Journal of Vestibular Research 25 (2015) 241–251
DOI 10.3233/VES-150564
IOS Press

Falls and fear of falling in vertigo and balance disorders: A controlled cross-sectional study

Cornelia Schlick[a], Roman Schniepp[a,b], Verena Loidl[a], Max Wuehr[a], Kristin Hesselbarth[a] and Klaus Jahn[a,c,*]
[a]*German Center for Vertigo and Balance Disorders, University of Munich, Germany*
[b]*Department of Neurology, University Hospital of Munich, Germany*
[c]*Schön Klinik Bad Aibling, Germany*

Received 7 April 2015
Accepted 28 October 2015

Abstract.
BACKGROUND: Vertigo and dizziness are among the most prevalent symptoms in neurologic disorders. Although many of these patients suffer from postural instability and gait disturbances, there is only limited data on their risk of falling.
METHODS: We conducted a controlled cross-sectional study at the tertiary care outpatient clinic of the German Center for Vertigo and Balance Disorders using a self-administered questionnaire to assess falls, fall-related injuries, and fear of falling. The recruitment period was 6 months.
RESULTS: A total of 569 patients (mean age 59.6 $\pm$ 17.1 years, 55% females) and 100 healthy participants were included (response rate $>$ 90%). Dizzy patients with central balance disorders (Parkinsonian, cerebellar, and brainstem oculomotor syndromes) had the highest fall rates ($>$ 50% recurrent fallers, odds ratio $>$ 10). The rate of recurrent fallers was 30% in bilateral vestibular failure and peripheral neuropathy (odds ratio $>$ 5). Patients with functional dizziness (somatoform or phobic vertigo) were concerned about falling but did not fall more often than healthy controls (odds ratio 0.87).
CONCLUSION: Falls are common in patients presenting to a dizziness unit. Those with central syndromes are at risk of recurrent and injurious falling. Fall rates and fear of falling should be assessed in balance disorders and used to guide the regimen of rehabilitation therapy. The identification of risk factors would help provide protective measures to these groups of patients.

Keywords: Balance, dizziness, falls, gait disorders, vertigo

1. Introduction

Falling is a frequent complication among the elderly. It not only causes medical and social impairments, such as fall-related injuries and loss of independence, but it also induces fear of falling which can result in a substantial decline in quality of life [38]. A meta-analysis found that vertigo, gait problems, and Parkinson's disease are among the strongest risk factors for falls in community-dwelling seniors [6]. Similarly, a recently published study on falls in neurological outpatients showed an annual fall incidence of 30% in patients presenting with vertigo, 55% in patients with peripheral neuropathy, and 77% in patients with Parkinson's disease [18]. The risk of falling was more than three, six, and even 17 times higher than in healthy persons [18].

Vertigo can be caused by a variety of disorders, mostly arising from the peripheral and central vestibular systems. Some of these disorders are known to cause falls, e.g., spinocerebellar ataxias and peripheral vestibular hypofunction [8,17]. However, clinical ex-

*Corresponding author: Klaus Jahn, German Center for Vertigo and Balance Disorders (DSGZ), University Hospital – Klinikum Grosshadern, Ludwig-Maximilians-University, Marchioninistrasse 15, 81377 Munich, Germany. Tel.: +49 89 4400 73671; Fax +49 89 4400 76671; E-mail: klaus.jahn@med.uni-muenchen.de.

ISSN 0957-4271/15/$35.00

perience in the German Center for Vertigo and Balance Disorders suggests that problems related to mobility like falling, tripping, and fall-related fears are found in a much wider spectrum of disorders. Comparable data on the occurrence and consequences of falls in the different groups of disorders is of great clinical importance for detecting those patients who require assessment and treatment for falls in clinical practice. Furthermore, disease-specific risk factors could then be derived to develop and implement the targeted prevention strategies.

The goal of this study was to identify the fall risk within the whole spectrum of patients who present to a tertiary outpatient dizziness clinic. In particular, we aimed to 1) investigate the prevalence of recurrent and severe fallers, 2) derive fall risk estimates, and 3) examine the degree of fear of falling according to disease-specific groups of patients with central, peripheral, and functional balance disorders. We hypothesized that the risk of falls gradually decreases from central through peripheral to functional disorders and that fear of falling affects the majority of dizzy patients.

2. Methods

2.1. Setting

A controlled cross-sectional study was conducted at the tertiary care outpatient clinic of the German Center for Vertigo and Balance Disorders (DSGZ). The DSGZ is part of the University hospital of the Ludwig-Maximilians University of Munich.

2.2. Participants

Between April and September 2013, all patients over 18 years presenting at the outpatient clinic were asked to participate in the study. The patients underwent a neurological examination with a structured medical history. Instrumental diagnostic tests were applied depending on the presentation and (suspected) diagnosis. Sociodemographic and clinical characteristics, medical diagnoses and onset of disease were retrieved from the medical records. According to the final diagnosis after complete clinical assessment, patients were assigned to one of the following disease-specific groups: (1) unilateral vestibular disorders including unilateral vestibular hypofunction (difference of $\geqslant 25\%$ in slow phase eye velocity between right and left sides on the caloric tests using the Jongkees's formula), benign paroxysmal positional vertigo (BPPV), Menière's disease (at least "probable" according to the American Academy of Otolaryngology-Head and Neck Surgery [24]), vestibular paroxysmia (at least "probable" according to Hüfner et al. [19], and perilymphatic fistula; (2) bilateral vestibular failure ($<$ 5°/sec of slow phase eye velocity in response to bithermal caloric tests in all four tests and a bilateral pathological head-impulse test); (3) peripheral neuropathy (reduced vibrotactile thresholds of $<$ 4/8 using a 64-Hz tuning fork at the lateral malleolus and absent ankle jerk reflexes); (4) combined peripheral disorders (unilateral/bilateral vestibular loss and peripheral neuropathy); (5) cerebellar disorder (cerebellar ataxia and/or cerebellar oculomotor disturbance; scale for the assessment and rating of ataxia = SARA $\geqslant 2$); (6) brainstem ocular motor disorders (pathological central nystagmus, horizontal or vertical gaze palsy, hypermetric saccades, internuclear ophthalmoplegia); (7) vestibular migraine (at least "probable" according to Lempert et al. [23]; (8) Parkinsonian syndromes including Parkinson's disease, progressive supranuclear palsy (PSP), multisystem atrophy (MSA), corticobasal degeneration (CBD), dementia with Lewy bodies; and (9) functional dizziness (according to Brandt et al. [4]). Patients were excluded in case of insufficient information from medical records, a diagnosis that could not be allocated to one of the groups, two or more differential diagnoses, concomitant orthopedic/neurological disease with motor impairment, or non-ambulatory status.

Healthy controls were recruited among accompanying persons at the outpatient clinic. All healthy participants needed to be over 18 years old. They underwent a structured interview about the presence of any vertigo or balance disorder, neurological or orthopedic disorder that affected balance, and subjective feelings of vertigo, dizziness, or unstable gait. If any were reported, the person was excluded from the study.

Participation in the study was voluntary. All participants gave their informed written consent before enrolling in the study. The study protocol was approved by the local Ethics Committee of the University Hospital of Munich (LMU) and was therefore performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

2.3. Survey instrument

A self-administered questionnaire was used to collect information on the frequency and severity of falls as well as fear of falling. The medical staff were trained to assist in filling out the questionnaire, if required (e.g., in case of comprehension difficulties, poor vision).

A fall was defined as an unexpected event in which the participant comes to rest on the ground, floor, or lower level [22]. A near-fall was defined as a slip, trip, or loss of balance without a fall to the ground or lower level [5].

In the first section of the questionnaire, patients and healthy controls were asked whether they had experienced near-falls and falls within the previous 12 months, and if they answered yes, how many. There were five response options for each of the two types of fall events (near-falls and falls): 1) none, 2) one, 3) two, 4) three to five, 5) more than five. Patients were also asked whether any near-falls and falls had occurred since the onset of their disease-specific symptoms. The participants were then asked to specify how many of the falls within the previous year resulted in 1) no injury, 2) a minor injury like bruises or abrasions requiring no medical attention, 3) a moderate injury like wounds, bruises, sprains, cuts or abrasions requiring medical attention without admission to the hospital and 4) a serious injury like fractures, head or internal injuries requiring hospital admission. The injury categories were defined according to Schwenk and colleagues [34]. In the second section, the 16-item Falls Efficacy Scale-International (FES-I) was used to assess fear of falling [11,36]. FES-I scores between 16 and 19 were considered low, scores between 20 and 28 moderate, and scores between 29 and 64 pronounced concern of falling [7].

2.4. Outcome classification

Frequency of falls was categorized by assigning the participants to four different groups. Participants were classified as “non-fallers” if they had not fallen at all, “single fallers” if they had fallen once, “recurrent fallers” if they had experienced two or more falls, and “frequent fallers” if they reported more than five falls during the previous 12 months. Data on near-falls was only considered for the analysis of fall severity, since the number of near-falls is assumed to be strongly affected by recall bias.

Severity of falls was categorized according to the Hopkins Falls Grading Scale [5] by allocating the participants to five groups: 1) non-fallers reporting neither near-falls nor falls, 2) near-fallers reporting near-falls but no falls (Grade 1), 3) fallers reporting falls that required no medical attention (Grade 2), 4) fallers reporting falls that required medical attention but no admission to the hospital (Grade 3), and 5) fallers reporting falls that required admission to the hospital (Grade 4). Grades 3- and 4-fallers were further designated “severe fallers”.

2.5. Data analysis

Each eligible patient was allocated to one of the disease-specific groups according to her/his medical diagnosis. Sociodemographic and clinical characteristics were then descriptively summarized. One-way ANOVA with post-hoc comparisons and Chi square tests were used to test differences in metric and categorical characteristics between the groups.

Proportions of fallers were calculated according to fall frequency (single, recurrent, and frequent) and fall severity (Grades 1, 2, 3 and 4). Logistic regression analysis was then performed to calculate age- and gender-adjusted odds ratios (95% CI) for being a recurrent and severe faller. Only patients with disease duration of $\geqslant$ 12 months were included for the fall prevalence and risk estimation to account for the 1-year observation interval.

FES-I data were summarized as median scores with upper/lower quartiles. The Kruskal-Wallis H test was used to evaluate whether there was a difference in FES-I scores between healthy participants and the disease-specific groups. Post-hoc comparisons using Mann-Whitney U tests with Bonferroni correction determined individual differences between the groups. In addition, the effect of older age ($\geqslant$ 65 years) on FES-I scores was tested by Mann-Whitney U tests. The nonparametric testing procedure was chosen because FES-I scores were not normally distributed.

Subgroup analyses were conducted within the groups of central disorders and in unilateral vestibular disorders. Differences in the proportions of recurrent and severe fallers were tested using Chi square tests, and differences in the FES-I scores were evaluated by Mann-Whitney U tests and the Kruskal-Wallis H test, respectively. First, patients with Parkinsonian syndromes, cerebellar, and brainstem oculomotor disorders presenting with a concomitant peripheral sensory deficit (e.g., peripheral neuropathy) were allocated to the group of the respective central disorder. This approach was selected for two reasons: 1) to avoid very small group sizes and 2) because the central deficit was hypothesized to be the predominant cause of falling. Subgroups of central disorders with and without the

Table 1
Disease-specific grouping

Disease group	n (%)
Central disorders	198 (34.8)
Parkinsonian syndromes	42 (7.4)
Idiopathic Parkinson's disease	23
Progressive supranuclear palsy	10
Multiple system atrophy	5
Corticobasal degeneration	3
Dementia with Lewy bodies	1
Cerebellar disorders	62 (10.9)
Sporadic adult onset ataxia	32
Idiopathic (without atrophy)	10
Vascular	7
Hereditary spinocerebellar ataxia	6
Episodic ataxia type II	4
Posttraumatic lesion	1
Paraneoplastic	1
Autoimmune (Susac syndrome)	1
Brainstem ocular motor disorders	22 (3.9)
Vascular	19
Paraneoplastic	2
Posttraumatic	1
Vestibular migraine	72 (12.7)
Peripheral disorders	198 (34.8)
Unilateral vestibular disorders	133 (23.4)
Benign paroxysmal positioning vertigo	49
Menière's disease	36
Unilateral vestibular hypofunction	36
(due to vestibular neuritis	28)
(due to vestibular schwannoma	6)
(due to labyrinthine infarct	2)
Vestibular paroxysmia	11
Perilymphatic fistula	1
Bilateral vestibular failure	21 (3.7)
Peripheral neuropathy	22 (3.9)
Combined peripheral disorders	22 (3.9)
Peripheral neuropathy and vestibular disorder	15
Multiple vestibular disorder	7
Functional dizziness	173 (30.4)

presence of a concomitant peripheral deficit were compared. Second, the group of cerebellar disorders comprised patients with and without gait ataxia. Differences between these two subgroups were tested. Third, the group of unilateral vestibular disorders included unilateral hypofunction, benign paroxysmal positional vertigo, Menière's disease, vestibular paroxysmia and perilymphatic fistula. As there was only one patient with perilymphatic fistula, this disorder was not a separate subgroup. Differences were evaluated between the remaining four subgroups.

Results were considered significant if $p < 0.05$. All data were double-entered in an Excel database and analyzed using the SPSS statistical software package 20 (Chicago, IL, USA).

3. Results

A total of 862 patients and 114 healthy participants were recruited; 63 patients and 11 healthy participants declined to participate in the study (response rate 92.1% and 90.4%, respectively). Two hundred and thirty patients were excluded due to insufficient information from the medical records ($n = 27$), a diagnosis that could not be allocated to one of the disease groups ($n = 122$), or two or more differential diagnoses ($n = 81$). Three of the healthy participants reported symptoms of gait disturbances or vertigo; they were also excluded. Finally, 569 patients and 100 healthy participants were included in the analysis.

Table 1 shows the disease-specific grouping of the patient cohort and the distribution of medical diagnoses within the groups. Central, peripheral, and functional disorders contributed about one third each to the patient cohort. Sociodemographic and clinical characteristics are presented in Table 2. Patients with Parkinsonian or combined peripheral disorders were significantly older, whereas patients with vestibular migraine were significantly younger than the healthy participants ($p < 0.05$). Patients with functional dizziness and those with vestibular migraine were significantly younger than the other patient groups ($p < 0.05$). There were no differences in disease duration between the patient groups.

3.1. Fall prevalence and risk of falling

Patients with central disorders showed the highest annual prevalence of recurrent falls (except vestibular migraine), and almost 30% of the patients with cerebellar disorders had fallen more than 5 times within the preceding year (Fig. 1). The fall status of patients with functional dizziness and vestibular migraine was similar to that of the healthy participants. Near-falls happened to more than 50% of the patients and healthy participants, but injurious falls predominantly occurred in Parkinsonian and cerebellar disorders (Fig. 2). Almost 25% of the patients with Parkinsonian syndromes required inpatient treatment due to a fall-related injury.

Table 3 presents the risk estimates for recurrent and severe falling. The risk of recurrent falls was greatly increased in Parkinsonian, cerebellar, and brainstem ocular motor disorders and moderately increased in peripheral disorders. Only patients with Parkinsonian and cerebellar disorders were at risk of severe falls. Risk estimates remained pretty much the same after adjusting for age and gender. Older age was an independent risk factor for both fall categories.

Table 2
Demographic and clinical characteristics of the patients and healthy participants

Group N	PS 42	CD 62	BOD 22	VM 72	UVD 133	BVF 21	PNP 22	CPD 22	FD 173	HP 100
Age [years], mean (SD)	72.8 (8.2)	61.8 (17.1)	68.3 (13.9)	44.5 (13.0)	58.8 (14.1)	62.8 (16.4)	70.3 (9.3)	71.3 (10.1)	49.2 (16. 9)	55.9 (16.2)
• 18–44, n (%)	1 (2.4)	10 (16.1)	2 (9.1)	36 (50.0)	22 (16.5)	4 (19.0)	–	1 (4.5)	74 (42.8)	27 (27.0)
• 45–64, n (%)	4 (9.5)	24 (38.7)	7 (31.8)	30 (41.7)	62 (46.6)	5 (23.8)	4 (18.2)	4 (18.2)	58 (33.5)	37 (37.0)
• ⩾ 65, n (%)	37 (88.1)	28 (45.2)	13 (59.1)	6 (8.3)	49 (36.8)	12 (57.1)	18 (81.8)	17 (77.3)	41 (23.7)	36 (36.0)
Gender										
• Female, n (%)	16 (38.1)	32 (51.6)	8 (36.4)	54 (75.0)	81 (60.9)	7 (33.3)	9 (40.9)	12 (54.5)	94 (54.3)	48 (48.0)
Disease duration [months]										
Mean (SD)	30.5 (26.2)	48.5 (66.3)	53.6 (72.7)	46.3 (53.6)	41.0 (70.1)	90.3 (98.2)	25.8 (28.1)	52.8 (93.5)	34.6 (51.3)	–
• < 12 months, n (%)	9 (21.4)	12 (20.0)	5 (22.7)	22 (32.4)	52 (43.3)	1 (4.8)	7 (33.3)	8 (38.1)	67 (40.4)	–
• ⩾ 12 months, n (%)	33 (78.6)	48 (80.0)	17 (77.3)	46 (67.6)	68 (56.7)	20 (95.2)	14 (66.7)	13 (61.9)	99 (59.6)	–
$n_{missing}$	0	2	0	4	13	0	3	1	7	
Co-morbidities										
cardiovascular, n (%)	5 (11.9)	4 (6.5)	5 (22.7)	none	2 (1.5)	2 (9.5)	2 (9.1)	none	2 (1.2)	4 (4.0)
orthopedic, n (%)	7 (16.7)	10 (16.1)	5 (22.7)	none	8 (6.0)	3 (14.3)	3 (13.6)	none	4 (2.3)	6 (6.0)
neurologic, n (%)	7 (16.7)	5 (8.1)	3 (13.6)	1 (1.4)	4 (3.0)	none	none	1 (4.5)	none	0 (0.0)
Concomitant peripheral disorders										
PNP, n (%)	5 (11.9)	15 (24.2)	6 (27.3)	none	–	–	–	–	–	–
BVF, n (%)	1 (2.4)	5 (8.1)	none	none	–	–	–	–	–	–
UVD, n (%)	2 (4.8)	2 (3.2)	3 (13.6)	none	–	–	–	–	–	–
Falls since onset of disease, n (%)	29 (69.0)	48 (77.4)	16 (72.7)	18 (25.0)	51 (38.3)	10 (47.6)	13 (59.1)	12 (54.5)	37 (21.4)	–

"Cardiovascular" includes chronic heart disease; "orthopedic" includes a history of orthopedic disease (e.g., hip replacement) without any motor impairment; "neurologic" includes a history of neurological disease (e.g., TIA, stroke) without any current motor or cognitive impairment. Abbreviations: BOD – brainstem ocular motor disorders, BVF – bilateral vestibular failure, CD – cerebellar disorders, CPD – combined peripheral disorders, FD – functional dizziness, HP – healthy participants, PS – Parkinsonian syndromes, PNP – peripheral neuropathy, VM – vestibular migraine, UVD – unilateral vestibular disorders.

3.2. *Fear of falling*

FES-I scores are presented in Fig. 3A. The Kruskal-Wallis H test showed significant differences between the groups (H(9) = 150.998, $p = 0.000$). Post-hoc analysis revealed that patients with central disorders (except vestibular migraine), peripheral disorders (except bilateral vestibular failure), and functional dizziness were significantly more concerned about falling than healthy participants ($p < 0.006$). Moreover, patients with Parkinsonian and cerebellar disorders showed significantly higher FES-I scores than patients with unilateral vestibular disorders or functional dizziness ($p < 0.006$). Older age was significantly associated with higher FES-I scores in patients with functional dizziness and most groups of peripheral disorders ($p < 0.05$, Fig. 3B).

3.3. *Subgroup analyses*

3.3.1. *Central disorders with and without concomitant peripheral deficits*

Between 20 and 40% of the patients with central disorders (PS, CD, and BOD) had a concomitant pe-

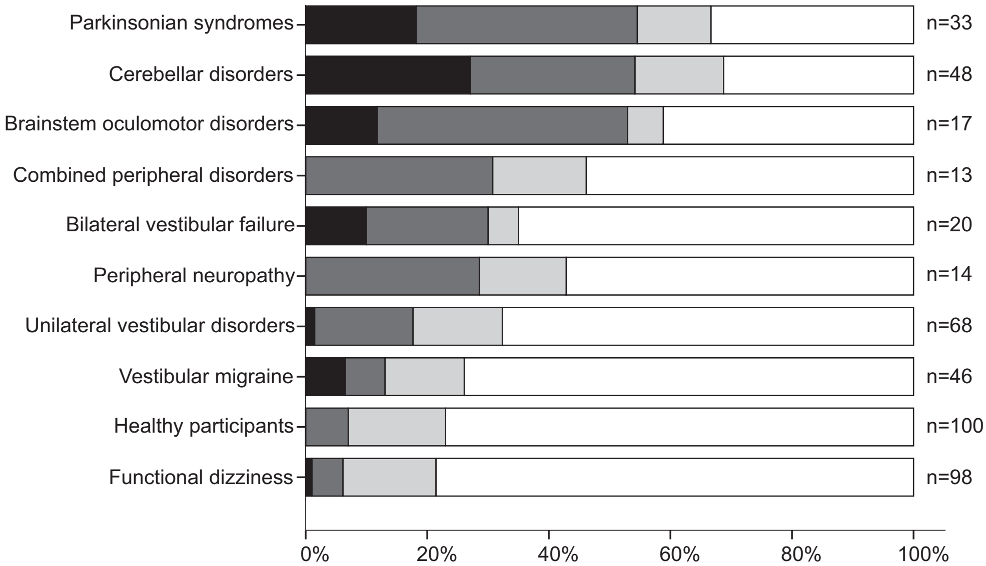

Fig. 1. Frequency of falls. Results from healthy participants and patients in the disease-specific groups are presented as the proportion of non–fallers (white), single fallers (light gray), recurrent fallers (two or more falls in the preceding 12 months, dark gray) and frequent fallers (more than 5 falls in the preceding 12 months, black).

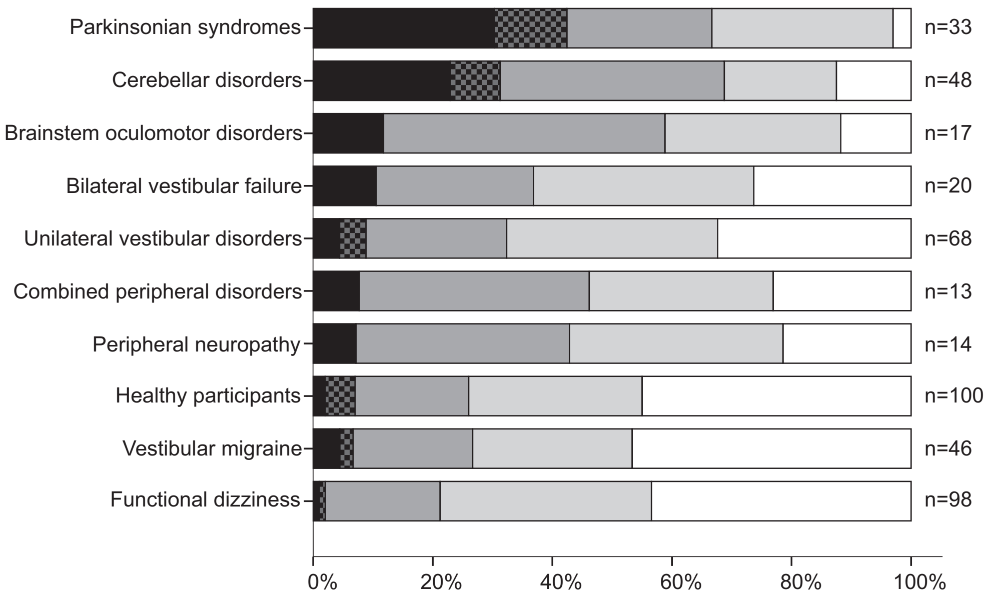

Fig. 2. Severity of falls. Results from healthy participants and patients in the disease-specific groups are presented as the proportion of non-fallers (white), near-fallers (light gray), fallers requiring no medical attention (gray), severe fallers requiring medical attention but no admission to the hospital (squared black) and severe fallers requiring hospital admission (black).

ripheral deficit (peripheral neuropathy and/or peripheral vestibular impairment, Table 2). Chi square tests for each of the three groups showed no significant differences in the proportions of recurrent and severe fallers. Similarly, Mann-Whitney U tests revealed no significant differences in the median scores of the FES-I.

3.3.2. Cerebellar disorders with and without gait ataxia

About 70% of the patients with cerebellar disorders presented with gait ataxia, and 30% had only cerebellar oculomotor deficits, mainly a downbeat nystagmus syndrome. Neither the proportions of recurrent and se-

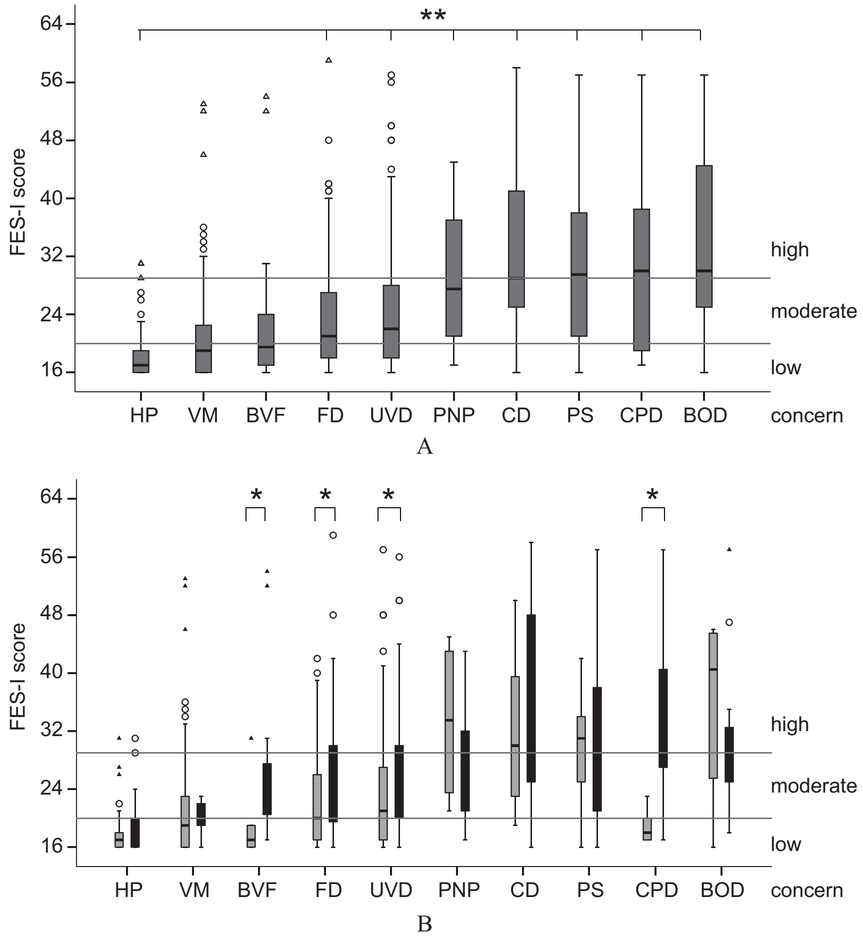

Fig. 3. Fear of falling. A) Results from healthy participants and patients in the disease-specific groups are presented as boxplot diagrams with median and upper/lower quartiles of the Falls Efficacy Scale-International scores. The majority of disease-specific groups showed higher FES-I scores than the group of healthy participants ($^{**}p < 0.006$). B) Results stratified by age, $<$ 65 years (light gray), $\geqslant$ 65 years (dark gray). In patients with functional and most peripheral disorders, older age increased the level of concern, whereas in patients with central disorders, age had no impact on the level of concern ($^{*}p < 0.05$). Abbreviations: BOD – brainstem ocular motor disorders, BVF – bilateral vestibular failure, CD – cerebellar disorders, CPD – combined peripheral disorders, FD – functional dizziness, HP – healthy participants, PS – Parkinsonian syndromes, PNP – peripheral neuropathy, VM – vestibular migraine, UVD – unilateral vestibular disorders.

vere fallers nor the median FES-I scores differed significantly between cerebellar patients with and without gait ataxia.

3.3.3. Subgroups of unilateral vestibular disorders

The proportions of recurrent fallers varied between 17 and 22% and the proportions of severe fallers ranged from 8 to 14%, with Menière's disease showing the lowest and unilateral vestibular hypofunction showing the highest percentage of fallers. Chi square tests detected no significant differences in the proportions of recurrent and severe fallers between the subgroups of Menière's disease, benign paroxysmal positional vertigo, unilateral vestibular hypofunction, or vestibular paroxysmia. Median FES-I scores varied between 20 and 25 points. The subgroup of unilateral vestibular hypofunction showed the highest, and the subgroup of vestibular paroxysmia showed the lowest FES-I values. The Kruskal-Wallis H test found no significant differences in the median FES-I scores between the subgroups.

4. Discussion

This is the first study on falls in a large cohort of patients who presented with key symptoms of vertigo

Table 3
Results of two logistic regression models. Analysis of the associations between the groups, age, gender and a) recurrent falling* and b) severe falling**

	Recurrent falling*			Severe falling**		
	Proportion of recurrent fallers, n (%)	Raw odds ratio (95% CI)	Adjusted odds ratio (95% CI)†	Proportion of severe fallers, n (%)	Raw odds ratio (95% CI)	Adjusted odds ratio (95% CI)†
Group						
Healthy participants	7/100 (7.0)	1	1	7/100 (7.0)	1	1
Parkinsonian syndromes	18/33 (54.5)	15.94 (5.70–44.63)	13.54 (4.68–39.16)	14/33	9.79 (3.46–27.50)	7.69 (2.62–22.50)
Cerebellar disorders	26/48 (54.2)	15.70 (4.67–29.18)	15.54 (5.90–40.93)	15/48 (31.3)	6.04 (2.26–16.12)	5.59 (2.07–15.05)
Brainstem ocular motor disorders	9/17 (52.9)	14.95 (4.40–50.81)	12.77 (3.71–43.89)	2/17 (11.8)	1.77 (0.34–9.35)	1.51 (0.28–8.09)
Combined peripheral disorders	4/13 (30.8)	5.91 (1.44–24.09)	5.32 (1.27–22.25)	1/13 (7.7)	1.12 (0.13–9.79)	0.85 (0.09–7.72)
Bilateral vestibular failure	6/20 (30.0)	5.7 (1.67–19.42)	5.51 (1.59–19.17)	2/19 (10.5)	1.56 (0.30–8.14)	1.41 (0.27–7.50)
Peripheral neuropathy	4/14 (28.6)	5.31 (1.32–21.36)	4.30 (1.04–17.83)	1/14 (7.1)	1.02 (0.17–8.99)	0.78 (0.09–7.10)
Unilateral vestibular disorders	12/68 (17.6)	2.85 (1.06–7.66)	2.71 (1.01–7.39)	6/68 (8.8)	1.29 (0.41–4.00)	1.13 (0.36–3.57)
Vestibular migraine	6/46 (13.0)	1.99 (0.63–6.30)	2.58 (0.79–8.47)	3/45 (6.7)	0.95 (0.23–3.85)	1.09 (0.26–4.59)
Functional dizziness	6/98 (6.1)	0.87 (0.28–2.68)	1.00 (0.32–3.14)	2/99 (2.0)	0.27 (0.06–1.35)	0.30 (0.06–1.51)
Age						
18–44	8/116 (6.9)	1	1	4/114 (3.5)	1	1
45–64	36/158 (22.8)	3.98 (1.77–8.94)	3.27 (1.34–7.82)	17/158 (10.8)	3.32 (1.09–10.14)	2.57 (0.81–8.19)
$\geqslant$ 65	54/183 (6.1)	5.65 (2.58–12.39)	3.07 (1.27–7.44)	32/184 (17.4)	5.79 (1.99–16.85)	3.27 (1.03–10.35)
Gender						
Male	53/221 (24.0)	1	1	25/221 (11.3)	1	1
Female	45/236 (19.1)	0.75 (0.48–1.17)	1.19 (0.71–2.00)	28/235 (11.9)	1.06 (0.60–1.89)	0.67 (0.37–1.15)

†Mutually adjusted for all other variables in the model; *At least two falls in the preceding 12 months; **Injurious falls requiring medical attention.

and dizziness. Besides faller rates and risk estimates, the study provides data on fear of falling in patients with vertigo and balance disorders.

The major findings of this study are: 1) Patients with central balance disorders are at a high risk of falls and are greatly concerned about falling (except patients with vestibular migraine). 2) Patients with peripheral sensory balance disorders are at a moderate risk of falls. Fear of falling is high in peripheral neuropathy but lower in peripheral vestibular disturbances. 3) Patients with functional dizziness are concerned about falling, although the actual fall rate is low.

4.1. *Falls in dizzy patients with central balance disorders*

In Parkinsonian, cerebellar and brainstem oculomotor ocular motor disorders, more than half of the patients experienced recurrent falls and more than 60% had fallen at least once. Similarly, high rates of fallers were found in previous work. Prospective data from the EuroSCA cohort showed that 85% of patients with spinocerebellar ataxias fell at least once a year [8]. A total 93% of patients with degenerative ataxias reported a history of falls within the previous year, and 50% experienced falls during a prospective 3-month interval [37]. A systematic review of Parkinson's disease showed that the prevalence of recurrent falls varies between 18 and 65%, mainly depending upon disease severity [3]. Within the spectrum of Parkinsonian syndromes, 77% of the patients fell during the course of the disease, ranging from 73% in Parkinson's disease to almost 100% in progressive supranuclear palsy and corticobasal degeneration [39]. The present study suggests that the risk of falls is similarly increased in patients with cerebellar disorders and basal ganglia movement disorders. Furthermore, patients with a downbeat nystagmus syndrome and other central vestibulo-ocular motor disturbances carry the same high risk of falls as patients with cerebellar ataxias.

Patients with Parkinsonian and cerebellar disorders were most prone to injurious falls, many of which required medical attention. Previous studies reported injurious falls in 25% of patients with Parkinson's disease within 3 months [28] and in 50% of patients with spinocerebellar ataxias within 1 year [8]. Difficulties while turning were found to specifically increase the risk of fall-related injuries in elderly people [27]. Impaired turning is a common feature in cerebellar ataxias [26,35] and Parkinson's disease [1,2], and may well also be a predictor for injurious falls in these patients. General preventive strategies for elderly people, such as reducing environmental hazards at home, wearing protective clothing and performing balance training [20], should be recommended to patients with central balance disorders. Beyond that, disease-specific fall prevention studies are necessary to decrease the risk of injuries.

Fear of falling was very pronounced in patients with central disorders. This is of clinical importance because falls and fear of falling were found to mutually reinforce each other, i.e., fear of falling can lead to an increased number of falls and vice versa [3,9]. Therefore, assessing fall-related anxiety and offering targeted coping interventions should be part of managing falls in these patients.

4.2. *Falls in dizzy patients with peripheral sensory disorders*

About one quarter of the patients with peripheral disorders were recurrent fallers, and at least one fall happened in about 40%. This is widely consistent with epidemiologic data from previous research. In peripheral vestibular hypofunction, 30% of the patients with a unilateral and 50% with a bilateral hypofunction had fallen since the onset of the disease [17]. A prospective trial on falls in peripheral neuropathy revealed that 40% of the patients experienced recurrent falls in a 12-month period [29]. The present study additionally proposes that falls occur in unilateral vestibular hypofunction, benign paroxysmal vertigo, Menière's disease, and vestibular paroxysmia alike. Moreover, faller rates and respective risk estimates are similar in patients with bilateral vestibular failure, peripheral neuropathy, and combined peripheral disorders.

Fear of falling was high in patients with peripheral neuropathy, suggesting a severe reduction in balance confidence due to the deficient sensory feedback from the lower legs. Patients with vestibular disturbances seemed to be less affected by fear of falls. However, older age was found to seriously increase the level of fall-related anxiety. Therefore, strategies to assess fall-related fear and promote balance confidence should be considered when treating peripheral neuropathy and elderly patients with vestibular disorders.

4.3. *Falls in functional dizziness*

Patients with functional dizziness were moderately concerned about falling despite the low fall prevalence. Gait changes, mainly a reduction in gait velocity, were found to be associated with fear of falling in phobic postural vertigo [30]. Based on these findings, prospective studies should investigate whether gait abnormalities can predict the emergence of fear of falling or vice versa and whether targeted gait training or cognitive-behavioral strategies effectively reduce fall-related anxiety in functional dizziness.

4.4. Study limitations

First, the assessment of fall events was retrospective and self-reported. This could have introduced recall bias resulting in an underestimation of the true faller rates [25]. Second, the recruitment procedure determined the sample size of the patient cohort. Therefore, some of the disease-specific groups provide only small sample sizes, particularly the groups peripheral neuropathy, bilateral vestibular failure, combined peripheral disorders, and brainstem ocular motor disorders. This may have affected the precision of prevalence and risk estimates as well as the statistical testing to detect group differences. Nevertheless, the results of this study show good consistency with data from previous studies (as described above) and provide the source information for designing prospective studies on the epidemiology and prevention of falls in disease-specific groups of patients with vertigo and balance disorders.

4.5. Consequences for the care of dizzy patients

Falls are alarmingly prevalent in patients with central balance disorders and, to a lesser extent, in patients with peripheral balance disorders. Fear of falling can manifest over the whole spectrum of disorders, including functional dizziness. Assessing, monitoring, and preventing falls and related fears needs to be integrated in the clinical management of vertigo and balance complaints. A practical approach is described within a guideline on multifactorial fall assessment [21]. Fall risk is strongly linked to gait problems [10]. One common gait characteristic in patients with bilateral vestibular failure, peripheral neuropathy, cerebellar ataxia, downbeat nystagmus syndrome, or Parkinson's disease is increased gait variability [16,31, 32,40]. This parameter was not only found to increase fall risk in the elderly [12–14] but also in cerebellar ataxias [33], peripheral neuropathy [40], and Parkinson's disease [15]. It, therefore, may serve as a useful measure for identifying future fallers within these patient groups. Prospective studies are needed to investigate such potential disease-specific risk factors, on the basis of which targeted fall prevention concepts could be developed.

Acknowledgements

This study was supported by the Federal Ministry of Education and Research in Germany (BMBF IFB 01EO1401). All authors declare that they have no conflict of interest to report.

The authors thank Judy Benson for copyediting the manuscript.

References

[1] S. Akram, J.S. Frank and M. Jog, Parkinson's disease and segmental coordination during turning: I. Standing turns, *Can J Neurol Sci* **40**(4) (2013), 512–519.
[2] S. Akram, J.S. Frank and M. Jog, Parkinson's disease and segmental coordination during turning: II. Walking turns, *Can J Neurol Sci* **40**(4) (2013), 520–526.
[3] N.E. Allen, A.K. Schwarzel and C.G. Canning, Recurrent falls in Parkinson's disease: a systematic review. Parkinsons Dis. 2013.
[4] T. Brandt, D. Huppert, M. Strupp et al., Functional dizziness: diagnostic keys and differential diagnosis, *J Neurol* **262** (2015), 1977–1980.
[5] M. Davalos-Bichara, F.R. Lin, J.P. Carey et al., Development and validation of a Falls-Grading Scale, *J Geriatr Phys Ther* **35** (2012), 1–5.
[6] S. Deandrea, E. Lucenteforte, F. Bravi et al., Risk factors for falls in community-dwelling older people: A systematic review and meta-analysis, *Epidemiology* **21** (2010), 658–668.
[7] K. Delbaere, J.C. Close, A.S. Mikolaizak et al., The Falls Efficacy Scale International (FES-I). A comprehensive longitudinal validation study, *Age Ageing* **39**(2) (2010), 210–216.
[8] E.M. Fonteyn, T. Schmitz-Hübsch, C.C. Verstappen et al., Prospective analysis of falls in dominant ataxias, *Eur Neurol* **69**(1) (2013), 53–57.
[9] S.M. Friedman, B. Munoz, S.K. West et al., Falls and fear of falling: which comes first? A longitudinal prediction model suggests strategies for primary and secondary prevention, *J Am Geriatr Soc* **50**(8) (2002), 1329–1335.
[10] D.A. Ganz, Y. Bao, P.G. Shekelle et al., Will my patient fall? *JAMA* **297**(1) (2007), 77–86.
[11] S.A. Greenberg, Analysis of measurement tools of fear of falling for high-risk, community-dwelling older adults, *Clin Nurs Res* **21**(1) (2012), 113–130.
[12] J.M. Hausdorff, H.K. Edelberg, M.E. Cudkowicz et al., The relationship between gait changes and falls, *J Am Geriatr Soc* **45** (1997), 1406
[13] J.M. Hausdorff, H.K. Edelberg, S.L. Mitchell et al., Increased gait unsteadiness in community-dwelling elderly fallers, *Arch Phys Med Rehabil* **78** (1997), 278–283.
[14] J.M. Hausdorff, D.A. Rios and H.K. Edelberg, Gait variability and fall risk in community-living older adults: a 1-year prospective study, *Arch Phys Med Rehabil* **82** (2001), 1050–106.
[15] J.M. Hausdorff, J.D. Schaafsma, Y. Balash et al., Impaired regulation of stride variability in Parkinson's disease subjects with freezing of gait, *Exp Brain Res* **149** (2003), 187–194.
[16] J.M. Hausdorff, Gait dynamics in Parkinson's disease: common and distinct behavior among stride length, gait variability, and fractal-like scaling, *Chaos* **19** (2009), 026113

[17] S.J. Herdman, P. Blatt, M.C. Schubert et al., Falls in patients with vestibular deficits, *Am J Otol* **21**(6) (2000), 847–851.

[18] B. Homann, A. Plaschg, M. Grundner et al., The impact of neurological disorders on the risk for falls in the community dwelling elderly: a case-controlled study, *BMJ Open* **3** (2013), 1–9.

[19] K. Hüfner, D. Barresi, M. Glaser et al., Vestibular paroxysmia: diagnostic features and medical treatment, *Neurology* **71**(13) (2008), 1006–1014.

[20] P. Kannus, H. Sievänen, M. Palvanen et al., Prevention of falls and consequent injuries in elderly people, *Lancet* **366**(9500) (2005), 1885–1893.

[21] R.A. Kenny, L.Z. Rubenstein, M.E. Tinetti et al., Summary of the updated American Geriatrics Society/British Geriatrics Society clinical practice guideline for prevention of falls in older persons, *J Am Geriatr Soc* **59**(1) (2011), 148–157.

[22] S.E. Lamb, E.C. Jørstad-Stein, K. Hauer et al., Development of a common outcome data set for fall injury prevention trials: the Prevention of Falls Network Europe consensus, *J Am Geriatr Soc* **53**(9) (2005), 1618–1622.

[23] T. Lempert, J. Olesen, J. Furman et al., Vestibular migraine: diagnostic criteria, *J Vestib Res* **22**(4) (2012), 167–172.

[24] J.A. Lopez-Escamez, J. Carey and W.H. Chung, Diagnostic citeria for Menière's disease, *J Vestib Res* **25**(1) (2015), 1–7.

[25] L. Mackenzie, J. Byles and C. D'Este, Validation of self-reported fall events in intervention studies, *Clin Rehabil* **20** (2006), 331–339.

[26] S. Mari, M. Serrao, C. Casali et al., Turning strategies in patients with cerebellar ataxia, *Exp Brain Res* **222**(1–2) (2012), 65–75.

[27] M.C. Nevitt, S.R. Cummings and E.S. Hudes, Risk factors for injurious falls: a prospective study, *J Gerontol* **46**(5) (1991), 164–170.

[28] R.M. Pickering, Y.A. Grimbergen, U. Rigney et al., A meta-analysis of six prospective studies of falling in Parkinson's disease, *Mov Disord* **22**(13) (2007), 1892–1900.

[29] J.K. Richardson, C. Ching and E.A. Hurvitz, The relationship between electromyographically documented peripheral neuropathy and falls, *J Am Geriatr Soc* **40**(10) (1992), 1008–1012.

[30] R. Schniepp, M. Wuehr, S. Huth et al., Gait characteristics of patients with phobic postural vertigo: effects of fear of falling, attention, and visual input, *J Neurol* **261**(4) (2014), 738–746.

[31] R. Schniepp, M. Wuehr, S. Huth et al., The gait disorder in downbeat nystagmus syndrome, *PLoS One* **9**(8) (2014), e105463.

[32] R. Schniepp, M. Wuehr, M. Neuhaeusser et al., Locomotion speed determines gait variability in cerebellar ataxia and vestibular failure, *Mov Disord* **27**(1) (2012), 125–131.

[33] R. Schniepp, M. Wuehr, C. Schlick et al., Increased gait variability is associated with history of falls in patients with cerebellar ataxia, *J Neurol* **261**(1) (2014), 213–223.

[34] M. Schwenk, A. Lauenroth, C. Stock et al., Definitions and methods of measuring and reporting on injurious falls in randomised controlled fall prevention trials: a systematic review, *BMC Med Res Methodol* **12** (2012), 501–514.

[35] M. Serrao, S. Mari, C. Conte et al., Strategies adopted by cerebellar ataxia patients to perform U-turns, *Cerebellum* **12**(4) (2013), 460–468.

[36] M.E. Tinetti, D. Richman and L. Powell, Falls efficacy as a measure of fear of falling, *J Gerontol* **45**(6) (1990), 239–243.

[37] B.P. Van de Warrenburg, J.A. Steijns, M. Munneke et al., Falls in degenerative cerebellar ataxias, *Mov Disord* **20**(4) (2005), 497–500.

[38] WHO, WHO global report on falls prevention in older age. Geneva, Switzerland: World Health Organization, 2007.

[39] D.R. Williams, H.C. Watt and A.J. Lees, Predictors of falls and fractures in bradykinetic rigid syndromes: a retrospective study, *J Neurol Neurosurg Psychiatry* **77**(4) (2006), 468–473.

[40] M. Wuehr, R. Schniepp, C. Schlick et al., Sensory loss and walking speed related factors for gait alterations in patients with peripheral neuropathy, *Gait Posture* **39**(3) (2014), 852–858.