p = 0.03$), indicating a vestibular asymmetry and a history of previous fractures ($p = 0.002$). Nine out of 12 subjects had fallen and sustained the hip fracture towards the slow phase of the nystagmus, which is expected in a vestibular related fall. Losing balance during testing was more frequent among the subjects than among the controls ($p = 0.002$). The subjects with head shake nystagmus swayed more than those without, especially in the sagittal plane during neck vibration with eyes closed ($p < 0.001$). Vibration perception was significantly poorer in the operated legs than in the healthy legs ($p = 0.021$) and in the legs of the controls ($p = 0.001$). The findings suggest that vestibular asymmetries may contribute to falls and fractures in elderly people. As such asymmetries can be compensated to a certain degree by specific training programs, these might be advisable for elderly people, especially those with a history of falls or fractures or where a vestibular asymmetry is suspected.

Key words: vestibular, elderly, hip fracture, vibration sensation, falls.

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INTRODUCTION

Fractures among elderly people represent a great health problem. This is particularly true for hip fractures, which often result in major changes in the lives of the victims and are costly for the community (1).

Most falls that lead to hip fractures are considered to be caused by postural imbalance (2, 3) and impaired mobility has been reported in fallers (2, 4, 5). Human postural control is dependent on sufficient information from visual, vestibular, proprioceptive and mechano-receptive organs (6). Damage to any of these sensory inputs or an impairment affecting the processing of these messages by the nervous system can disturb the triggering and regulation of movements (7). Recordings of vibration-induced sway can objectively measure postural performance (8) and has been used for evaluation of postural control in elderly people (9, 10) and in patients suffering from vestibular disorders (11, 12).

Vestibular asymmetry (9) and diminished vibration sensation associated with an increased body sway has been reported in healthy elderly people (9, 13, 14). Whether these impairments are more abundant among people who have fallen and sustained hip fractures is not clear.

The aim of this study was to assess postural control, vestibular symmetry and vibration sensation in the legs among otherwise healthy individuals who had sustained a hip fracture and to compare these findings with those from a group of healthy elderly people.

MATERIAL AND METHODS

Subjects and controls

The subjects and controls considered themselves in good health, performed all personal activities of daily living (ADL), walked indoors without walking aids and lived independently in the community. They had no current or historical diagnosis of cerebral vascular insult (CVI), showed no overt clinical vestibular or neurological signs and had no obvious complaints of dizziness, light-headedness or vertigo. The subjects were asked to abstain from alcohol and sedatives during the 24-hour period preceding the tests.

The subjects were recruited from a list of 113 (71 female and 42 male) hip fracture patients under the age of 80 years, treated in the Department of Orthopaedics, Lund University Hospital, Sweden, during the years 1994 and 1995. All subjects with total hip replacement were excluded. A total of 17 women and 2 men (17%) met the inclusion criteria and participated in the study (Fig. 1). The subjects were between 65 and 79 years of age (mean age 72.5 years) and had sustained the hip fracture in an accidental fall 12–33 months earlier. Nine subjects had sustained cervical and 10 trochanteric hip fracture.

The subjects were compared with 28 healthy age-matched controls (mean age 72.0 years). These included 26 women under the age of 80 years and 2 age-matched males from a group of 49 healthy individuals that has been described previously (9).

Data collection

Health and current physical activity. Upon attendance at the Department of Otorhinolaryngology, Lund University Hospital, the

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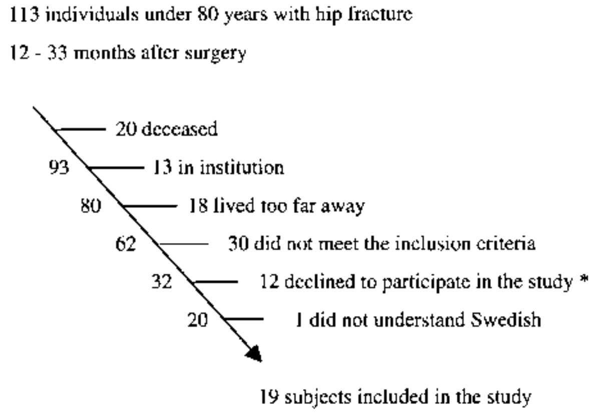

Fig. 1. Inclusion process of consecutive hip fracture patients. (*Mainly because of pain in fractured hip during walking.)

participants in the study signed an informed consent and answered a questionnaire about their health and current level of physical activity recorded on a 6-grade scale according to Mattiasson-Nilo et al. (15).

Head shaking nystagmus and grouping by health status. Goggles equipped with infrared charged couple device (CCD) cameras, excluding visual cues, were used to test for vestibular asymmetry. The participants were exposed to a head shake test (~2 Hz/15 seconds) in a supine position. The occurrence of nystagmus was considered to indicate asymmetric vestibular function (16). In accordance with the findings from the medical history and the CCD camera inspection, the subjects and controls were divided into 3 sub-groups:

1. individuals without head shake nystagmus and medical history, other than the hip fracture in the subjects case were placed in a “no findings group”;
2. those with a medical history but no head shake nystagmus were placed in a “medical group”;
3. participants with head shake nystagmus were placed in a “nystagmus group”.

Vibration sensation

Vibration sensation was tested with a tuning fork (256 Hz) at the base of the first metatarsal bone, the medial malleolus and the medial surface of the tibia levelled with the tibial tuberosity.

1. Vibration detected in all 3 areas was assigned sensation 1.
2. Vibration at the malleolus and medial surface of the tibia was assigned sensation 2.
3. Vibration only at the medial surface of the tibia was assigned sensation 3.

Postural measurements

Recordings of vibration-induced postural sway were used to measure postural control. The vibration was simultaneously applied to the gastrocnemius muscles of both legs either at high intensity (850 mW, amplitude 1.0 mm) or at low intensity (120 mW, amplitude 0.4 mm) and high intensity to the paravertebral muscles of the neck. The subjects stood erect but relaxed on the force platform, with the heels approximately 4 cm apart and feet at a 30° angle, arms crossed over the chest and eyes either closed or focused on a mark on the wall at a distance of 1.25 m.

Six different tests were conducted in the following order:

1. high intensity vibration to calf – with eyes closed and eyes open;
2. high intensity vibration to neck – with eyes closed and eyes open;
3. low intensity vibration to calf – with eyes closed and eyes open.

Each test started with a recording of a quiet stance for 30 seconds, followed by vibration at 60 Hz turned on or off according to a PRBS (pseudorandom, binary sequence) schedule with pulses between 0.8 and 6.4 seconds for 205 seconds. See (9) for further details of the method.

Statistics. For the statistical analysis, JMP (version 3.0, SAS Institute Inc., USA) was used, and $p < 0.05$ was considered statistically significant.

A one-way ANOVA, Fisher’s exact test, likelihood ratio and Wilcoxon/Kruskal-Wallis rank sum test were used where appropriate.

Table I. *Subjects and controls arranged in groups according to age and health status*

	Fractures 19 (17 females, 2 males) n (%)	Controls 28 (26 females, 2 males) n (%)
Age (years)		
64–69	6 (31.6)	10 (35.7)
70–74	7 (36.8)	7 (25)
75–79	6 (31.6)	11 (39.3)
Mean	72.5	72
Health groups		
No findings	1 (5.3)	11 (39.3)*
Medical	5 (26.3)	7 (25)
Nystagmus	13 (68.4)	10 (35.7)*

* $p < 0.05$ Fisher’s exact test.

RESULTS

Current physical activity and age

The subjects were slightly less active with a mean of 3.5 (range 2–4), than the controls with a mean of 4 (range 3–5).

The difference in age between the subjects and the controls (Table I) was not significant ($p = 0.15$, one-way ANOVA).

Head shaking nystagmus and grouping by health status

Only 1 subject, fitted into the ‘No findings group’, significantly less than among the controls ($p = 0.01$) (Table I). The prevalence of nystagmus among the subjects was significantly higher than among the controls ($p = 0.04$). All the subjects presenting head shake nystagmus, had additional medical ailments (Table II), most noticeable of which were the number of other fractures (Table II).

After head-shaking nystagmus, side of hip fracture, dizziness, other falls and fractures

Of the 12 subjects with horizontal (left/right) head shake nystagmus, 9 had the hip fracture on the same side as the direction of the slow phase of nystagmus (Fig. 2).

The subjects acknowledging some dizziness tended to have head shake nystagmus, but there was no significant correlation between these factors (Table III). History of fractures was significantly more frequent among the subjects than among the controls ($p = 0.007$). The total number of fractures, excluding the hip fractures, was significantly higher for the subjects than for the controls ($p = 0.001$). The majority of the subjects reporting other falls and fractures had head shake nystagmus (Table III).

Table II. *Frequency of different ailments in the subjects' "medical" (n = 5) and "nystagmus" (n = 13) groups*

Medical history/findings	Subgroups "Med" (*n*)	"Nyst" (*n*)
Surgery for lumbal discus prolapse		1e
Lumbago		2
Ischias		3a,e
Stenosis of the spinal canal		1
Osteopenia		1
Hip complaints		1
Neck complaints		3
Knee complaints	1	1
Operation; hallux valgus, Hammer toes		2
Hypertension (treated)		3
Hypotension	1	1
Rheumatic fever		1e
Heart fibrillations	1	2
Unspecified neurological disease		1e
Polymyalgia		1a
Chronic ear inflammation		1
Ear disease, unspecified		1f
Dizziness	2	5
Cancer mammae	1b	1a
Cancer kidney, lung	1x,c	
Medicated struma	1	3
Diabetes medicated	1	
Operation for cataract	1e	2e
Pneumonia		1c
Psoriasis	1	
Emphysema	1	
Asthma	1	
Intestinal disorders; liver, kidney	1	3
Dislocated shoulder		1a
Fracture of knee (car accident)		1e
Fracture of pelvis	1c,d	3x,a,b
Fracture of vertebra		1a
Former fracture of hip		1e
Fracture of crus	1c	1a
Colles fracture		6a,b
Fracture of humerus		3b,e

a–f, x Where appropriate, the number of years since the events are indicated by: a = 1–5, b = 6–10, c = 11–15, d = 16–20, e > 20 years ago, f = as a child. x = last year.

Vibration sensation

The vibration sensation in the fractured leg was significantly decreased compared with the other leg ($p = 0.021$) and the controls ($p = 0.001$) (Fig. 3). The leg not fractured had slightly reduced sensation compared with the controls.

Postural measurements and loss of balance

During high-intensity vibration to the calves when standing with eyes closed, 42% (8/19) of the subjects vs 4% (1/28) of the controls lost their balance. The frequency of losing balance was significantly higher for the subjects than for the controls ($p = 0.002$). All except 1 of the individuals losing their balance had head shake nystagmus (Table III).

Two subjects with head shake nystagmus showed imbalance during high-intensity vibration to the neck, standing with eyes closed, but none of the controls had difficulties with this test.

The subjects with head shake nystagmus swayed more in all the tests than did the subjects without head shake nystagmus. This increased sway was significant ($p < 0.001$, Wilcoxon/Kruskal-Wallis rank sum test) in the sagittal plane during neck vibration with eyes closed and with eyes open ($p < 0.05$, Wilcoxon/Kruskal-Wallis rank sum test) and in quiet stance with eyes closed ($p < 0.05$, Wilcoxon/Kruskal-Wallis rank sum test).

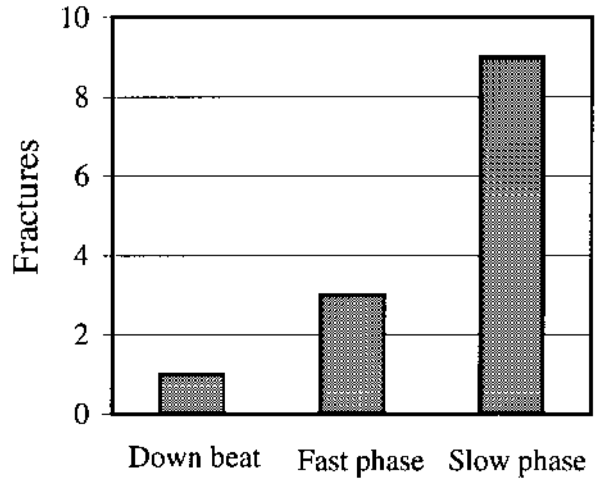

Fig. 2. Side of fracture correlated with direction of head shake nystagmus.

In comparison with the controls, the subjects did not have significantly greater body sway.

DISCUSSION

All the subjects were rehabilitated and considered themselves in good health, except for the hip fracture. Although only 1 subject did not have ailments in the medical history nor demonstrated head shake nystagmus in the nystagmoscopy. This might reflect the overall medical status in hip fracture patients and be an indication of functional deterioration (17–19), bearing in mind that the subjects were the most active and youngest of all hip fracture patients in our population.

Inspection with CCD cameras was used to detect vestibular asymmetry as it gives the possibility to access eye movements in 3 dimensions. The head shake test was preferred to caloric irrigation as it is a functional test depending on both labyrinths simultaneously in the high frequency range. Furthermore, it also accounts for compensation. The observation that 68% of the subjects presented nystagmus after head shaking was remarkable. This prevalence of nystagmus was significantly higher than that found in the controls. Nystagmus after head shaking is generally considered pathological (20) and demonstrates clinically asymmetry of the vestibular reflexes (21). Age-dependent loss of sensory cells in the vestibular end-organ paralleling that found in the cochlea has been reported (22). The above implies that if there is a side difference in the number of functioning afferents and then over the years the total number of afferents decreases, the relative asymmetry increases, which may lead to

Table III. *Nystagmus related to dizziness, falls, fractures and loss of balance during testing among the subjects and controls*

	Subjects ($n = 19$)		Controls ($n = 28$)	
	Total (n)	Nyst ($n = 13$) (n)	Total (n)	Nyst ($n = 10$) (n)
Dizziness		5	8	4
History of falls	10	7	?	?
History of fractures excluding the hip fracture	9	7	3**	1
during last 10 years	6	6	0	0
High intensity vibration calves-eyes close				
Subjects lost balance		7	1**	1
test stopped		4		
support needed		3		1
Number of fractures				
Fractures (n) excluding the hip fractures		16	5***	3
during last 10 years	12	12	0***	0

Total = number of subjects and controls; or incidents.
Nyst = how many of total had nystagmus.
? = not asked.
** $p < 0.01$; ***$p < 0.001$ Fisher's exact test.

asymmetric vestibular-postural responses impairing the balance control.

The vestibular sensory organs contribute to stabilizing the eyes and head in space, but are also important during fast postural movements (23). Vidal et al. found a massive projection of short latency vestibular-evoked potentials into the prefrontal lobe. They suggest that vestibular information could rapidly trigger complex motor patterns, which would take into account the risk at stake (24). Deficient or inaccurate information from the vestibular organs or the central nervous processing could thus arouse a movement pattern that is incorrect or insufficient to prevent a fall.

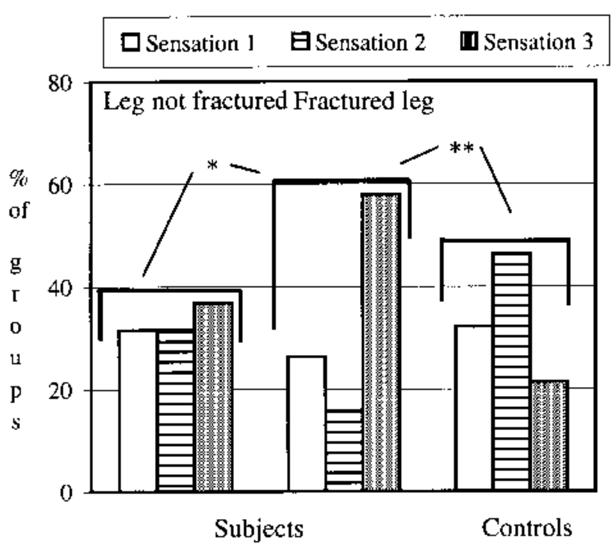

Fig. 3. Vibration perception in the legs of subjects and controls. Sensation 1 = vibration detected at the base of the first metatarsal bone, medial malleolus and medial surface of the tibia. Sensation 2 = vibration detected at the medial malleolus and the medial surface of the tibia. Sensation 3 = vibration detected at the medial surface of the tibia. *$p < 0.05$; **$p < 0.01$, Likelihood ratio.

Individuals with a vestibular end-organ lesion tend to fall in the direction of the slow phase of nystagmus. Nine out of the 12 subjects with horizontal head shake nystagmus had a fracture indicating a fall towards that side. Some patients with vestibular asymmetry caused by a cerebellar lesion would be expected to fall towards the fast phase of the nystagmus (25). Although the subjects had no history of such a disorder, one cannot rule out the possibility of subclinical lesions (26) or asymmetric atrophy. The majority of the subjects with histories of previous falls, and all the subjects with fractures during the preceding 10 years, had signs of vestibular asymmetry. The test "stops walking when talking" could be a predictor of falls (27) because elderly with vestibular asymmetry experience an increased imbalance when turning their heads to talk while walking.

The subjects had decreased vibration sensation in the fractured leg. This might have existed prior to the fracture, or the cause could be the fracture and its aftermath. Differences in sensation between the right and left legs were not found in our controls, which is in agreement with other reports (28). In cases of unilateral arterial impairments a higher vibratory threshold in the affected extremity has been reported (29). It is possible that the fracture and the surgery, followed by diminished mobility and weight bearing, affected the circulation, resulting in an increased vibratory threshold.

Reduced vibration sensation in healthy elderly people has been found to coincide with increased sway (9). Proprioceptive loss by itself might thus be considered a risk factor for falls (9). It seems less likely that the head shake nystagmus could be secondary to a proprioceptive disturbance. Six subjects did not show nystagmus at all postoperatively and no side differences in vibration sensation was found among the controls but still about one-third of them demonstrated head shake nystagmus. This suggests that such asymmetries may exist prior to the hip fracture. Subject with expected proprioceptive disturbance of the cervical spine causing dizziness and somewhat reduced postural control do not show head shake nystagmus (30).

Over 40% (8/19) of the subjects and 4% (1/28) of the controls lost their balance in the most challenging balance test, indicating decreased postural control among the subjects. The 1 control and all but 1 of the subjects, losing their balance had signs of vestibular asymmetry. The subjects with head shake nystagmus tended to have larger sway in most of the tests than did the subjects without nystagmus. These findings suggest a vestibular impairment of importance, as such patterns of sway have been associated with vestibular lesion (12).

Hip fractures in elderly people have multitude of causes (18). The findings in our study point to concomitant balance disturbances caused by vestibular asymmetry. The reduced postural control, the abundance of vestibular asymmetries and the high frequency of fractures on the predicted side among otherwise healthy hip fracture subjects indicate that a vestibular asymmetry might be a significant contributor to hip fractures. The direct contribution of a vestibular asymmetry in falls and fractures is debatable. A vestibular impairment may contribute to the induction of falls, as suggested by the impaired postural control. If the vestibular information on direction and speed of the fall is improper the subject may not be able to launch appropriate avoidance behaviour before impact. A vestibular impairment would then worsen the outcome of the fall.

This novel observation in hip fracture patients also has clinical implications, as vestibular asymmetries can be compensated to a certain degree by rehabilitation (31). Initiating such programs among elderly people might therefore reduce the number of fractures, thus benefiting individuals and society.

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