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Which Method of Fall Ascertainment Captures the Most Falls in Prefrail and Frail Seniors?

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There is no consensus on the most reliable method of ascertaining falls among the elderly. Therefore, we investigated which method captured the most falls among prefrail and frail seniors from 2 randomized controlled trials conducted in Zurich, Switzerland: an 18-month trial (2009–2010) including 200 community-dwelling prefrail seniors with a prior fall and a 12-month trial (2005–2008) including 173 frail seniors with acute hip fracture. Both trials included the same methods of fall ascertainment: monthly active asking, daily self-report diary entries, and a call-in hotline. We compared numbers of falls reported and estimated overall and positive percent agreement between methods. Prefrail seniors reported 499 falls (fall rate = 2.5/year) and frail seniors reported 205 falls (fall rate = 1.4/year). Most falls (81% of falls in prefrail seniors and 78% in frail seniors) were reported via active asking. Among prefrail seniors, diaries captured an additional 19% of falls, while the hotline added none. Among frail seniors, the hotline added 16% of falls, while diaries added 6%. The positive percent agreement between active asking and diary entries was 100% among prefrail seniors and 88% among frail seniors. While monthly active asking captures most falls in both groups, this method alone missed 19% of falls in prefrail seniors and 22% in frail seniors. Thus, a combination of active asking and diaries for prefrail seniors and a combination of active asking and a hotline for frail seniors is warranted.

aged; ascertainment methods; diaries; falls; frailty; hotlines; seniors

Abbreviations: CI, confidence interval; MMSE, Mini-Mental State Examination; OR, odds ratio; PPA, positive percent agreement; RCT, randomized controlled trial; SD, standard deviation.

Falls are common among older adults, with 28%–35% of community-dwelling seniors aged 64 years or more suffering at least 1 fall per year (1) and 60% suffering recurrent falls in the subsequent year (2). While most often falls contribute to minor injuries, such as bruises or scrapes (3), 6% of falls lead to fractures (4), 9% lead to emergency room visits, and 30% cause fear of falling, with resulting restrictions in mobility and quality of life (5). Finally, 40% of all nursing home admissions are due to a fall (6), and falls are an independent predictor in functional decline (7). Thus, falls contribute to a substantial personal and health economic burden (8). In 2015, the total cost of fatal and nonfatal injury due to falls among US seniors aged 65 years or more was $68.8 million (9). Therefore, recognizing and reducing fall events in America's growing senior population remains a primary public health target.

Agreement on the definition of a fall event and on optimal methods of fall ascertainment is instrumental, as it has a substantial impact on the incidence of falls and on the assessment of interventions associated with falls as an outcome measure (10–12). While there is international agreement on the definition of a fall event (13), there is no agreement on a gold standard for fall ascertainment methods. Several methods have been proposed for monitoring falls among community-dwelling seniors, including recall via telephone or face-to-face interviews and prospective recording using fall calendars or diaries (12, 14–16). While prior studies relied on recall at different intervals (17), the Prevention of Falls Network Europe has proposed prospective assessment and a minimum of monthly reporting (18), based on the important observation that falls tend to be forgotten, especially if they are not associated with major injury (19). Several

previous studies suggested that retrospective recall produces fewer falls than prospective data collection (20–22) and that the length of the recall period can have considerable effects on the comprehensiveness of fall ascertainment (17). In fact, the accuracy of 12-month fall recall may decrease from 80% to 20% among seniors who fell on 3 or more occasions during that period (11).

The population to be studied also plays an important role in the selection of fall assessment methods. While most studies have focused on community-dwelling seniors, fewer studies have compared fall ascertainment methods among institutionalized seniors (23–27) and in general among those at high risk of falling (28). Only 1 study evaluated 2 fall assessment methods (automatic phone vs. calendar) among frail seniors; those authors concluded that once-a-week phone calls were more reliable and better accepted than fall calendars (29).

Despite prior efforts to compare fall ascertainment methods, there is still no consensus on the best method for fall assessment and whether the same recommendations apply to healthy seniors and those at high risk of falling. Moreover, a direct head-to-head comparison of several prospective ascertainment methods in high-risk populations is still missing. Therefore, our objective in this study was to assess which of 3 different prospective ascertainment methods (monthly active asking, dairies, or a hotline) best captures most falls among prefrail and frail seniors.

METHODS

Settings and participants

We used data from 2 randomized controlled trials (RCT) conducted at the Centre on Aging and Mobility, University of Zurich (Zurich, Switzerland): the Zurich Disability Prevention Trial (2009–2010; clinicaltrials.gov identifier NCT01017354) (2), whose participants are hereafter referred to as "prefrail seniors," and the Early Rehabilitation After Hip Fracture Study (2005–2008; clinicaltrials.gov identifier NCT00133640) (30), whose participants are hereafter referred to as "frail seniors."

The first trial, carried out among prefrail seniors, enrolled 200 community-dwelling seniors aged 70 years or more and compared outcomes for 3 monthly oral doses of vitamin D3: 24,000 IU/month, 60,000 IU/month, or a combination of 24,000 IU/month and calcifediol (300 μg/month) (2). The duration of follow-up was 12 months with a 6-month open follow-up after the double-blinded trial phase, with clinical visits at baseline, 6 months, and 12 months. During the 6-month open follow-up period, participants also received a monthly telephone call, with a final telephone call at month 18. The primary outcome of this trial was functional decline, and the secondary outcome was falls. Given the frailty status of participants, 20 participants died before the end of the study and 48 dropped out for medical reasons. However, we used all of the information obtained prior to death or dropout in our analysis.

The second trial, carried out among frail seniors, enrolled 173 acute hip fracture patients aged 65 years or more and compared outcomes for 2 daily doses of vitamin D3 (800 IU/day vs. 2,000 IU/day) with or without a simple home exercise program (30). The duration of follow-up was 12 months, with clinical visits at baseline, 6 months, and 12 months. Falls were the primary outcome of this trial.

Assessment of study population characteristics

Comorbid conditions were assessed with the Charlson comorbidity index (31), and cognitive function was assessed with Folstein et al.'s Mini-Mental State Examination (MMSE) (32). To be eligible in the original trial, prefrail seniors had to reach an MMSE score of ≥27 points and frail seniors had to reach a score of ≥15 points.

Fall definition and fall ascertainment methods

For both RCTs, falls were defined according to the criteria of the Frailty and Injuries: Cooperative Studies of Intervention Techniques (FICSIT) Trials as "unintentionally coming to rest on the ground, floor or other lower level that excludes coming to rest against furniture, wall, or other structure" (13, p. 301). Coming to rest against furniture or a wall was not counted as a fall (13). In both studies, falls were assessed in 3 ways: by "active asking" by a study nurse via monthly phone calls or clinical visits at 6, 12, and 18 months; by a fall hotline where participants could phone any time to report a fall; and by a daily diary filled in by the participants whenever a fall occurred. For frail seniors, the hotline could also be used by caregivers. Each fall report was assessed with a standardized fall protocol in both RCTs administered by a trained study nurse to document the date and circumstances of the fall and related injuries. For this study, falls identified through any of these 3 sources were aggregated and considered to constitute the population of total falls. To minimize double counting, during the monthly phone calls and clinical visits, participants were additionally asked about their diaries and hotline reports, and falls that were reported for the same day were considered as 1 fall despite the reporting method. We estimated the number of participants classified as fallers as those reporting any falls during the follow-up period using any of the 3 methods.

Statistical analyses

Baseline characteristics, including age, sex, body mass index (weight (kg)/height $(m)^2$), living situation, MMSE score, and comorbid conditions, were determined by population of origin. Fall rates were estimated as the total number of falls divided by the length of follow-up in days (until the end of the study, dropout, or death) and were further divided by 365 for estimation of yearly rates. We used Venn diagrams to analyze the number of fall events ascertained through each method to identify which combination included the most falls. We estimated the total number of fall events and the total number of missed falls by method, and then we compared the disagreement between methods using McNemar's test. Using the total number of fall events as a reference, we estimated positive percent agreement (PPA) between reporting methods, overall agreement between reporting methods, and the kappa (κ) statistic. We estimated Wald asymptotic confidence intervals for the PPA based on the normal approximation to the binomial distribution. We conducted the same analyses for the total population, comparing the total number of fallers (persons reporting any falls during the follow-up period) by assessment method, and estimated agreement between groups.

As an exploratory analysis, we evaluated the association between the characteristics of fallers (age, comorbidity, and

cognitive status) and the characteristics of the falls (time of day, first fall vs. recurrent fall, presence of injuries) by reporting method using binary logistic regression, clustering by patient given the repeated fall events per person. In the analysis of fallers, the population was all study subjects and the binary outcome was whether a study subject experienced a fall or not. In the analysis of falls, the "population" was all falls detected by any of the 3 methods, and the outcome was whether that fall had been detected by monthly active asking or not (followed by a separate binary logistic regression analysis with the outcome of whether that fall was detected by diary or not or by hotline or not). All analyses were performed using SAS statistical software, version 9.4 (SAS Institute, Inc., Cary, North Carolina), with a statistical significance level of $P = 0.05$ (2-sided).

RESULTS

Baseline characteristics are presented in Table 1. Prefrail seniors (i.e., those who reported a previous fall) had a mean age of 78 (standard deviation (SD), 5) years, and 67% were women. Frail seniors (i.e., those with a previous hip fracture) had a mean age of 84 (SD, 7) years, and 79% were women. While all prefrail seniors were community-dwelling, among frail seniors only 80% of men and 77% of women were community-dwelling prior to their hip fracture. Notably, cognitive function as measured by the MMSE score was lower in frail seniors than in prefrail seniors (Table 1).

Falls among prefrail seniors

A total of 499 fall events were reported among prefrail seniors within 18 months of follow-up (mean = 362 (SD, 31) days). Thirty-four percent of seniors reported more than 1 fall during the study period. Among the 200 prefrail seniors, the overall fall rate was 2.5 falls per year (same rates for men and women). The majority of all fall events (81%; $P < 0.001$) were reported by monthly active asking (i.e., a monthly phone call plus a clinical visit), followed by the diary method (61%); only 5 falls were reported by hotline (1%) (upper half of Table 2; Figure 1A). While 42% of all falls were reported by more than 1 method, only 0.8% of falls were reported by all 3 methods simultaneously (Figure 1A). The percentage of missed falls was 19% when relying on active asking alone, 39% for the diary method, and 99% for the hotline (Table 2, top). Similarly, a total of 147 participants reported a fall; 136 fallers (93%) were identified through active asking, 117 (80%) were identified through diaries, and 5 (3%) were identified through the hotline (Table 2, bottom). Overall, active asking was significantly better in identifying falls/fallers than the diary and hotline methods. Comparing the diary and hotline methods, diaries identified more falls/fallers than the hotline ($P < 0.0001$ for both) (Table 2).

Falls among frail seniors

A total of 205 fall events were reported among frail seniors within 12 months of follow-up (mean = 312 (SD, 129) days). Among the 173 frail seniors, the overall fall rate was 1.4 falls per year (1.2 falls/year for men and 1.4 falls/year for women). The majority of fall events were reported by monthly active asking (78%; $P < 0.001$), followed by diaries (45%) and the hotline (37%) (Table 2, Figure 1B). Forty-seven percent of all falls were reported by more than 1 method, and 12% were reported by all 3 methods simultaneously (Figure 1B). The percentage of missed falls was 22% for monthly active asking, 55% for diaries,

Table 1. Baseline Characteristics of Prefrail Seniors From the Zurich Disability Prevention Trial and Frail Seniors From the Early Rehabilitation After Hip Fracture Study, Switzerland, 2005–2010

Baseline Characteristic	Prefrail Seniors (With a Fall Event) ($n = 200$)			Frail Seniors (With a Hip Fracture) ($n = 173$)		
	Mean (SD)	No.	%	Mean (SD)	No.	%
Age, years	77.7 (5.0			84.2 (6.9)		
Body mass index[a]	26.2 (4.0)			24.3 (4.3)		
MMSE score	28.6 (1.0)			24.7 (3.7)		
Mean CCI score	0.6 (0.9)			2.6 (1.9)		
Discrete CCI score						
0		127	63.8		18	10.5
1		40	20.1		32	18.7
2		25	12.6		40	23.4
≥3		7	3.5		81	47.4
Female sex		134	67.0		137	79.2
Living situation						
At home		200	100.0		134	77.5
Assisted living		0	0.0		29	16.8
Nursing home		0	0.0		10	5.8

Abbreviations: CCI, Charlson comorbidity index; MMS, Mini-Mental State Examination; SD, standard deviation.
[a] Weight (kg)/height (m)^2.

Table 2. Numbers of Fall Events and Numbers of Subjects Who Fell as Reported by 3 Different Methods, Zurich Disability Prevention Trial (Prefrail Seniors) and Early Rehabilitation After Hip Fracture Study (Frail Seniors), Switzerland, 2005–2010

Ascertainment Method	Total				Reported Uniquely by This Method		Comparison With Other Methods[a]					
	Reported		Missed				Active Asking		Diary		Hotline	
	No.[b]	%	No.	%	No.	%	Categorization	*P* Value	Categorization	*P* Value	Categorization	*P* Value
							Fall Events					
Prefrail seniors ($n = 499$ falls)												
Active asking	405	81	94	19	195	39		N/A	Significantly better	<0.0001	Significantly better	<0.0001
Diary	303	61	196	39	94	19	Significantly worse	<0.0001		N/A	Significantly better	<0.0001
Hotline	5	1	494	99	0	0	Significantly worse	<0.0001	Significantly worse	<0.0001		N/A
Frail seniors ($n = 205$ falls)												
Active asking	160	78	45	22	70	34		N/A	Significantly better	<0.0001	Significantly better	<0.0001
Diary	92	45	113	55	13	6	Significantly worse	<0.0001		N/A		0.09
Hotline	75	37	130	63	25	12	Significantly worse	<0.0001		0.09		N/A
							Subjects Who Fell					
Prefrail seniors ($n = 147$ fallers)												
Active asking	136	93	11	7	29	20		N/A	Significantly better	0.003	Significantly better	<0.0001
Diary	117	80	30	20	11	7	Significantly worse	0.003		N/A	Significantly better	<0.0001
Hotline	5	3	142	97	0	0	Significantly worse	<0.0001	Significantly worse	<0.0001		N/A
Frail seniors ($n = 92$ fallers)												
Active asking	74	80	18	20	24	26		N/A	Significantly better	<0.0001	Significantly better	<0.0001
Diary	48	52	44	48	5	5	Significantly worse	<0.0001		N/A		0.31
Hotline	41	45	51	55	10	11	Significantly worse	<0.0001		0.31	N/A	N/A

Abbreviation: N/A, not applicable.

[a] Reported fall rates were compared using McNemar's test.

[b] Number of fall events (upper half of table) or number of subjects who fell (lower half of table).

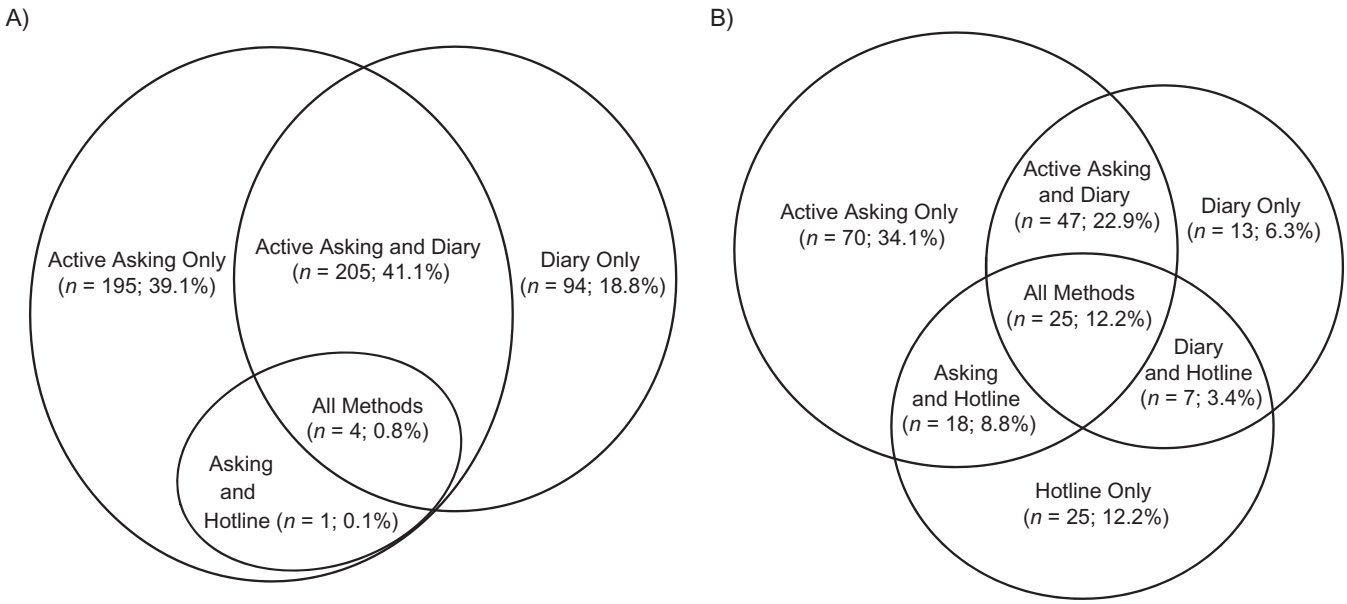

Figure 1. Categorization of fall events by reporting method for prefrail seniors (A) and frail seniors (B), Switzerland, 2005–2010. Prefrail seniors reported 499 fall events (405 by active asking, 303 by diary, and 5 by hotline). Frail seniors reported 205 fall events (160 by active asking, 92 by diary, and 75 by hotline).

and 63% for the hotline (Table 2). Similarly, a total of 92 participants reported a fall; 74 fallers (80%) were identified through active asking, 48 (52%) were identified through diaries, and 41 (45%) were identified through the hotline (Table 2, bottom). Overall, active asking was significantly better in identifying falls/fallers than the diary method and better than the hotline. Comparing the diary and hotline methods, there were no significant differences between methods ($P = 0.31$).

Agreement (combining fall assessment methods)

Among prefrail seniors, the PPA between the total number of falls and active asking alone was 81%, and for the diary method alone it was 61%. Adding diaries to active asking increased the PPA to 100%, whereas adding the hotline to active asking did not increase the PPA (PPA = 81%). Use of diaries and the hotline had a PPA of 61% compared with the total number of falls. Similar results were observed for the analyses of fallers versus nonfallers, where diaries and active asking had a PPA of 100% compared with the total number of fallers (lower half of Table 3). There was low agreement between methods in the analyses of fall events (upper half of Table 3), but in the analyses of fallers, there was moderate agreement between active asking and diaries ($\kappa = 0.56$ (asymptotic standard error, 0.06); Table 3, bottom).

Among frail seniors, the PPA between the total number of fallers and active asking alone was 78%, and for diaries alone it was 45%. Adding diaries to active asking increased the PPA to 88%, whereas adding the hotline to active asking increased the PPA even more (PPA = 94%). Use of diaries and the hotline together had a PPA of 66% as compared with the total number of falls (Table 3, top). Similar results were observed for the analyses of fallers versus nonfallers, but the PPA for diaries and the hotline versus the total number of fallers was higher (PPA = 80%). Overall, the agreement between methods was low for the analyses of falls and moderate for the analyses of fallers (for diaries vs. active asking, $\kappa = 0.48$ (asymptotic standard error, 0.07)).

Characteristics of falls and selection of reporting method

In the analyses of fall events (Table 4, top), falls reported by active asking were less likely to include falls from patients with comorbidity (odds ratio (OR) = 0.82, 95% confidence interval (CI): 0.69, 0.97) and less likely to include falls occurring in the morning versus at other times of the day (OR = 0.34, 95% CI: 0.17, 0.66). In contrast, falls reported by hotline were more likely to include falls from patients with more comorbidity (OR = 1.68, 95% CI: 1.38, 2.04). No significant differences were observed for characteristics of falls reported by diary. In addition, there was no significant difference between any method of reporting and falls that led to minor or major injuries.

In the analyses of fallers (Table 4, bottom), fallers identified by the diary method were younger (OR = 0.93, 95% CI: 0.89, 0.97) and had higher cognitive function (OR = 1.12, 95% CI: 1.02, 1.24), whereas fallers identified by the hotline had a greater number of comorbid conditions (OR = 1.52, 95% CI: 1.23, 1.88) and lower cognitive function (OR = 0.86, 95% CI: 0.77, 0.97).

DISCUSSION

To our knowledge, this was the first study comparing 3 different methods of prospective fall ascertainment among both frail and prefrail seniors. Over 18 months of follow-up, 499 fall events

Table 3. Agreement Between Fall Assessment Methods, Zurich Disability Prevention Trial (Prefrail Seniors) and Early Rehabilitation After Hip Fracture Study (Frail Seniors), Switzerland, 2005–2010

Ascertainment Method	No. Reported[a]	PPA	95% CI	Overall Agreement	κ (ASE)
Fall Events					
Prefrail seniors ($n = 499$ falls)					
Diary alone	303	61	56, 65	N/A	N/A
Active asking alone	405	81	78, 85	N/A	N/A
Diary and active asking	499	100	100, 100	0.42	−0.34 (0.03)
Hotline and active asking	405	81	78, 85	0.20	0.005 (0.002)
Diary and hotline	304	61	57, 65	0.40	0.01 (0.01)
Frail seniors ($n = 205$ falls)					
Diary alone	92	45	38, 52	N/A	N/A
Active asking alone	160	78	72, 84	N/A	N/A
Diary and active asking	180	88	83, 92	0.47	0.004 (0.05)
Hotline and active asking	192	94	90, 97	0.27	−0.26 (0.06)
Diary and hotline	135	66	59, 72	0.50	−0.03 (0.07)
Subjects Who Fell					
Prefrail seniors ($n = 147$ fallers)					
Diary alone	117	80	73, 86	N/A	N/A
Active asking alone	136	93	87, 97	N/A	N/A
Diary and active asking	147	100	100, 100	0.80	0.56 (0.06)
Hotline and active asking	136	93	88, 97	0.35	0.02 (0.01)
Diary and hotline	118	80	74, 87	0.42	0.02 (0.02)
Frail seniors ($n = 92$ fallers)					
Diary alone	48	52	42, 62	N/A	N/A
Active asking alone	74	80	72, 89	N/A	N/A
Diary and active asking	82	89	83, 95	0.76	0.48 (0.07)
Hotline and active asking	87	92	87, 96	0.66	0.26 (0.07)
Diary and hotline	68	80	74, 87	0.73	0.29 (0.08)

Abbreviations: ASE, asymptotic standard error; CI, confidence interval; N/A, not applicable; PPA, positive percent agreement.

[a] Number of fall events (upper half of table) or number of subjects who fell (lower half of table).

were reported among 200 prefrail seniors, and over 12 months of follow-up, 205 fall events were reported among 173 frail seniors. The majority of fall events were captured by the monthly active asking method in both populations, with active asking being significantly better than diaries and hotlines among frail and prefrail seniors. However, relying on this method alone would have contributed to underreporting of falls by 19%–22%. Thus, for optimal ascertainment of falls in prefrail and frail seniors, more than 1 method may be needed to capture most fall events. Our study supports a combination of monthly active asking and diaries among prefrail seniors and a combination of monthly active asking and diaries or a hotline among frail seniors. Notably, on the basis of our findings, relying on a diary/calendar alone, as previously suggested for community-dwelling seniors (21), may be an insufficient method of fall ascertainment in prefrail and frail seniors, missing 39% of all fall events in prefrail seniors and 55% in frail seniors, despite the monthly collection of diaries.

Previous studies that compared the use of retrospective phone calls with other methods have observed varying sensitivity (31%–97%) and specificity (91%–99%) in comparison with diaries or fall calendars, depending on the length of the recall period (14, 17). However, the use of different ascertainment methods prevents direct comparison between studies (12). With regard to high-risk populations, only 1 small previous study carried out among frail seniors aged 69–86 years ($n = 15$) compared the performance of daily fall calendars mailed every 2 weeks with that of automated phone calls made once a week for 3 months (29). While participants reported that both methods were easy to use, they preferred the phone calls to calendars, as they found calendars more burdensome. Moreover, about 25% of calendars were lost or incomplete (29). This finding suggests that directly asking people about falls by phone may be more reliable than using diaries/calendars among frail seniors, in contrast to several previous studies of community-dwelling (21) and younger (17) seniors in which diaries/calendars appeared to work well (17).

To date, there is no consensus on the best assessment method for falls (14). Thus, given the lack of a gold standard, we estimated PPA instead of sensitivity (33), using the total number of

Table 4. Characteristics of Fall Events[a] and of Subjects Who Fell[b], by Reporting Method, Zurich Disability Prevention Trial (Prefrail Seniors) and Early Rehabilitation After Hip Fracture Study (Frail Seniors), Switzerland, 2005–2010

Characteristic	Fall Ascertainment Method					
	Active Asking		Diary		Hotline	
	OR	95% CI	OR	95% CI	OR	95% CI
	Fall Events					
Age, years	0.98	0.92, 1.05	0.96	0.92, 1.01	1.03	0.97, 1.10
CCI score	0.82	0.69, 0.97	0.93	0.79, 1.09	1.68	1.38, 2.04
MMSE score	1.07	0.97, 1.20	1.05	0.94, 1.16	0.94	0.83, 1.07
First fall vs. recurrent falls	1.29	0.69, 2.43	1.19	0.86, 1.66	1.18	0.68, 2.03
Falls occurring indoors at home vs. outdoors	1.15	0.58, 2.68	0.92	0.61, 1.40	1.96	1.04, 3.67
Falls occurring in morning vs. other times of day	0.34	0.17, 0.66	1.14	0.73, 1.77	1.06	0.48, 2.34
	Subjects Who Fell					
Age, years	0.96	0.90, 1.01	0.93	0.89, 0.97	1.02	0.96, 1.09
CCI score	0.93	0.73, 1.18	0.97	0.80, 1.17	1.52	1.23, 1.88
MMSE score	1.11	0.98, 1.26	1.12	1.02, 1.24	0.86	0.77, 0.97

Abbreviations: CCI, Charlson comorbidity index; CI, confidence interval; MMSE, Mini-Mental State Examination; OR, odds ratio.

[a] A total of 565 fall events were reported by means of active asking, 395 fall events were reported by diary, and 80 fall events were reported by hotline.

[b] A total of 209 subjects reported falls by means of active asking, 165 reported falls by diary, and 46 reported falls by hotline.

falls/fallers as the reference. Among prefrail seniors, the PPA was highest for the combination of diaries and active asking (PPA = 100%), whereas use of a hotline and active asking was not better than active asking alone. Among frail seniors, use of a hotline and active asking had the highest PPA. In both groups, there was moderate agreement between diaries and active asking in the analyses of fallers ($\kappa = 0.57$ and $\kappa = 0.48$ among prefrail and frail seniors, respectively), although agreement was lower than in a previous study comparing calendars with quarterly telephone surveys among seniors of similar age (21).

Put together, monthly active asking and diaries captured supposedly all falls occurring among prefrail seniors but missed 12% of falls occurring among frail seniors, where the hotline was the second-best method. Additonally, there was a difference in hotline use among prefrail seniors (1%) and frail seniors (37%); this could be explained by the higher proportion of participants who had caregivers in the first year after their acute hip fracture, who were able to call the hotline at all times and felt more responsible for doing so. This is further supported by the fact that falls reported by hotline were significantly more likely to include seniors with more comorbidity or lower cognitive function. In contrast, falls reported by diary were more likely to include seniors with higher cognitive function. Thus, reporting by diary was possibly preferred in the prefrail group, as they were younger and had higher MMSE scores.

Notably, among both prefrail and frail seniors enrolled in our study, monthly active asking was the method by which most falls were reported. While active asking relies on recall over the preceding 4 weeks, prospective calendars might be burdensome for seniors, as previously reported (29). Nonetheless, monthly active asking missed 19% of falls in prefrail seniors and 22% in frail seniors. Thus, a combination of active asking and diaries may provide more comprehensive fall assessment, especially among prefrail seniors. However, using several methods simultaneously is time- and cost-intensive, especially in large and long-term trials and cohort studies. Moreover, all 3 methods still rely on self-reporting. Alternatively, objective ascertainment methods such as wearable technological devices (emergency call systems like wrist sensors, accelerometers) may be attractive solutions but still need validation (34). However, seniors may find these devices intimidating or decline to use them, since the devices may identify them as fallers (35).

Our study had several strengths. First, to our knowledge, it was the first study to compare 3 different prospective methods of fall ascertainment among seniors at high risk of falling—that is, prefrail seniors with a previous fall event and frail seniors with a previous hip fracture. Second, to minimize reporting bias, our study staff in both original RCTs was trained in standardized fall data survey methods and application of the same fall protocol documenting the circumstances and injuries related to the fall event, thus reducing interviewer bias. This ensured standardized data collection across both RCTs. Further, we used an internationally accepted definition of falls (13); thus, differences in interpretation of a fall event were likely to have been minimal. Finally, our sample was larger than those in previous studies addressing fall ascertainment methods among groups at high risk for falls (28, 29).

There were also limitations to our study. One limitation inherent to the study population of prefrail and frail seniors was that the original trials from which our population was derived had different exclusion criteria for low cognitive function (MMSE scores <15 and <25 for the frail and prefrail populations, respectively). Cognitive function was shown to influence fall recall in a prior study of community-dwelling seniors aged 60 years or

older (19). In that study, among seniors with an MMSE score below 24, 36% did not recall a fall, as compared with 9% who did not recall a fall among seniors with an MMSE score of 27 or more (19). While our frail subgroup had lower mean cognitive function (mean MMSE score: men = 24.4, women = 24.8) than the prefrail subgroup (mean MMSE score: men = 28.5, women = 29.7), there were no significant differences in the MMSE scores between fallers and nonfallers in either subgroup or between those who reported falls by hotline and those who reported falls by other methods among frail seniors (data not shown). In support of the findings of Cummings et al. (19), prefrail seniors had slightly higher agreement on falls reported by diaries and active asking in comparison with frail seniors (PPA = 0.52 vs. PPA = 0.45), but this difference was not significant.

Another limitation was the minimal use of the hotline as a fall ascertainment method among prefrail seniors in our study; only 1% of them used this option as compared with 37% among frail seniors. However, this also indicates that prefrail seniors prefer a diary to a hotline as an immediate fall ascertainment method. Our findings may not be generalizable to healthy seniors with a lower risk of falls. Finally, because we used 3 different methods for fall assessment, the true number of falls remains unknown, since under- or overreporting was still possible. The main reasons for underreporting include unrecognized falls due to trivialization (36) and memory problems (37). Overreporting has been found in several studies (11, 21, 22) that have considered calendars as a gold standard; thereby falls reported by phone calls but not included in the calendars were considered examples of "telescoping" or "positive expectation bias" due to being part of a clinical study (22).

In summary, our results support monthly active asking as the most comprehensive method of fall ascertainment in both prefrail and frail seniors. However, even with monthly active asking as an individual method, about 20% of falls were missed in both prefrail and frail seniors—falls which were captured by a second method. Notably, relying on diaries alone as the second-best individual method led to underreporting of 39% of falls among prefrail seniors and 55% among frail seniors. Having a hotline available among frail seniors allowed investigators to capture falls that would otherwise have been missed by active asking or the diary method. Nonetheless, to allow the field of fall ascertainment to move forward, similarly to former efforts to describe osteoporosis (38), a reference standard for the description of falls needs to be defined. On the basis of this study, we suggest that among prefrail and frail seniors, the reference standard for use in all trials against which other methods can be compared is monthly active asking.

In conclusion, in our study of seniors at high risk of falling, monthly active asking was the most comprehensive method of fall ascertainment. However, fall ascertainment may be further enhanced by about 20% if monthly active asking is combined with a second method: diaries among prefrail seniors and a hotline among frail seniors.

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