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'Faster counting while walking' as a predictor of falls in older adults

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Abstract

Objective: to establish whether changes in a spoken verbal task performance while walking compared with being at rest could predict falls among older adults.
Design: prospective cohort study of 12 months' duration.
Setting: twenty-seven senior housing facilities.
Participants: sample of 187 subjects aged 75–100 (mean age 84.8 ± 5.2). During enrollment, participants were asked to count aloud backward from 50, both at rest and while walking and were divided into two groups according to their counting performance. Information on incident falls during the follow-up year was monthly collected.
Measurements: the number of enumerated figures while sitting on a chair and while walking, and the first fall that occurred during the follow up year.
Results: the number of enumerated figures under dual-task as compared to single task increased among 31.5% of the tested subjects ($n = 59$) and was associated with lower scores in MMSE ($P = 0.034$), and higher scores in Geriatric Depression Scale ($P = 0.007$) and Timed Up & Go ($P = 0.005$). During the 12 months follow-up, 54 subjects (28.9%) fell. After adjusting for these variables, the increase in counting performance was significantly associated with falls (adjusted OR = 53.3, $P<0.0001$). Kaplan–Meier distributions of falls differed significantly between subjects who either increased or decreased their counting performance ($P<0.0001$).
Conclusions: faster counting while walking was strongly associated with falls, suggesting that better performance in an additional verbal counting task while walking might represent a new way to predict falls among older adults.

Keywords: *dual-task, falls, cognitive performance, older adults*

Falls in the elderly are an important public-health problem. Around 50% of adults aged over 80 years suffer a fall at least once a year [1]. Falling leads to injuries [2, 3], hospitalisation [4, 5] and loss of independence [6] and imposes high costs to public health and social services. It has been shown that a wide range of fall prevention strategies are effective [1, 5, 7–9] in individuals at high risk for falling. The detection of an increased risk of sustaining a fall is essential for efficient fall prevention in the elderly.

A large proportion of falls in the elderly occurs while walking [10, 11]. The ability to adapt gait patterns to unexpected situations has an important role in the safety of gait. With advancing age, the addition of daily living activities to walking becomes more difficult and often turns into complex multi-task situations, thus increasing the risk of falls [12]. Changes in gait characteristics due to a simultaneously performed attention-demanding task have been reported frequently in the elderly [13] but associated only occasionally with an increased risk for falling [10]. Despite the development of dual-task-based fall risk assessment tests, findings about the relationship between dual-task-related gait changes and falls remain controversial [10].

Recent reviews have suggested that changes in dual-task-related performance mainly result from interference caused by competing demands for attention resources between gait and attention-demanding task performed while walking [10, 13]. Most dual-task-based fall risk assessment tests are focused on gait changes while performing a spoken verbal task used as attention-demanding task [10]. However, in such tests, spoken verbal task performance can change as well as gait performance. A few studies have reported performance in both of these tasks when performed simultaneously [14–16]. Yet no data exist on the relationship between change in spoken verbal task performance while walking and the occurrence of falls in the elderly. We hypothesised that changes in walking-associated spoken verbal task performance could be related to an increased risk for falling among older adults.

The aim of this study was to establish whether changes in a spoken verbal task performance while walking compared with being at rest could predict falls among older adults.

Methods

Study population

All residents aged 75 and older, living independently in 27 senior housing facilities in Saint-Etienne, a mid-sized town (approximately 250,000 inhabitants) in eastern France, were potentially eligible. Between 3 December 2001, and 3 September 2002, 1,080 eligible subjects were identified. After information meetings, 420 (38.9% of eligible population) residents agreed to participate and 187 (17.3% of eligible population) were included after having given their informed consent. A full medical evaluation was performed to rule out the following exclusion criteria: history of falls in the past year; acute medical illness in the past 3 months; neurological disease such as Parkinson's disease, cerebellar disease, myelopathy, peripheral neuropathy and severe cognitive impairment (Folstein's Mini Mental State Examination $<16/30$, [17]); severe depressive symptoms (score of the 15-items Geriatric Depression Scale >10, [18]); major orthopaedic diagnoses involving the lumber vertebra, pelvis or lower extremities; use of walking aids.

During baseline assessment the use of psychoactive drugs including benzodiazepines, antidepressants and neuroleptics, and the number of drugs taken per day were recorded. Basic mobility was assessed with the Timed Up & Go test [19]. Abnormal mobility was defined as a time $\geq$20 s. Cognitive impairment was defined as a MMSE score below 25. Participants were told that they participated to the development of a fall risk screening tool. The study was conducted in accordance with the ethical standards set forth in the Helsinki declaration (1983). The local ethics committee approved the project.

Procedures

The participants were asked to perform, in a randomised order, the following tasks to the best of their capacity: counting backward aloud starting from 50 while sitting on a chair or while walking. Before testing, a trained evaluator gave standardised verbal instructions regarding the test procedure with a visual demonstration of the walking test. Each subject completed one trial for all the testing conditions. The walking trial was performed on a 10-meter walkway in a well-lit environment. The subjects walked at their self-selected speed and wore their own footwear. To ensure safety, a belt was placed around each subjects' waist for easy grasp by a research assistant who walked behind the subjects during the walking trial. The trials were timed with a stopwatch to 0.01 s following a standard procedure. The enumerated figures were recorded with a tape recorder. We defined the number of enumerated figures while walking as the number achieved at completion of the 10 meters distance. The corresponding figure at rest was defined as the number of enumerated figures spoken during the same time than required for completion of the walking distance.

Follow-up

Information on incident falls during the follow-up year was collected by phone each month. A fall was defined as unintentionally coming to rest on the ground, floor, or other lower level. The date, the number, the characteristics, and consequences of falls were asked using a standardised questionnaire. In case of moderate cognitive impairment ($16<$ score MMSE <25), information on falls was obtained from a guardian, a nurse or a person who lived with the subject.

Outcome measures

The number of enumerated figures while sitting on a chair and while walking, as well as the first fall that occurred during the follow-up year were used as the primary outcome. At the end of the follow-up period, a counting performance score was defined in the protocol and calculated from the following formula: (number of enumerated figures while walking − number of enumerated figures while sitting). The result was applied to classify subjects into two groups: increase in counting performance while walking (i.e. >0) and decrease in counting performance while walking (i.e. ≤0).

Statistical analysis

The subjects' baseline characteristics were summarised using means and standard deviations or frequencies and percentages, as appropriate. Comparisons between both groups were performed using the independent samples *t*-test for continuous variables, and Chi-square test for categorical variables. The elapsed time to the first fall event was studied by survival curves computed according to the Kaplan–Meier method and compared by the log-rank test. Subjects were censored when they completed the 12-month follow-up. Uni- and multivariate logistic regression analyses were performed to specify the relationships between the occurrence of a first fall event during the follow-up and counting performance score coded as a binary variable, and the baseline characteristics that significantly differed between the two subjects' groups. *P*-values less than 0.05 were considered as statistically significant. All the statistics were performed using the Stata Statistical Software, release 9.2 [20].

Results

During the 12 months follow-up 6 (3.2%) subjects died, all after the first fall. All participants were able to complete single and dual-task, without falling. A majority of them (68.5%, $n = 128$) decreased their counting performance under dual-task as compared to single task (17.8 ± 5.9 single task figures versus 14.9 ± 5.1 dual-task figures, $P<0.0001$; counting performance score: −2.9 ± 3.0 figures), whereas 31.5% ($n = 59$) increased their counting performance (14.5 ± 6.3 single task figures versus 18.1 ± 7.2 dual-task figures, $P<0.0001$; counting performance score: +3.6 ± 2.3 figures). The baseline characteristics for both groups of subjects are summarised in Table 1. Subjects who had a higher counting performance while walking than sitting, i.e. a positive counting performance score, had significantly lower scores in MMSE ($P = 0.034$), and higher scores in both the 15-items Geriatric Depression Scale ($P = 0.007$) and Timed Up & Go Test ($P = 0.005$). There was no significant difference between the groups for the other baseline characteristics.

After 1 year of follow-up, 54 subjects (28.9%) reported a fall, the majority of them 46/59 (85.2%) belonging to those who increased their counting performance with only 8/128 (14.8%) falls occurring in the decreased counting performance group. As indicated in Table 2, the occurrence of falls was associated with an abnormal score (i.e. ≥20 s) at the Timed Up & Go Test (crude OR = 2.6, $P = 0.016$) and an increase in the number of enumerated figures while walking (crude OR = 53.0, $P<0.0001$). After adjusting for the MMSE score, 15-items Geriatric Depression Scale, and Timed Up & Go Test, only the increase in the number of enumerated figures while walking was significantly associated with falls (adjusted OR = 53.3, $P<0.0001$). The pseudo R2, the amount of variance explained by the model, was high (0.48). This logistic regression analysis was performed on 182 subjects because of missing data for the MMSE and 15-items Geriatric Depression Scale score respectively in 2 and 3 subjects. The specificity and the sensitivity were high (90.0%, 117/130; 86.5%, 45/52, respectively). The positive predictive value for falls related to a positive counting performance score amounted to 85.2% (46/54) and the negative predictive value was 90.2% (120/133). Kaplan–Meier's distributions of falls differed significantly between subjects who either increased or decreased their counting performance while walking (Figure 1, log-rank test 136.83, $P<0.0001$).

Discussion

Our results provide, to the best of our knowledge, the first evidence that improved performance in a spoken verbal task while walking compared with being at rest is strongly associated with the occurrence of falls among older adults.

Walking is an automated motor behaviour that is mostly controlled by subcortical regions [21]. Automaticity implies that gait can be performed without attention. However, changes in gait characteristics due to a simultaneously performed attention-demanding task such as spoken verbal tasks have been reported previously among older adults [13], suggesting an increasing involvement of attention in gait

Table 1. Base-line characteristics of subjects classified by changes in counting performance score

Characteristics	Counting performance score[a] Decrease ($n = 128$)	Increase ($n = 59$)	*P*-value[b]
Age, mean ± SD (years)	84.2 ± 5.3	86.1 ± 5.1	0.137
Female, *n* (%)	108 (84.4)	50 (84.7)	0.133
Number of drugs/day, mean ± SD	6.1 ± 2.8	6.4 ± 2.9	0.102
Sedative medications, *n* (%)	63 (49.2)	33 (55.9)	0.462
MMSE score (/30),			
Mean ± SD	25.4 ± 3.1	24.4 ± 3.2	0.034
<25, *n* (%)	61 (48)	37 (63.8)	0.054
GDS-15 score (/15),			
Mean ± SD	2.2 ± 1.8	3.1 ± 2.6	0.007
>4, *n* (%)	13 (10.4)	13 (22.0)	0.101
Timed 'Up & Go' (seconds)			
Mean ± SD	23.2 ± 8.0	26.2 ± 8.6	0.005
≥ 20	81 (63.3)	47 (79.7)	0.015

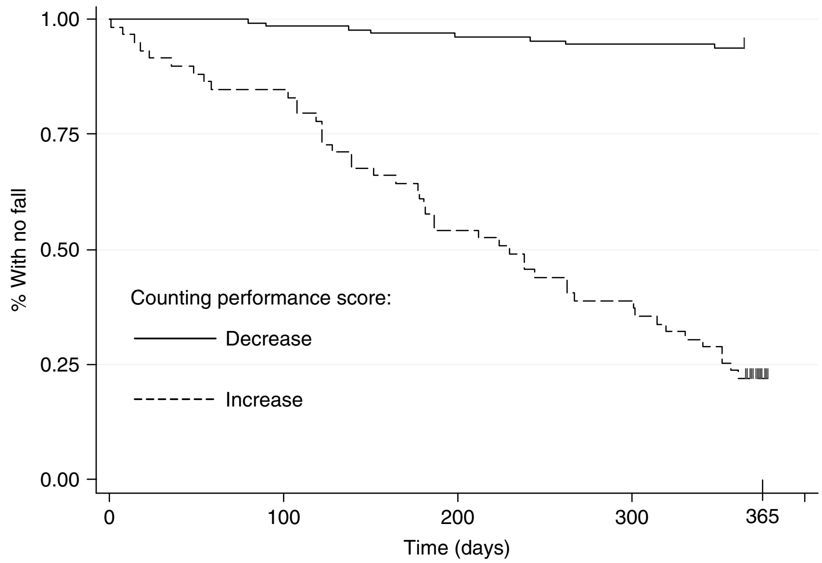
Abbreviations: SD, standard deviation; MMSE, Folstein's Mini Mental State Examination; GDS-15, 15 items form of Geriatric Depression Scale.
[a] Calculated from the formula (number of enumerated figures while walking − number of enumerated figures while sitting) and classified into two categories (increase (i.e. >0) and decrease (i.e. ≤0)).
[b] Based on independent samples *t*-test or chi-square test, as appropriate.

Table 2. Uni- and multivariate logistic regression predicting the occurrence of a first fall during the 1 year follow-up

Variable	Crude OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
MMSE <25	1.9 (0.9–3.7)	0.055	1.4 (0.5–3.8)	0.492
GDS-15 >4	2.0 (0.8–4.7)	0.105	1.3 (0.3–4.8)	0.716
Timed Up & Go ≥20 s	2.6 (1.2–5.6)	0.016	2.4 (0.7–7.4)	0.145
Increase in counting performance[a]	53.0 (20.6–136.3)	<0.0001	53.3 (19.5–145.4)	<0.0001

Abbreviations: OR, odds ratio; CI, confident interval; MMSE, Folstein's Mini Mental State Examination (max 30); GDS-15, 15 items form of Geriatric Depression Scale (max 15).

[a] Calculated from the formula (number of enumerated figures while walking − number of enumerated figures while sitting) and classified into two categories (increase (i.e. >0) and decrease (i.e. ≤0)).



Number at risk

Counting performance score:

Decrease	128	126	123	121	120
Increase	59	50	32	23	13

Figure 1. Kaplan–Meier estimates of the probability of sustaining a first fall during the 1 year follow-up according to counting performance score.

control with normal aging. Further, there is some evidence about a possible relationship between dual-task-related gait changes and the risk for falling [10]. In 1997, Lundin-Olsson *et al.* [22] were the first to establish a link between the inability to walk and talk at the same time and the occurrence of falls. This simple screening test dependably predicted falls in the studied sample of older adults. However, despite the development of other similar dual-task-based fall risk assessment tests, findings about the relationship between dual-task-related gait changes and falls remain controversial [10].

Recent reviews have suggested that dual-task-related gait changes mainly result from interference caused by competing demands for attentional resources between gait and spoken verbal tasks [10, 13]. All the dual-task-based fall risk assessment tests have focused on dual-task-related gait changes [10], in order to predict falls. Only one cohort study by Bootsma-van der Wiel [14] has reported older subjects' performance in a walking-associated spoken verbal task, consisting in the enumeration of animal names or professions, but without establishing a relationship with the occurrence of falling risk. Bootsma-van der Wiel's study showed that the number of enumerated words while walking was always lower than the number of enumerated words while performing the enumerating task alone in fallers and non-fallers. Furthermore, the performance on verbal fluency task was significantly lower under single and dual-task conditions in fallers compared with non-fallers. In agreement with these findings, a majority of participants in our study sample (68.5%, $n = 128$) actually decreased their counting performance while walking. The risk of falls was low in this group. Fifty-nine subjects (31.5%) increased their counting performance while walking and surprisingly had a significantly higher risk of falling compared to their counterparts. The relationship between faster counting while walking and falls was remarkably strong compared to other common risk factors for falls [23], with an adjusted odds ratio of 53.3. Moreover, subjects who had a positive counting performance score, had a high sensitivity, specificity and positive predictive value for falls, suggesting that change in spoken verbal task performance while walking might be a new way to identify older adults prone to falling. In addition, our dual-task test is simple and requires no specific equipment that makes it easy for application in general practice.

The positive counting performance score could be explained by two complementary approaches. First, we hypothesise that the specific features of the spoken verbal task selected for our study explain this particular behaviour of older adults who are prone to fall. Although both the verbal fluency task used in Bootsma-van der Wiel's study and our counting backward task are spoken verbal tasks, they differ at least in one characteristic: compared to enumerating words, counting backward is a task that includes a strong rhythmic component. Walking is also a rhythmic motor behaviour. It has been shown that two simultaneously performed rhythmic activities can strongly influence each other. With regard to walking, Ebersbach *et al.* [24] have found significant decreases of gait cycle duration in association with a simultaneous faster finger-tapping task, interpreted as a 'magnet effect', which is a term used to describe the tendency of biological oscillators to attract each other. In our study, older adults who were prone to fall showed a similar behaviour by increasing their counting performance while walking.

Secondly, change in gait or in cognitive performance while dual-tasking results from interference interpreted as an involvement of attention in gait control [13]. Two categories of interferences have been established. One results from a central overload due to an involvement of different processes of information requiring attention and is called capacity interference [25]. The interference shown in the subjects who did not fall in our study may be explained by this theoretical approach because counting and walking are two tasks that use different processes. Gait is a motor task, whereas mental calculation is a cognitive task essentially related to the working memory [15]. In contrast to the capacity interference, the cross-talk models are based on peripheral overload and assume that a task similarity reduces interference leading to better performance [25]. This model could explain the increase in cognitive performance while walking compared with sitting in subjects who fell.

The successful combination of two rhythmic tasks leading to an overall improved performance might have some importance for the design of fall-prevention interventions. It has been shown that irregular gait, characterised by a high stride-to-stride variability, is associated with a high risk for falling in the elderly [13, 25, 27]. For example, a small increase in stride-to-stride variation of stride length of 0.017 m doubled the likelihood of future falling during the next 6 months [25]. It is therefore most likely that fallers in our sample had irregular gait while walking alone. By combining the two rhythmic tasks of walking and backward counting, fallers might not only have a positive counting performance score but also enhanced their gait regularity. We recently reported that regular long-term practice of Jacques-Dalcroze eurhythmics, consisting of varied multi-task exercises performed to the rhythm of improvised piano music, resulted in low gait variability while both walking alone and dual-tasking [28]. Further research is needed to explore the potential role of eurhythmics in fall prevention among older adults.

Our study has several limitations. First, the studied older adults might not be representative of all older adults because they lived in senior housing facilities. We targeted a relatively healthy subgroup of institutionalised elders for two main reasons. The common fall risk assessment models show relatively poor performance and are not easy to apply in general practice [4, 23]. Furthermore, we developed a dual-task fall risk assessment to be used for primary fall prevention. The first fall represents a key event for an older adult due to fall-related adverse outcomes [1, 4]. Preventing the first fall among older adults could avoid or delay fall-related adverse outcomes and, therefore, improve quality of life and reduce costs of health and social services [1]. Secondly, another limitation could be related to the motivation of participants who were probably more motivated and showed greater interest in health issues and the risk of falling than the general population of older adults who live in independent senior living facilities. Thirdly, our results represent the first evidence that a higher counting performance while walking than sitting in a spoken verbal task is strongly associated with the occurrence of falls among older adults, and therefore, need to be confirmed by future studies with larger samples and in other settings. Fourthly, the prevalence of falls in our study was low (28.9%) as compared to previous studies showing a prevalence around 50% among adults aged over 80 years [1–4]. Approximately 50% of participants had a cognitive impairment in our study. Therefore, a recall bias could be evoked because cognitively impaired older adults may underreport falls [29].

In conclusion, in this sample of independent older adults, improved counting performance while walking compared with counting performance alone was strongly associated with the occurrence of falls, suggesting that improved performance in a simultaneous counting task while walking might be a new, inexpensive way to identify older adults with high falling risk. Further research is needed to confirm the association between falls and performance changes in other walking-associated tasks to validate the improvement in counting performance as a predictor for falling in the elderly.

Key points

- Dual-task-related gait changes mainly result from interference caused by competing demands for attentional resources between gait and spoken verbal tasks.
- Despite the development of dual-task-based fall risk assessment tests, findings about the relationship between dual-task-related gait changes and falls remain controversial.

- Improved performance in a spoken verbal task while walking compared with being at rest is strongly associated with the occurrence of falls among older adults.

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Role of the Sponsor

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Conflict of interest statement

We declare that we have no conflict of interest.

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