Mobility has a non-linear association with falls risk among people in residential aged care: an observational study

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Questions: What is the association between mobility and falls risk for people living in residential aged care? Can the Physical Mobility Scale discriminate between residents at risk of falling and those not at risk? Design: Prospective longitudinal observational study. Setting: Six residential aged care facilities in Australia. Participants: Eighty-seven high- and low-level care permanent residents. Outcome measures: The primary outcome measure was the number of falls in the six months after the initial mobility assessment. Mobility of all participants was assessed using the Physical Mobility Scale, which includes nine mobility items assessed on a 0–5 scale yielding a total score out of 45. Results: During the six-month study period, 131 falls were reported. Residents with mild mobility impairment (Physical Mobility Scale total score 28–36) had the highest fall risk (hazard ratio = 1.98, 95% CI 1.30 to 3.03). Residents with fully dependent mobility (Physical Mobility Scale total score 0–9) had the lowest risk for falls (HR = 0.05, 95% CI 0.01 to 0.32). Conclusion: Aged care residents with mild mobility impairment are at increased risk of falls and are an appropriate target for falls prevention strategies. Although improving the mobility of residents with moderate to severe mobility impairment may enhance their independence and reduce their burden on staff, paradoxically this may also increase their risk of falls. When these residents improve enough to progress into a higher category of mobility, physiotherapists should be aware that this may increase the risk of falls and should consider instituting appropriate falls prevention strategies. [Barker AL, Nitz JC, Low Choy NL, Haines TP (2012) Mobility has a non-linear association with falls risk among people in residential aged care: an observational study. Journal of Physiotherapy 58: 117–125]

Key words: Aged, Nursing homes, Outcome assessment (health care), Mobility limitation, Accidental falls

Introduction

Falls in older people are an endemic problem and are frequent events for many older people living in residential aged care (Berry et al 2007). In this setting, falls occur more frequently than among older people living in the community (Chen et al 2005, Kehinde 2009). The consequences of falls in this population are often traumatic, precipitating almost 90% of all fractures, and are also the most common injury-related cause of death (Kryzziannik et al 2002). Several factors contribute to increased falls risk in this setting. These are typically classified as intrinsic (factors attributable to the individual) or extrinsic (factors attributable to the environment). More than 50 intrinsic falls risk factors have been identified by past research in the residential aged care setting (Barker 2008). Reduced mobility, including deficits in static and dynamic balance and deficits in strength, was associated with an increased risk of falling in several studies (Granacher et al 2011). Mobility is included as a risk factor item on many tools for assessing falls risk (Barker et al 2009, Lundin-Olsson et al 2000, Morse 2006, Rosendahl et al 2008, Young et al 1989) and several balance and mobility measures have been proposed as useful screening tools for falls risk in residential aged care (Lundin-Olsson et al 2003, Rockwood et al 2000, Thapa et al 1996).

The substantial growth in falls prevention research over the last decade has highlighted inconsistencies in the association between mobility and falls risk in residential aged care. Some studies report that residents with greater mobility impairment are at increased risk of falling (Avidan et al 2005, French et al 2007, Kiely et al 1998, Kron et al 2003, Nordin et al 2008), while others report a decreased risk (Becker et al 2005, Delbaere et al 2008, Kallin et al 2002, Kerse et al 2004, van Doorn et al 2003). One study reports a non-linear association between mobility and falls risk in this setting (Lord et al 2003). Thus, further work is required to better understand the association between mobility and falls risk in this setting.

The large Australian study of 1000 residents by Lord et al (2003) reported that fall rates were highest in those with fair standing balance, intermediate in those with the best standing balance, and lowest in those with the worst standing balance. A non-linear association was also evident.

What is already known on this topic: Aged care residents with moderate standing balance have greater risk of falling than those with either good or poor standing balance. Similarly, those with moderate sit-to-stand ability have greater risk of falling than those with either good or poor sit-to-stand ability.

What this study adds: The same relationship of greater falls risk among aged care residents with intermediate ability also exists for other aspects of mobility including bed and chair mobility, dynamic standing balance, and ambulation. The Physical Mobility Scale can be used to discriminate aged care residents who are most and least likely to fall.
when sit-to-stand ability was combined with standing balance. Using this dual classification, fall rates were highest in those who could rise from a chair but could not stand unaided (81%) and lowest in those who could neither rise from a chair nor stand unaided (48%). The study also found a different risk factor profile between residents who could and could not stand unaided. For residents who could stand unaided, unique risk factors included increased age, male sex, higher care classifications, incontinence, and slow reaction times. Risk factors unique to residents who could not stand unaided included: intermediate (low/hostel) versus nursing home (high) care, poor health status, Parkinson's disease and being able to get out of a chair.

Evaluating the falls risk of residents in aged care facilities is complicated. Inconsistencies in the association between mobility impairment and falls risk reported by past studies may be partially attributable to differences in the methods for measuring mobility. Measurement of mobility requires an understanding of the multiple components underpinning mobility. There are several components to consider, including bed mobility, sitting and standing balance, transfers, and ambulation. In addition, residents often require mobility aids and staff assistance to perform mobility tasks. Some studies have investigated the association between falls and a single mobility task, such as sit to stand (Kallin et al 2004, Lord et al 2003), negotiation of stairs (Kallin et al 2002), or ambulation (French et al 2007, Maurer et al 2005). In comparison, the Physical Mobility Scale is a comprehensive, reliable and valid interval measure of resident mobility (Barker et al 2008, Nitz et al 2006, Pike and Landers 2010). It quantifies the amount of assistance and equipment an individual requires to safely perform nine mobility tasks ranging from bed mobility to standing balance (Nitz et al 2006). The investigation of the association between mobility impairment assessed using the Physical Mobility Scale and falls risk has not been reported previously. This study aimed to build on existing research by characterising the association between mobility impairment as measured by the Physical Mobility Scale and falls risk, for people living in residential aged care.

Therefore the research questions for this study were:
1. What is the association between mobility and falls risk for people living in residential aged care?
2. Can the Physical Mobility Scale discriminate between residents at risk of falling and those not at risk?

Method

Design
This study used a prospective cohort design to investigate the association between falls risk and mobility impairment. Residents from six residential aged care facilities were invited to participate in the study. Facilities were identified through convenience sampling. After baseline assessment with the Physical Mobility Scale, participants were followed for six months to record the number of falls.

Participants and centres
Permanent high care (nursing home) and low care (hostel) residents were eligible for inclusion in the study if they had lived at the facility for longer than 12 months. The participating facilities were located in Queensland, Australia. The facilities provide accommodation, meals, clinical care, and social activities for people in their later stages of life. Participants were recruited by personal approach. Where residents were unable to provide consent due to cognitive or physical impairment, consent was sought from a family member or guardian. Data were collected in 2006.

Outcome measures
The primary outcome of interest was the number of falls in the six months after the initial mobility assessment. The definition of a fall used was ‘a person unintentionally coming to rest on the ground’ (Jensen et al 2002, Vu et al 2006). Participant medical notes and incident reports were audited at two-monthly intervals by the research physiotherapist for entries relating to falls.

The putative predictors assessed were the individual items and total score of the Physical Mobility Scale (Nitz et al 2006). The Physical Mobility Scale includes nine mobility tasks ranging from bed mobility to ambulation, which are scored on a six-point scale from full dependence (0) to highest independence (5). Item scores are summed to give a total score (0–45) representing overall mobility, with lower scores indicating greater mobility impairment. Physical Mobility Scale assessments were carried out by physiotherapists who were independent of the staff employed by the residential aged care facilities. Physical Mobility Scale assessments were completed at three time points: baseline, and at two and four months after the baseline assessment. Thus, multiple Physical Mobility Scale assessments and fall data were included for each resident.
Table 1. Baseline characteristics of participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Participants (n = 87)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs), mean (SD)</td>
<td>82 (11)</td>
</tr>
<tr>
<td>Gender, n female (%)</td>
<td>49 (56)</td>
</tr>
<tr>
<td>Type of care, n (%)</td>
<td></td>
</tr>
<tr>
<td>High level (nursing home)</td>
<td>77 (89)</td>
</tr>
<tr>
<td>Low level (hostel)</td>
<td>10 (11)</td>
</tr>
<tr>
<td>Diagnosis*, n (%)</td>
<td></td>
</tr>
<tr>
<td>Dementia</td>
<td>44 (51)</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>20 (23)</td>
</tr>
<tr>
<td>Previous fractured femur</td>
<td>10 (11)</td>
</tr>
<tr>
<td>Depression</td>
<td>16 (18)</td>
</tr>
<tr>
<td>Mobility, n (%)</td>
<td></td>
</tr>
<tr>
<td>Bed/chair bound</td>
<td>15 (17)</td>
</tr>
<tr>
<td>Wheelchair mobile</td>
<td>1 (1)</td>
</tr>
<tr>
<td>Ambulant with carer assistance</td>
<td>25 (29)</td>
</tr>
<tr>
<td>Supervision / prompting</td>
<td>28 (32)</td>
</tr>
<tr>
<td>Ambulates independently</td>
<td>18 (21)</td>
</tr>
<tr>
<td>Requires a gait aid</td>
<td>52 (60)</td>
</tr>
<tr>
<td>Physical Mobility Scale category, n (%)</td>
<td></td>
</tr>
<tr>
<td>Fully dependent (total score 0 to 9)</td>
<td>13 (15)</td>
</tr>
<tr>
<td>Severe mobility impairment (total score 10 to 18)</td>
<td>4 (5)</td>
</tr>
<tr>
<td>Moderate mobility impairment (total score 19 to 27)</td>
<td>16 (18)</td>
</tr>
<tr>
<td>Mild mobility impairment (total score 28 to 36)</td>
<td>22 (25)</td>
</tr>
<tr>
<td>Highest independence (total score 37 to 45)</td>
<td>32 (37)</td>
</tr>
</tbody>
</table>

*Up to four diagnoses were recorded for each participant

Figure 2. Risk of falling (hazard ratio) by Physical Mobility Scale total score category. The greater the hazard ratio of a Physical Mobility Scale total score category, the more likely participants in that category were to fall.
Research

Figure 3. Risk of falling (hazard ratio) by Physical Mobility Scale item score. The greater the hazard ratio of a Physical Mobility Scale item category, the more likely participants in that category were to fall. Dotted line indicates right side.

Data analysis

The association between Physical Mobility Scale total score and item scores, and risk of falling was assessed using Prentice, Williams, and Peterson conditional risk set survival models for recurrent events (Prentice et al 1981). An advantage of these models over traditional survival models is that they can be applied to data that include multiple observations for each participant, eg, multiple risk factor assessments and multiple outcome events. The recurrent event models used in this analysis were based on data that included up to three Physical Mobility Scale score observations for each resident corresponding to the baseline, two, and four month assessments and additional observations for each fall event that occurred. Total scores were coded into a priori specified score categories to allow non-linear associations to be explored. Five score categories were selected to ensure an adequate number of observations in each category. Too few observations in categories can lead to predictive models that are unstable and may provide imprecise and inaccurate associations. Each Physical Mobility Scale total score category was entered in a univariable model to establish the risk, reported as a hazard ratio, of sustaining a fall for each Physical Mobility Scale total score category.

The ability of the Physical Mobility Scale items and total score categories to discriminate fallers from non-fallers was also explored through Prentice, Williams, and Peterson...
From each model the prognostic separation (D) and proportion of variation explained ($R^2$) based on D were calculated (Royston and Sauerbrei 2004). The D index represents an estimate of the log hazard ratio comparing two equal-sized groups overcoming the generality issues associated with comparing hazard ratios across different study samples (Royston and Sauerbrei 2004). The proportion of variation explained ($R^2$) provides a measure of the fit of the classification system to the observed data (Royston and Sauerbrei 2004). The larger is the separation (D), the greater is the discrimination between levels of falls risk between item and total score categories (Royston et al 2004). Robust estimates of the standard errors were used to incorporate the correlation of observations within individuals (Twisk et al 2005). The proportional hazards assumption of each survival model was tested with the scaled Schoenfield residuals tests (Machin et al 2006). Methods for calculating sample size and power estimates for epidemiological modeling studies that use recurrent events survival models to investigate associations between predictors and outcome events are not readily available. As such, a pragmatic sample size was selected that was considered appropriate to determine meaningful associations and that would provide a representative sample of people living in residential aged care.

**Figure 3.** Risk of falling (hazard ratio) by Physical Mobility Scale item score. The greater the hazard ratio of a Physical Mobility Scale item category, the more likely participants in that category were to fall.

conditional risk set survival models for recurrent events (Prentice et al 1981).

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Results

Flow of participants, therapists, centres through the study

Of the 298 residents living in the six facilities, 100 were excluded from the study because they had been living at the facility for less than 12 months. Of the 198 residents who were eligible to participate in the study, 87 agreed to participate, as presented in Figure 1.

The demographic and health characteristics of the residents who participated in the study are presented in Table 1. No participants withdrew from the study and no adverse events attributable to the study assessments were reported. Table 1 also presents the percentage of residents in each Physical Mobility Scale category at the baseline assessment. The category with the greatest number of participants (37%) was the ‘highest independence’ mobility category (Physical Mobility Scale total score 37–45).

Association between mobility and falls risk

Mobility impairment as measured by the Physical Mobility Scale total score had a non-linear association with risk of falling (Figure 2). Residents with mild impairment (Physical Mobility Scale total score 28–36) had the highest risk for falling, which was statistically significant when compared to residents in all other score categories (hazard ratio = 1.98, 95% CI 1.30 to 3.03). Residents in the fully dependent mobility category (Physical Mobility Scale total score 0 to 9) had the lowest risk category for falls, which was also statistically significant when compared to residents in all other score categories (hazard ratio = 0.05, 95% CI 0.01 to 0.32).

Associations between individual item scores on the Physical Mobility Scale and falls risk are presented in detail in Figure 3. For bed and chair mobility tasks, the risk of falling increased as mobility improved between item scores of 0 and 4 with a score of 4 (requires supervision) being associated with the highest risk of falling. For example, in Figure 3D (Sit to stand), residents who required the assistance of equipment such as a frame or rail to steady themselves once standing (score of 4) had a substantially higher risk of falling compared to residents who could not stand even with hands-on assistance, who required hands-on assistance to stand, or who could stand from a chair without using their arms. On standing mobility tasks the risk of falling increased as mobility improved between item scores of 0 and 3 with a score of 3 (requiring the assistance of one person) being associated with the highest risk of falling. For example, in Figure 3F (Standing balance), residents who could stand and turn their head and trunk to look behind to the left and right (score of 3) had a substantially higher risk of falling compared to people who could not stand without hands-on assistance or people who could perform single leg stance. In all item categories, people who were fully dependent were at the lowest risk of falling.

Discriminating fallers from non-fallers

No violations of the proportional hazards assumption were found. The D and R² statistics indicated that both the Physical Mobility Scale item scores and total score categories were discriminatory of residents at risk of falling from those not at risk (Table 2).

Table 2. Evaluation of the ability of the Physical Mobility Scale items and total score categories to discriminate fallers from non-fallers.

| Item Explained variation Prognostic separation |
|-----------------------------------------------|-----------------------------------------------|
| Item Explained variation R² (95% CI) Prognostic separation D (95% CI) |
| Rolling | 0.07 (0.01 to 0.19) | 0.57 (0.14 to 1.00) |
| Supine to sit | 0.05 (0.00 to 0.15) | 0.48 (0.10 to 0.86) |
| Sitting balance | 0.08 (0.01 to 0.18) | 0.60 (0.23 to 0.97) |
| Sit to stand | 0.06 (0.02 to 0.17) | 0.53 (0.10 to 0.94) |
| Stand to sit | 0.08 (0.01 to 0.21) | 0.62 (0.17 to 1.06) |
| Standing balance | 0.19 (0.07 to 0.34) | 1.01 (0.55 to 1.46) |
| Transfers | 0.13 (0.02 to 0.28) | 0.78 (0.27 to 1.28) |
| Mobility | 0.13 (0.03 to 0.27) | 0.81 (0.38 to 1.23) |
| Total score | 0.15 (0.04 to 0.28) | 0.85 (0.43 to 1.28) |

Discussion

This study provides valuable insight into the associations between the mobility of aged care residents and their risk of falling. The results provide support to the findings of a prior large Australian study (Lord et al 2003), which also found a non-linear association between standing balance and falls. The findings of this study extend the prior work by Lord and colleagues by demonstrating that the non-linear association exists between falls and other mobility tasks such as supine to sit, sitting balance, and ambulation. This information is particularly useful in the residential aged care setting where about 1 in 5 residents are non-ambulant (Table 1), which means administration of several other mobility falls risk screens such as standing balance ability, the timed-up-and go, or functional reach tests are not possible. This study also provides fall risk categories for scores obtained from the commonly used Physical Mobility Scale. Prior studies have highlighted the advantages of using the Physical Mobility Scale as a key assessment tool in this setting (Barker et al 2008, Nitz et al 2006, Pike and Landers 2010). The Physical Mobility Scale can be applied to all residents not just those able to stand with or without assistance. It can be completed by observation of the resident moving in everyday tasks and does not depend on the resident being able to follow instructions to perform the assessed mobility tasks. The Physical Mobility Scale also provides an interval-level measure of mobility and so offers advanced research application because parametric statistical analyses can be employed. This study adds to these advantages by providing falls risk categories for total scores obtained. This is a useful property of the Physical Mobility Scale because many falls risk assessment tools used in the residential aged...
Our study shows that residents categorised as having mild mobility impairment (Physical Mobility Scale total score 28–36) had the highest risk of falling. This means that residents requiring mainly supervision or prompting on most mobility tasks were at higher risk of falling compared to residents requiring hands-on assistance. Residents requiring minimal assistance are likely to have cognitive impairment (needing supervision or prompting) or have poorer dynamic balance (requiring stand-by assistance or hand holds). If residents with mild mobility impairment are mobilising or transferring alone, any inability to recognise, judge, and avoid hazardous situations encountered in their environment might contribute to their increased falls risk. This suggests that attention to improving mobility (to a Physical Mobility Scale total score > 36), reducing environmental hazards and increasing resident monitoring systems could be required to reduce the incidence of falls in these residents.

The non-linear association between mobility and falls risk is intuitive. Residents who are bed or chair bound are unlikely to fall because they do not have the capacity to perform activities where they can potentially fall. Residents who can get out of bed or stand from a chair without assistance but require supervision or hand-hold support from a rail or chair arms are more at risk of falling than residents who can perform these tasks independently. This non-linear association has important implications for future falls epidemiological research and it is possible that a non-linear association also exists for other fall risk factors. Caution should therefore be exercised when interpreting prior study findings that have assumed the association between mobility or other risk factors and fall risk is linear.


The non-linear association creates a paradox for those seeking to enhance the mobility of aged care residents. Enhancing mobility can be beneficial for improving the independence of residents and minimising the burden they place on care staff. However, enhancing the mobility of people with moderate to severe mobility impairment may place them in a higher risk category for falls. Despite this potential increased risk of falls, it is not appropriate to reduce mobility rehabilitation for these patients. This is because the falls risk may be outweighed by the many benefits of improved mobility in residential aged care populations, such as reduced risk of respiratory infections (Binder et al 2003), improved health-related quality of life (Andersen 2004), and reduced mortality (Gambassi et al 1999). Residents may consider that the improved independence alone outweighs the falls risk. Improving the mobility of residents also frees up care staff to attend to other tasks. Therefore, instead of reducing mobility rehabilitation, precautions should be taken to account for the possible increased risk of falling as mobility improves. For example, falls prevention strategies could be instituted, such as balance, strength, functional task safety and cognitive loading (Granacher et al 2011). Other strategies could include environment modification, increased supervision through positioning in common areas such as resident lounge, and toileting schedules to minimise the likelihood that these residents will attempt to mobilise on their own. Further research could investigate the tradeoffs between increased falls risk and health benefits with mobility rehabilitation.

Our study did not investigate the association between other commonly reported dimensions of intrinsic falls risk such as cognitive impairment, medications use or sensory impairment. The prevalence of dementia in this study was high (50%). The sample size of this study was too small to investigate the interaction between mobility, dementia, and falls risk. However, a diagnosis of dementia has consistently been reported to be associated with a significantly increased risk of falling in the residential aged care setting by several prior studies (Avidan et al 2005, Machin et al 2006, Nordin et al 2008, Pearce et al 2007). Increasing cognitive load, for example by dual tasking, appears to result in deterioration in postural control and gait parameters (Binder et al 2003, Melzer et al 2007). Given the complexity of factors associated with falls risk, this association warrants investigation in future research.

Several limitations of the study need to be acknowledged. First, the sample size used was relatively small. A large proportion (56%) of residents eligible to participate were not recruited because informed consent could not be obtained. During recruitment there was significant difficulty in obtaining consent to participate from a family member or guardian if the resident was unable to provide consent, which resulted in low recruitment numbers. This highlights the recruitment difficulties encountered in the residential aged care population. Second, the reliance on facility incident reports and medical notes for the measurement of falls may have resulted in some falls not being captured (Kanten et al 1993). Third, the Hawthorne effect may also have been a confounder of the study results as the facility staff had knowledge of the study being in progress (Herbert 2005). This awareness may have modified the staff’s usual approach to care such that the results may not be reflective of what would usually happen outside the study period.

In summary, there is a non-linear association between mobility impairment and falls risk. Residents requiring supervision were found to be at greater risk of falling than those who were non-ambulant or independent. The increased risk in residents with mild mobility impairment suggests that these residents should be the prime target for fall prevention strategies.

Ethics: The University of Queensland Medical Research Ethics Committee approved this study. All participants gave written informed consent before data collection began. Where residents were unable to provide consent due to cognitive or physical impairment, consent was sought from a family member or guardian.

Competing interests: Dr Terry Haines is the director of Hospital Falls Prevention Solutions Pty Ltd, through
which capacity he has provided consultation services and expert testimony for Minter Ellison law firm. However, he has not provided consultation services to residential aged care facilities and his expert testimony did not concern the aged care facility setting. Terry also assists with statistical advice and the development of papers for the Journal of Physiotherapy.

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**Website**