Chapter 7

The FARE: a new way to express FAlls Risk among older persons including physical activity as a measure of Exposure

Wijlhuizen GJ, Chorus AMJ, Hopman-Rock M.

Submitted
Abstract

Objectives
Many commonly used ways to express falls risk do not include exposure to hazards. We compared two expressions of falls risk among community dwelling older persons: the commonly used population incidence (fallers per 1000 person-years) and the new FAlls Risk by Exposure (FARE), expressed as the number of fallers per 1000 physically active person-days.

Methods
Prospective follow-up study among community dwelling older persons (N=771). Baseline data on age, gender, disabilities (vision, mobility), and number of days per week with minimally 30 minutes of physical activity were collected. Falls were registered monthly. Falls risk was expressed as the number of falls per 1000 person-years and as the number of falls per 1000 physically active person-days (FARE). A balance control difficulty score was based on the sumscore of 11 disability items.

Results
Increased difficulty controlling balance was linearly associated with reduced exposure to risky situations (Spearman correlation coefficient = -.56) and to an increased falls risk per 1000 person-years. In contrast, the FARE score increased exponentially.

Conclusions
The FARE is recommended for use in public health policy and research on falls prevention because it takes into account the risk compensation behavior of older persons who experience increased difficulty controlling their balance.
Introduction

From a general perspective, accident or injury risk is the probability of having an accident or injury per unit of exposure. A unit of exposure can be regarded as a trial, which can result in the occurrence or non-occurrence of an accident or injury. The risk of accident or injury can be expressed in several ways. For example, the population incidence (number of cases per 1000 person-years), but also the number of cases per 1000 person-hours of involvement in related activities, or with regard to traffic, the number of cases per 1000 person-miles driven. The denominator in each of these latter expressions is a measure of exposure to the hazard that is involved in participation in the activity.

The significance of using exposure data in risk analysis was addressed by Hale and Glendon. “If a person carries out a particular activity many times and occasionally it goes wrong enough to result in an accident, very different interventions will be necessary to improve matters, compared with instances where a person carries out an activity infrequently, but it almost always goes wrong. Data on the exposure to the hazard or on demands for specific actions must therefore form as fundamental a part of the analytical database of health and safety as records of accidents and occupational diseases.” However, exposure data are often not measured in studies of falls among older persons. The risk of falls is commonly expressed as the number of falls or fallers per 1000 person-years, as recommended by Gillespie and Lamb. Nevertheless, Todd and Skelton addressed the role of exposure when discussing risk factors: “Some studies suggest a U-shaped association, that is, the most inactive and the most active people are at the highest risk of falls. This reveals the complex relationship between falls, activity, and risk. The type and extent of environmental challenges that an older person chooses to embrace interact with the person’s intrinsic risk factors.” According to Skelton and Jorstad-Stein et al., while exercise has a beneficial effect on a person’s balance, it can also be considered a general measure of that person’s exposure to hazardous situations that put demands on that person’s ability to control balance. Indeed, some studies found indications that increased physical activity was associated with an increased falls incidence per 1000 persons-years. Wijlhuizen et al. found that outdoor falls occurred more often among persons who walked and bicycled more frequently, and Ebrahim et al. reported that brisk walking may increase the risk of falls. Therefore, a measure of the level of physical activity could be an appropriate measure of exposure to falls. This is supported by the observation that older persons tend to reduce their level of physical activity as they become afraid of falling. Thus reducing exposure to hazards could be seen as a behavioral response to perceived difficulties controlling balance in order
to maintain balance control. This tendency to reduce exposure to hazards may be reinforced by the person feeling less unsure of their balance when fewer demands are made on their ability to maintain balance. In fact, the person seems to be preventing falls and also perceives this as a way of preventing falls.

From the perspective of public health, this tendency to reduce exposure to challenging situations has two important consequences. First of all, when identifying persons at risk of falls (per 1000 person-years), persons will not be classified as being at risk as long as they are able to reduce exposure sufficiently to compensate for their difficulty in controlling balance. Secondly, in the long-term, reducing exposure to hazards contributes to inactivity, which contributes to increased and probably more complex problems in controlling balance, ultimately increasing the risk of falls. The complexity of the balance control problems will require relatively complex multifactorial interventions to prevent future falls, interventions that have not been proven to reduce falls related fractures or other injuries that are perceived as a major public health problem.

Therefore, a new way to express the risk of falls among older individuals is needed that incorporates physical activity as a measure of exposure. This expression takes into account the tendency of older persons to reduce exposure to hazards as their difficulty controlling balance increases. Thus the risk of falling will increase if a person reduces their physical activity even if their falls incidence per 1000 person-years does not increase.

The objective of this study is to compare and discuss two expressions of falls risk among community dwelling older persons: the commonly used population incidence (fallers per 1000 person-years) and the new FAAlls Risk by Exposure (FARE), expressed as the number of fallers per 1000 physically active person-days.

**Methods**

**Subjects**
A questionnaire was sent to 2500 community dwelling older persons aged 71 and older in Heerenveen and Drachten (middle-sized Dutch towns). The subjects were randomly drawn from the local registry office from four stratified age (five years) categories. Older subjects were overrepresented in the sample because a higher non-response was expected among these individuals. All subjects, mean age of 80.1 years and 40% men, were asked to participate in a prospective follow-up study; 771 (31%) agreed to participate (figure 1).
Subjects who received the baseline questionnaire:
N = 2500
Mean age: 80.1
Men: 40%

Respondents who participated from the start of the follow-up:
N = 771 (31%)
Mean age: 79.3
Men: 42%

Respondents included in the analysis:
N = 704 (28%)
Mean age: 79.1
Men: 42%

Figure 1  Flow chart showing the stages in the study procedure and numbers of subjects and respondents by age and gender

Falls, balance control difficulty, and physical activity
The baseline questionnaire contained questions about age, gender and specific disabilities (difficulty with nearby vision, distant vision, carrying a 5 kilo bag for 10 meters, walking 400 meters without stopping, independent use of the toilet, bending to pick up an object, getting out of bed, walking across rooms at the same level, getting up from a chair, walking stairs, walking after getting out of bed). The level of difficulty performing each activity was scored as (1) no, (2) moderate, (3) severe difficulty, (4) not able to perform. In addition, at baseline questions were asked about the number of days a week in which subjects were physically active at a moderate level (such as brisk walking or bicycling) for at least 30 minutes, separately for summer and winter\(^{26}\) as a measure of exposure. At follow-up, for 10 months all subjects were automatically telephoned monthly by a computer system using voice recognition technology, and asked for involvement in falls. If a fall was reported, within a week a personal telephonic interview was held about the circumstances of the fall (e.g.: time and location). The procedure is described in more detail in Wijlhuizen et al.\(^{27}\)
Statistical Analysis

Subjects with a missing value for one of the disability items or the exposure measure were excluded from analysis. The number of persons who fell at least once inside or outside the home during day-time (from 8 a.m. to 12 p.m.) was taken as an indicator of the risk of falling; falls occurring at night were excluded.

The indicator of the difficulty controlling balance was calculated by summing the difficulty scores (1 to 4) for the 11 disability items, based on findings from Era et al. The total score for balance control difficulty varied from 11 (no difficulty on all items) to 38 (not able to perform almost all of the activities). Four categories were constructed, taking into account the skewness of the distribution of difficulty scores:

1. No difficulty (scores: 11-14; n=365, 52%)
2. Slight difficulty (scores: 15-19; n=177, 25%)
3. Moderate difficulty (scores: 20-25; n=110, 16%)
4. Severe difficulty (scores: 26-38; n=52, 7%)

The exposure measure was constructed by summing the number of days a week, in summer and winter, that a person was physically active for minimally 30 minutes; the score ranged from 0 to 14. We then assigned a score 1 to those subjects reporting 0 physically active days, because zero physical activity (including low intensity level) was assumed not realistic for most community dwelling individuals. Therefore, an exposure score of 1 indicates that a subject is physically active for 30 minutes less than 1 day a week, in summer or winter. Subsequently, the number of physically active days in an average week over a year was computed by dividing the range of 1 to 14 physically active days by two; resulting in a range of exposure of 0.5 to 7 days.

The association between the level of balance control difficulty and exposure was computed, using the Spearman rank correlation. As outcome measures, we calculated falls risk in two ways, namely, based on the ratio between the number of fallers in each category per 1000 person-years, and per 1000 physically active person-days (the FARE) in this category. For both expressions, the falls risk ratios were computed using the ‘no balance control difficulty’ group as a reference group.

Results

In total 771 community dwelling persons (42% men) aged between 71 and 96 years (mean age men: 79.4 (sd 4.3), women: 79.2 (sd 4.3)) participated in the follow-up period of 10 months. In total, 205 persons fell 376 times in 771*10/12 person-years; an incidence of 319 fallers per 1000 person-years. Between 8 a.m. and 12 p.m., 176 persons fell at least once; an incidence of 274 per 1000 person-years. Among the 704 respondents who were included in the analysis (figure 1), 42% were men (n=294); mean age for men was 79.3 (sd=4.1) and for women 79.0 (sd=4.3), as shown in table 1.
Table 1  
*Subjects included in the analysis by age and gender*

<table>
<thead>
<tr>
<th>Age</th>
<th>Men N (%)</th>
<th>Women N (%)</th>
<th>Total N (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>71-75</td>
<td>50 17%</td>
<td>96 23%</td>
<td>146 21%</td>
</tr>
<tr>
<td>76-80</td>
<td>148 50%</td>
<td>189 47%</td>
<td>337 48%</td>
</tr>
<tr>
<td>81-85</td>
<td>73 25%</td>
<td>96 23%</td>
<td>169 24%</td>
</tr>
<tr>
<td>86+</td>
<td>23 8%</td>
<td>29 7%</td>
<td>52 7%</td>
</tr>
<tr>
<td>Total</td>
<td>294 100%</td>
<td>410 100%</td>
<td>704 100%</td>
</tr>
</tbody>
</table>

The level of difficulty of performing the various disability items is presented in table 2. ‘Independent use of the toilet’ and ‘Walking across rooms at the same level’ were least frequently reported as difficult (over 90% reported no difficulty), whereas ‘Carrying a 5 kilo bag for 10 meters’, ‘Walking 400 meters without stopping’, and ‘Walking stairs’ were most frequently reported as difficult to perform (between 21% and 31% reported at least severe difficulty).

We then computed the indicator of balance control difficulty. Among the 704 respondents, in total 154 daytime fallers and 2762 physically active person-days were recorded (see table 2).
### Table 2
Results of baseline questionnaire (disability, physical active person-days) and follow-up falls registration (number of fallers during daytime, per 1000 person-years and per 1000 physically active person-days; the FARE)

<table>
<thead>
<tr>
<th>Disability item</th>
<th>No (1)</th>
<th>Moderate (2)</th>
<th>Severe (3)</th>
<th>Not able (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearby vision (reading small words)</td>
<td>460 (65%)</td>
<td>164 (23%)</td>
<td>39 (6%)</td>
<td>41 (6%)</td>
</tr>
<tr>
<td>Distant vision (recognizing face)</td>
<td>590 (83%)</td>
<td>82 (12%)</td>
<td>12 (2%)</td>
<td>20 (3%)</td>
</tr>
<tr>
<td>Carrying a 5 kilo bag for 10 meters</td>
<td>357 (51%)</td>
<td>127 (18%)</td>
<td>38 (5%)</td>
<td>182 (26%)</td>
</tr>
<tr>
<td>Walking 400 meters without stopping</td>
<td>381 (54%)</td>
<td>153 (22%)</td>
<td>34 (5%)</td>
<td>136 (19%)</td>
</tr>
<tr>
<td>Independent use of the toilet</td>
<td>656 (94%)</td>
<td>44 (6%)</td>
<td>2 (0%)</td>
<td>2 (0%)</td>
</tr>
<tr>
<td>Bending to pick up an object</td>
<td>420 (60%)</td>
<td>191 (27%)</td>
<td>52 (7%)</td>
<td>41 (6%)</td>
</tr>
<tr>
<td>Getting out of bed</td>
<td>605 (87%)</td>
<td>86 (12%)</td>
<td>10 (1%)</td>
<td>3 (0%)</td>
</tr>
<tr>
<td>Walking across rooms at the same level</td>
<td>640 (91%)</td>
<td>52 (7%)</td>
<td>7 (1%)</td>
<td>5 (1%)</td>
</tr>
<tr>
<td>Getting up from a chair</td>
<td>577 (82%)</td>
<td>106 (15%)</td>
<td>18 (3%)</td>
<td>3 (0%)</td>
</tr>
<tr>
<td>Walking stairs</td>
<td>404 (58%)</td>
<td>151 (21%)</td>
<td>56 (8%)</td>
<td>93 (13%)</td>
</tr>
<tr>
<td>Walking after getting out of bed</td>
<td>451 (64%)</td>
<td>217 (31%)</td>
<td>36 (5%)</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level of balance control difficulty**</th>
<th>No (11-14)</th>
<th>Slight (15-19)</th>
<th>Moderate (20-15)</th>
<th>Severe (26-38)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subjects N (%)</td>
<td>365 (52%)</td>
<td>177 (25%)</td>
<td>110 (16%)</td>
<td>52 (7%)</td>
<td>704 (100%)</td>
</tr>
<tr>
<td>Fallers at daytime N (%)</td>
<td>60 (39%)</td>
<td>37 (24%)</td>
<td>34 (23%)</td>
<td>23 (14%)</td>
<td>154 (100%)</td>
</tr>
<tr>
<td>Physically active person-days N (%)</td>
<td>1865 (68%)</td>
<td>643 (23%)</td>
<td>206 (7%)</td>
<td>48 (2%)</td>
<td>2762 (100%)</td>
</tr>
<tr>
<td>Mean per person per week</td>
<td>5.1</td>
<td>3.6</td>
<td>1.9</td>
<td>0.9</td>
<td>3.9</td>
</tr>
<tr>
<td>Fallers Per 1000 person-years N</td>
<td>197</td>
<td>251</td>
<td>371</td>
<td>531</td>
<td>263</td>
</tr>
<tr>
<td>Risk ratio***</td>
<td>1.0</td>
<td>1.3</td>
<td>1.9</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>Fallers Per 1000 physically active person-days N (the FARE)</td>
<td>32</td>
<td>58</td>
<td>165</td>
<td>479</td>
<td>56</td>
</tr>
<tr>
<td>Risk ratio***</td>
<td>1.0</td>
<td>1.8</td>
<td>5.2</td>
<td>15.0</td>
<td></td>
</tr>
</tbody>
</table>

* Due to missing data the Total N=704 differs from the total number of subjects that participated (N=771), and the number of fallers (176). Each level of difficulty received a quantification (1) to (4).

** Based on sumscore of the level category quantifications over the 11 disability items (ranging from 11 to 38)

*** Category 'No difficulty' is taken as reference category.

The mean level of physical activity, expressed as the number of days that respondents were physically active for at least 30 minutes in an average week (table 2), was 3.9 days (sd = 2.5). Individuals who reported no difficulty controlling their balance were
about 5 times more active than those who reported severe difficulty controlling their balance (mean 5.1 physically active days versus 0.9 physically active days, respectively). The level of balance control difficulty was inversely associated with the number of physically active days; Spearman -.56; p<.000, indicating that the association was significantly different from zero.

Regardless of the method used to express the falls risk, (number of fallers per 1000 person-years and per 1000 physically active person-days), the risk of falls increased with increasing difficulty controlling balance. However, when expressed as the number of fallers per 1000 physically active person-days (the FARE), the risk of falling increased exponentially compared with the linear increase when the risk of falling was expressed as falls risk per 1000 person-years.

Figure 2  Relative risk of becoming a faller during daytime with increasing difficulty in controlling balance expressed per 1000 person-years and 1000 physically active person-days (the FARE).

Discussion

Comparison of two ways of expressing falls risk revealed different patterns of risk as balance control difficulty increased. The falls risk, per 1000 person-years, increased linearly, whereas the Falls Risk by Exposure (FARE), expressed as the number of fallers per 1000 person-days with at least 30 minutes of physical activity, increased...
exponentially with difficulty controlling balance. The exponential increase of the FARE was due to the strongly reduced physical activity (exposure) among subjects who reported increased difficulty controlling balance. This reduction in exposure can be interpreted as a behavioral mechanism whereby subjects try to remain in control of their balance as they experience increased difficulty controlling balance. By avoiding involvement in certain physical activities, they reduce demands on their balance control.\textsuperscript{19,21,22} By reducing exposure to potentially hazardous (risk of falling) situations, subjects succeed in reducing their falls risk substantially from a relative strong exponential to a moderate linear increase as balance control difficulty increases. This finding questions the suitability of the falls risk measure expressed per 1000 person-years because it is insensitive to exposure reduction among subjects who experience balance control difficulty.

In addition, the level of exposure differed widely among the participants, with subjects without balance control difficulties being about 5 times more active than subjects with great difficulty controlling balance. The insensitivity of the commonly used falls risk measure (expressed per 1000 person-years) to these large variations in falls exposure may have important consequences for the interpretation of data and for public health policy on falls prevention. First of all, this insensitivity results in a large and systematic underestimation of falls risk, compared with that calculated with the FARE expression. It seems to imply that factors that affect balance control among older subjects do not appear to increase their falls risk per 1000 person-years, as persons apparently compensate by reducing exposure to hazards. This might explain the inconsistent findings for the association between measures of balance control and falls per 1000 person-years.\textsuperscript{29} In addition, falls risk expressed in this way is not sensitive to changes in exposure that result from interventions that influence risk factors for falls.\textsuperscript{10,11} If a falls prevention intervention, for instance balance and mobility training, results in an improved ability to control balance and increased physical activity, but not in a reduction in falls per 1000 person-years, this intervention is generally perceived as being ineffective.\textsuperscript{30}

Apart from the issue of sensitivity of the commonly used measure of falls risk, the data presented in figure 2 illustrate that older subjects are quite effective in reducing their falls risk by reducing physical activity. However, this beneficial effect on falls risk is only temporary because reduced physical activity will reduce their balance control capability in the long term.\textsuperscript{31} Therefore, subjects who do not fall but strongly reduce their physical activity should also be targeted for falls prevention interventions. They might mask their reduced balance control capability and put themselves at high risk of falling in the future as their balance control capability is reduced to such a level that a further reduction in physical activity is not feasible (e.g.: as getting out of a chair becomes very difficult).
The FARE expression, in which the number of cases (N) is divided by a related measure of exposure (E); FARE = N/E, can be applied to other situations (at home or outside the home), time of day, or activities (e.g.: walking outside the home, bicycling, climbing stairs). While the FARE can be calculated at a population level, as was done in this paper, it can also be applied to indicate the falls risk at the individual level, which is required for performing regression analyses. Then, the outcome measure in falls risk analysis should be the number of falls or being a faller or not, divided by exposure (e.g.: the number of physical active days) of each individual.

**Limitations**

In order to prevent the falls risk from becoming zero or infinite, two restrictions are required. The first is that respondents who have zero exposure should be excluded from analysis. Conceptually, this restriction is sound if one considers the situation in which the risk of falling from a bicycle is studied and one includes subjects who do not bicycle at all. Those who do not bicycle, and therefore do not fall from a bicycle, might actually have chosen to stop bicycling because of their perceived balance control difficulty. Including these persons in the analyses might strongly reduce the contrasts between fallers and non-fallers. The second restriction relates to the number of falls or fallers (N) in the equation. At the individual level non-fallers should be coded as 1. Those who did fall should be coded as 2 (or higher if their number of falls is higher than one). In this case, FARE = (1+N)/E. Thus subjects with the lowest falls risk were those who did not fall (N=0) and who were physically active 7 days a week (value is 7); their falls risk was 1/7=.14. In contrast, subjects with the highest falls risk are those who fell once or more often (N=1 or higher) and who were inactive (value=.5 in our study); their falls risk was 2/.5=4 or higher.

At the population level, the number of falls or fallers can be put in the equation if they are greater then 0. If the number of falls or fallers equals zero, one should add one fall or faller identical to the equation at the individual level. In our study, we used the self-reported number of days in which subjects were at least 30 minutes physically active as the measure of physical activity. The current availability of these data in some national physical activity statistics, and the relative ease of obtaining these data are important advantages for using this measure as a general indicator of physical activity. On the other hand, the reliability of self-reported physical activity data needs to be evaluated because there is currently no established measure of physical activity.

The suggested measure of exposure, the number of person-days with at least 30 minutes of physical activity, is not applicable to falls that happen at night (from
12 p.m. to 8 a.m.), because these falls generally happen as subjects are asleep and get out of their beds. The frequency of getting out of bed at night might be a feasible exposure measure, because it is easy to measure (asking subjects) and it involves physical activity.

The balance control variable was used in this study as an example of a potential risk factor for falls to illustrate the differences in risk ratios as presented in figure 2. Replication or comparison of both expressions of falls risk is recommended for other known risk factors for falls, such as medication use or vision disability. The exposure and balance control data were obtained at baseline and falls were reported during follow-up. This limits the reliability of findings because falls, exposure, and balance control data are combined to express the falls risk. To increase reliability, exposure and balance control data should be monitored more frequently during follow-up.

Conclusions

The number of falls per 1000 person-years (as commonly used) does not adequately reflect the falls risk of older individuals because it does not take into account large differences between the level of physical activity of older individuals. Therefore we formulated a new expression of falls risk, the Falls Risk by Exposure (FARE), which includes the level of physical activity as a measure of exposure. The FARE is recommended because it takes into account the risk compensation behavior of older persons who experience increased difficulty controlling balance and reduce their physical activity level. For public health policy for falls prevention, this measure implies that persons at risk for falls can be identified more adequately. Also in the evaluation of falls prevention programs, the impact on falls risk can be determined taking into account the possible changes in exposure due to interventions that improve balance control among persons at risk for falls.
Literature

12. Todd C, Skelton D. What are the main risk factors for falls among older people and what are the most effective interventions to prevent these falls? Copenhagen, WHO Regional Office for Europe (Health Evidence Network report; http://www.euro.who.int/document/E82552.pdf, accessed [day month year]) 2004.
