Recurrent and Injurious Falls in the Year Following Hip Fracture: A Prospective Study of Incidence and Risk Factors From the Sarcopenia and Hip Fracture Study


1 Exercise, Health and Performance Faculty Research Group, Faculty of Health Sciences, University of Sydney, Lidcombe, New South Wales, Australia.
2 Balmain Hospital, New South Wales, Australia.
3 Royal Prince Alfred Hospital, Camperdown, New South Wales, Australia.
4 Gastrointestinal Investigation Unit and Centre for In Vivo Body Composition, Royal North Shore Hospital, St. Leonards, New South Wales, Australia.
5 St. George Hospital, Kogarah, New South Wales, Australia.
6 Department of Aged Care & Rehabilitation Medicine, Royal North Shore Hospital, St. Leonards, New South Wales, Australia.
7 Centre for Experimental Radiation Oncology, Cancer Care Centre, St. George Hospital, Kogarah, New South Wales, Australia.
8 Present address: Australian Clinical Trials Registry, NHMRC Clinical Trials Centre Level 5, Camperdown, New South Wales, Australia.
9 Faculty of Medicine, University of New South Wales, Sydney, Australia.
10 Hebrew SeniorLife, Boston, Massachusetts.
11 Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University, Boston, Massachusetts.

Background. The incidence and etiology of falls in patients following hip fracture remains poorly understood.

Methods. We prospectively investigated the incidence of, and risk factors for, recurrent and injurious falls in community-dwelling persons admitted for surgical repair of minimal-trauma hip fracture. Fall surveillance methods included phone calls, medical records, and fall calendars. Potential predictors of falls included health status, quality of life, nutritional status, body composition, muscle strength, range of motion, gait velocity, balance, walking endurance, disability, cognition, depression, fear of falling, self-efficacy, social support, physical activity level, and vision.

Results. 193 participants enrolled in the study (81 ± 8 years, 72% women, gait velocity 0.3 ± 0.2 m/s). We identified 227 falls in the year after hip fracture for the 178 participants with fall surveillance data. Fifty-six percent of participants fell at least once, 28% had recurrent falls, 30% were injured, 12% sustained a new fracture, and 5% sustained a new hip fracture. Age-adjusted risk factors for recurrent and injurious falls included lower strength, balance, range of motion, physical activity level, quality of life, depth perception, vitamin D, and nutritional status, and greater polypharmacy, comorbidity, and disability. Multivariate analyses identified older age, congestive heart failure, poorer quality of life, and nutritional status as independent risk factors for recurrent and injurious falls.

Conclusions. Recurrent and injurious falls are common after hip fracture and are associated with multiple risk factors, many of which are treatable. Interventions should therefore be tailored to alleviating or reversing any nutritional, physiological, and psychosocial risk factors of individual patients.

Key Words: Falls—Hip fracture—Osteoporosis—Aging.
of “recurrent falls” (i.e., two or more falls) and “injurious falls,” in patients after hip fracture.

Specific studies of patients after hip fracture are thus necessary to establish whether risk factors applicable to general community-dwelling older adults are relevant in this population. Information from such studies could be used to target specific interventions to evidence-based risk factors.

We therefore conducted a 1-year prospective investigation of patients with hip fracture to determine the incidence of falls and fall-related injuries, and to assess potential risk factors for recurrent and injurious falls across multiple domains, using robust quantitative assessments.

**Methods**

**Recruitment**

The Sarcopenia and Hip Fracture (SHIP) cohort was recruited from three acute care hospitals in Sydney, Australia: Royal North Shore Hospital, Royal Prince Alfred Hospital, and St. George Hospital. Between June 2000 and July 2002, all patients admitted with “hip or femur fracture,” “hip or pelvic pain,” or “fall” were identified by means of emergency and operating room lists. Patients were eligible for study inclusion if 60 years or older, admitted for surgical repair of minimal-trauma hip fracture, able to consent, English speaking, and not residing in a nursing home, terminally ill, or severely demented. Severe dementia was defined as those persons who could not reliably consent to study participation. This was evaluated on a case-by-case basis by a research assistant with input from study physicians and other medical staff, as well as patient families, where indicated. Eligible patients were approached by a research assistant who obtained written informed consent. Proxy consent was not permitted. Ethics approval was granted by the University of Sydney Human Research Ethics Committee, and each hospital’s relevant ethics committee.

**Baseline Measures**

All baseline measures (Table 1) formed the group of potential risk factors for injurious and recurrent falls that were examined in this study.

Hospital medical records were abstracted to collect the following data: site of hip fracture, comorbidities, type of surgical repair, in-hospital complications and consults, date of first and full weight bearing, mobility status at discharge, number and type of medications, length of acute hospital stay,
and discharge location. Admission diagnoses were used to determine a score for the High-Risk Diagnoses for the Elderly Scale, a simple and valid tool for prediction of 1-year mortality in elderly hospitalized patients (12). Demographic information (age, sex, ethnicity, marital status, education level, residence, work history, annual income, alcohol and smoking history, and use of independent activities of daily living assistive devices and community health services), fall-related data for the admission hip fracture (other injuries, activity at time of fall, and fall location), and 12-month pre-fracture fall history (number of falls) were collected through an interview.

Standardized assessments began approximately 2 weeks after hip fracture. Nutritional status was assessed using serum albumin and 25-hydroxyvitamin D3 levels, total lymphocyte count, and the Hutchinson modification of the Block Food Frequency Questionnaire, with nutrient analysis using the United States Department of Agriculture Grand Forks Database, modified to reflect the Australian food supply (13). An energy intake less than 30 kcal/kg/d was considered inadequate. Serum albumin level of less than 35g/L was considered low (14). Coefficient of variation (CV) for method of albumin determination was 1.7% for day-to-day variability. Serum vitamin D level was considered normal if greater than 50.0 nmol/L (15). Between-run and within-run CVs for method of serum vitamin D measurement were 7.1% and 4.8%, respectively. A total lymphocyte count less than 1,500 cells/mm³ was taken as lymphopenia (16). Creatinine clearance was calculated from serum creatinine using the Cockcroft–Gault formula and considered “low” if less than 65 mL/min (17). The World Health Organization definition of normal (≥130 g/L in men, ≥120 g/L in women) hemoglobin was used. If study blood sample was missed, medical records data were abstracted for any available data on laboratory tests. The Mini-Nutritional Assessment (MNA) (18) was used to provide a global index of risk of malnutrition, using a combination of health status, anthropometric, psychological, and dietary intake questions and measurements at a single point in time. Anthropometric measures included height, fasting body weight, sum of seven skinfolds, and circumference measures (mid-arm, mid-thigh, and mid-calf). The mean of three measures taken for each circumference and skinfold measure was reported. CVs for skinfold measurement were as follows: biceps 4.3%, triceps 2.8%, midaxillary 3.5%, subscapular 2.7%, suprailiac 3.2%, abdominal 2.8%, and thigh 2.1%. CVs for mid-arm, mid-thigh, and mid-calf circumferences were 0.4%, 0.3%, and 0.3%, respectively. Body mass index (BMI) was calculated as fasting body weight (kg)/height (m²). The average resistance (CV = 0.1%) and reactance (CV = 0.5%) values of three sequential bioelectrical impedance analysis (BIA) measures using an RJL Systems BIA-Quantum Machine (RJL Systems Inc., Clinton, MI) were used to calculate whole-body skeletal muscle mass (SMM) (19) and fat-free mass (FFM) (20). Fat mass was calculated by subtracting FFM from fasting body weight. Skeletal muscle index (SMI) was calculated as SMM (kg)/height (m²) (21). Sarcopenia was defined as SMI less than 7.0 kg/m² for women and less than 9.5 kg/m² for men (21). Standing height was predicted from measured knee height for non-weight-bearing participants using the formula provided by Chumlea and associates (22). Body composition was classified using BMI and BIA sarcopenia data as follows: “normal” (BMI <25 kg/m² and not sarcopenic), “overweight or obese” (BMI ≥25 kg/m² and not sarcopenic), “sarcopenic” (sarcopenic and BMI <25 kg/m²), or “sarcopenic obesity” (sarcopenic and BMI ≥25 kg/m²). Patients were classified as being “at nutritional risk” if any of the following was met: (i) MNA score reflective of “at risk of malnutrition” or “undernourished”; (ii) overweight or obese, sarcopenic, or sarcopenic obesity body composition; (iii) lymphopenia; (iv) hypoalbuminemia; or v) vitamin D deficient.

Isometric handgrip strength of the nondominant hand was assessed using a JAMAR handgrip dynamometer (Sammons Preston, Bolingbrook, IL), with CV = 7.2%. Peak isometric elbow extension, hip abduction, knee extension, and ankle dorsiflexion strength were measured on both right and left sides, as the highest of three measures, using an isometric digital dynamometer (Chatillon Dynamometer CSD200; Amtek TCI Division, Largo, FL). Isometric strength CVs were 11.1% for elbow extension, 14.1% for hip abduction, 15.0% for knee extension, and 13.2% for ankle dorsiflexion.

Walking endurance was assessed using the 6-minute walk test. Habitual and maximal gait velocities were assessed over 2 m (Ultra-timer; Raymar, Oxfordshire, UK). The average and fastest times of two trials were taken as habitual (CV = 8.7%) and maximal (CV = 7.6%) gait velocity, respectively.

Static balance was assessed up to 15 seconds in five different positions: feet apart in parallel stance, feet together in parallel stance, half-tandem stance, tandem stance, and one-legged stance. Each test was performed without the use of an assistive device (except feet apart in parallel stance, which was also performed with the use of a frame) and with eyes open until the participant was unable to maintain the position or 15 seconds had elapsed. A total static balance time was calculated by summing the time recorded for each of the six tests (possible range = 0–90 seconds). Dynamic balance was assessed by a 3-m forward tandem walk. The test was performed twice, with the best score (lowest combined time + errors) used in analyses. CV for tandem walk score was 5.7%.

Shoulder flexion (CV = 1.8%), knee extension (CV = 2.4%), and combined ankle plantarflexion–dorsiflexion (CV = 4.2%) active ROM (range of motion) were measured with a Plurimeter-V (Australasian Medical & Therapeutic Instruments, Brisbane, Australia). Visual capacities including near visual acuity (Vocational Near Vision Test Type from 38 cm; HS Clement Clarke International, Harlow, Essex, UK), depth perception (Randot Stereotest; Stereo Optical Company Inc., Chicago, IL), and contrast sensitivity (Pelli Robson Contrast Sensitivity Chart from 1 m; HS Clement Clarke International)
were also assessed. Mild and moderate visual impairment were defined as a presenting visual acuity of less than 6/12 to 6/18 and less than 6/18 to 6/60, respectively (23). Contrast sensitivity was considered impaired if less than 1.65 log units (24). All tests of visual function were performed with binocular vision, using the refractive correction the participant presented with on the day of the tests.

Pre-fracture functional status was assessed with Part C (activities of daily living [ADL]) of the National Health and Nutrition Examination Survey (NHANES) I Epidemiologic Follow-Up Study, 1986 (25). Individuals were asked how much difficulty they had (before hip fracture) in doing 23 ADLs when they were alone and without the use of an assistive device. Response choices for each question were as follows: no difficulty (0), some difficulty (1), much difficulty (2), and unable to do (3). The disability score is the average of the eight category scores. Katz Index of Independence in ADL assessment (26) was also used to reflect pre-fracture functional status. Pre-fracture habitual physical activity level was assessed by the Harvard Alumni physical activity index (27) and the Physical Activity Scale for the Elderly (28). The Mini-Mental State Examination, Geriatric Depression Scale, Tinetti Falls Efficacy Scale (29), Self-Efficacy Gauge (30), and the 11-item Duke Social Support Index (31) were also administered. Health-related quality of life post-fracture was assessed using the Medical Outcomes Study Short-Form Health Survey (SF-36 v. 1) (32).

Medical diagnoses and medications, vision, fall and self-efficacy, cognition, depressive symptoms, body composition and nutritional measures (except dietary intake), SF-36 scores, and all biochemical and physical function (gait speed, balance, ROM, strength) tests were reflective of participants’ status at the time of interview (post-fracture). Demographic information, dietary intake, NHANES and Katz disability, number of assistive devices, habitual physical activity level, and social support referred to participants’ pre-fracture status.

Follow-Up Fall Surveillance

A fall was defined as “unintentionally coming to rest on the ground, floor, or other lower level” (33). The number of falls was collected by means of monthly fall event calendars and phone interviews. Phone interviews also collected information about injuries (fracture or soft-tissue injury) and treatment. Soft-tissue injuries included strains, sprains, lacerations, and bruising. The source (phone or calendar) identifying the highest number of falls was used in analyses, assuming that underreporting of falls would be more likely than overreporting. Proxy reporting was permitted for cognitively impaired patients. Data from medical records were extracted to confirm and check for additional fall-related hospitalizations and fractures. Participants who died during the study period and those who refused one or more fall follow-up assessments were included in fall outcome measures if data were collected for at least 1 month.

Fall Surveillance Response Rate

Monthly phone call compliance was calculated by dividing the number of phone calls completed by the number expected if all participants completed 12 months. The return rate of monthly fall event calendars was calculated by dividing the number of calendars received, by the number expected if all participants completed 12 months. Both compliance measures were adjusted for the number of whole months lost by those who withdrew from the study prior to the collection of any fall surveillance data and those who died during the study period. Twenty-two participants enrolled in the study before we began collecting fall event calendar data and were excluded from the fall event calendar response rate but not from other falls data analyses.

Statistical Analyses

Data were assessed for normality of distribution visually and statistically. Descriptive outcomes are presented as mean ± SD for normally distributed data, and median (25th to 75th percentile) for skewed (skewness greater than 1.0 or less than −1.0) data. Fall rate per person-year for each participant = number of falls collected for the participant/the proportion of the year that the participant was in the study. Univariate analyses using independent t test, chi-square test, or simple regression were performed for potential fall-related risk factors (all measures from Table 1) for three dependent variables (yes or no): recurrent falls (more than one fall), all fall-related injuries (soft-tissue injury or fracture, or both), and fall-related fractures. Skewed data were analyzed after log(base 10) transformation. If log transformation did not improve the normality of data distribution of the independent variable, a Mann–Whitney test was performed using raw data. All significant univariate relationships were then adjusted for age using analysis of covariance or logistic regression where appropriate. Significant age-adjusted associations are presented in Table 3. Multivariate logistic regression models were constructed for each of the three dependent outcomes (fall events) using variables that were significantly related with the dependent variable of interest after controlling for age. To reduce multicollinearity, of those independent variables found to be highly interrelated (r > .7) within the same model, only the independent variable with the strongest age-adjusted relationship with the dependent variable was included. Significant multivariate predictors of fall events are presented in Table 4. Independent t tests or chi-square analyses, where appropriate, were performed to assess relationships between baseline measures of interest. All analyses were performed using StatView version 5.0 (SAS Institute Inc., Cary, NC) and SPSS version 16.0 (SPSS Inc., Chicago, IL) with the significance level set at p < .05.
RISK FACTORS FOR FALLS AFTER HIP FRACTURE

RESULTS

Flow of Participants
Sixty-four percent (193) of 303 eligible patients enrolled (Figure 1); 14 withdrew and 1 died during baseline assessments prior to contributing any fall-related data; 18 died during follow-up. Of the 178 participants with fall surveillance data, there was a total follow-up period of 2,047 patient-months (mean = 11 months per patient).

Baseline Participant Characteristics
Participants were aged 81 ± 8 years (range 60–97 years) and 72% were women. Among all eligible patients, those who were included in fall outcomes (n = 178) were of similar age (81 ± 9 vs 82 ± 9 years, p = .08), but more likely to be men (30% vs 17%, p = .02) than those who refused. Baseline data were collected 18 ± 6 days after hip fracture and took approximately 2 weeks to complete.

Prior to hip fracture, 92% of participants were living independently and 8% lived in hostel accommodation. Forty-two percent of the cohort reported falling in the year prior to hip fracture and 20% reported recurrent falls. Severe mobility impairment was evident with habitual walking velocity (0.30 ± 0.16 m/s), and 6-minute walk distance (111.4 m; 70.4–171.4 m) was less than one third of normative values for older adults (34). Seventy-five percent of participants were sarcopenic, more than half (58%) were undernourished or at risk of malnutrition (35), and 55% were deficient in vitamin D (15).

Further description of this cohort is presented elsewhere (36).

Fall Surveillance Response Rate
Monthly fall event calendar compliance was 55% (1,006/1,834), and phone call compliance was 75% (1,538/2,047). The main reason for nonreturn of fall calendars was participant or proxy refusal; for noncollection of phone call data, it was research assistant error. There was no follow-up fall information (by either calendar or telephone) for only 12 of 171 participants who enrolled in the study after the fall follow-up calendars were introduced. Participants with more fall data (≥75%) collected were younger than those who had less fall data collected (fall calendar data: 79 ± 9 vs 82 ± 9 years, p = .12; monthly call data: 79 ± 9 vs 82 ± 8 years, p = .04).

Descriptive Fall Outcomes
Falls data are presented in Table 2. There were 22 fractures: 9 hip (including 3 periprosthetic fractures), 4 upper
Incidence of Falls and Injuries

Participants who were included in the multivariate model for injurious falls were younger (79 ± 9 vs 82 ± 9 years, \( p = .03 \)), had less disability (NHANES disability score 0.8 vs 1.1, \( p = .03 \)), were stronger (handgrip strength 18.9 vs 16.2 kg, \( p = .04 \)), and had a lower rate of cognitive impairment (29% vs 52%, \( p = .005 \)) than those who were excluded from the model (due to missing data). There were no differences between these two groups in gender, number of chronic diseases, 6-minute walk distance, or rate of depression.

Risk Factors for Injurious Falls

Risk factors for all fall-related injuries.—More characteristics related to physical impairment (pre-fracture disability, decreased lower extremity strength, balance, range of motion, and pre-fracture physical activity level) were identified as risk factors for fall-related injuries compared with those identified for recurrent fallers (Table 3). No significant independent risk factors were identified in multivariate analysis (Table 4).

Participants who were included in the multivariate model for injurious falls were younger (79 ± 9 vs 82 ± 9 years, \( p = .01 \)), had less disability (NHANES disability score 0.9 vs 1.2, \( p = .04 \)), and had a lower rate of depression (34% vs 65%, \( p = .01 \)) than those who were excluded from the model (due to missing data). There were no differences between these two groups in gender, number of chronic diseases, 6-minute walk distance, or rate of cognitive impairment.

Risk Factors for Recurrent Falls

Significant risk factors for recurrent falls (Table 3) were predominantly markers of higher comorbidity (more diseases, medications, and lower vitamin D, quality of life, and grip strength). Simple regression analyses revealed that serum vitamin D was significantly correlated with muscle strength (handgrip: \( r = .3, \ p = .001 \); total bilateral lower limb: \( r = .2, \ p = .046 \)) and static balance (\( r = .3, \ p = .003 \)). In multivariate analysis, congestive heart failure (CHF) and quality of life (role emotional [RE] subscale) were independent and significant predictors of recurrent falls (Table 4). Participants with CHF had worse static balance than those without CHF (58.7 [15.0–63.3] vs 65.2 [60.0–77.9] seconds, \( p \leq .001 \)) but were not different in strength, body composition, or gait velocity. RE score was not significantly related to gait or balance.

Participants who were included in the multivariate model for recurrent falls were younger (79 ± 9 vs 83 ± 8 years, \( p = .02 \)) and tended to have less disability (NHANES disability score 0.9 vs 1.2, \( p = .05 \)) than those who were excluded from the model (due to missing data). There were no differences between these two groups in gender, number of chronic diseases, handgrip strength, 6-minute walk distance, or rate of depression or cognitive impairment.

Discussion

Incidence of Falls and Injuries

More than half (56%) of the study participants fell at least once in the year after hip fracture, and 28% had recurrent falls. These figures are similar to those reported after just 6 months following hip fracture by Shumway-Cook and associates (9) and nearly twice as high as those reported by Fox and associates at 2 years (11). These differences may be explained by the use of a less rigorous fall definition (9) and the exclusion of “frail patients” (11). Compared with “healthy” community-dwelling older adults

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Table 2. Falls Outcomes in the 12 Months After Hip Fracture (N = 178)

| Category                                      | Total number of falls | Time to first fall (d) | Fall rate per person-year | Nonfallers, n (%) | Fallers, n (%) | Single fallers | Recurrent fallers | Injurious fallers, n (%)¹ | Persons sustaining a fall-related soft-tissue injury, n (%)² | Persons admitted to hospital following a fall, n (%) | Persons sustaining a fall-related fracture, n (%) | Persons sustaining a fall-related hip fracture, n (%)³ |
|-----------------------------------------------|-----------------------|------------------------|---------------------------|-------------------|----------------|----------------|------------------------|--------------------------|-----------------------------------------------------------|------------------------------------------------------|------------------------------------------------------|
| Total                                         | 227                   | 154 ± 115              | 1.0 (0–2.0)               | 79 (44)           | 53 (30)        | 49 (28)       | 50 (28)                | 53 (30)                  | 43 (24)                                                   | 23 (13)                                              | 21 (12)                                              | 9 (5)                                                 |

Notes: Continuous variables with normal data distributions are presented as mean ± SD. Skewed data are presented as median (25th to 75th percentile). Categorical data are presented as number of participants (percent of total cohort).

* Fall rate per person-year was calculated as the average fall rate per person-year of all participants. Fall rate per person-year for each participant = number of falls collected for the participant/the proportion of the 1 year that the participant was in the study. The denominator = 1 for all participants except the 17 who died (after collection of at least 1 month’s fall data) during the follow-up period.

1 An injurious fall resulted in a soft-tissue injury or fracture, or both.
2 Soft-tissue injuries include sprains, strains, lacerations, and bruises.
3 Hip fractures include two ipsilateral and seven contralateral fractures. Of the nine hip fractures, three were periprosthetic fractures.
Table 3. Risk Factors for Recurrent Falls and Injurious Falls

<table>
<thead>
<tr>
<th>Risk Factors for Recurrent Falls</th>
<th>Nonfallers/single fallers</th>
<th>Recurrent fallers</th>
<th>OR (95% CI)</th>
<th>p Value</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of chronic diseases*</td>
<td>2.5 ± 1.8</td>
<td>3.2 ± 1.5</td>
<td>1.24 (1.03–1.50)</td>
<td>.03</td>
<td>175</td>
</tr>
<tr>
<td>Number of medications†</td>
<td>5.6 ± 2.8</td>
<td>7.4 ± 3.0</td>
<td>1.24 (1.10–1.40)</td>
<td>&lt;.001</td>
<td>175</td>
</tr>
<tr>
<td>Vitamin D nmol/L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moderate to severe deficiency (≤25 nmol/L)</td>
<td>49.0 (37.0–65.3)</td>
<td>38.0 (21.3–64.3)</td>
<td>0.13 (0.03–0.69)</td>
<td>.02</td>
<td>144</td>
</tr>
<tr>
<td>Congestive Heart Failure‡</td>
<td>6.4%</td>
<td>20.0%</td>
<td>3.51 (1.05–3.94)</td>
<td>.01</td>
<td>175</td>
</tr>
<tr>
<td>Disability§</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NHANS category score for “hygiene”</td>
<td>1.3 ± 1.4</td>
<td>1.9 ± 1.3</td>
<td>1.37 (1.05–1.77)</td>
<td>.02</td>
<td>160</td>
</tr>
<tr>
<td>Nondominant handgrip strength (kg)</td>
<td>19.0 ± 8.0</td>
<td>15.5 ± 5.5</td>
<td>0.93 (0.87–1.00)</td>
<td>.04</td>
<td>141</td>
</tr>
<tr>
<td>Quality of life#</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF-36 general health</td>
<td>65.7 ± 15.2</td>
<td>58.3 ± 16.9</td>
<td>0.97 (0.95–0.99)</td>
<td>.01</td>
<td>144</td>
</tr>
<tr>
<td>SF-36 role emotional</td>
<td>100 (66.7–100)</td>
<td>66.7 (33.3–100)</td>
<td>0.46 (0.30–0.70)</td>
<td>&lt;.001</td>
<td>144</td>
</tr>
<tr>
<td>SF-36 mental component summary</td>
<td>52.3 ± 11.0</td>
<td>47.3 ± 11.3</td>
<td>0.96 (0.93–0.99)</td>
<td>.02</td>
<td>143</td>
</tr>
</tbody>
</table>

Risk Factors for Injurious Falls

<table>
<thead>
<tr>
<th>Risk Factors for All Fall-Related Injuries</th>
<th>Persons sustaining no injurious falls</th>
<th>Persons sustaining an injurious fall</th>
<th>OR (95% CI)</th>
<th>p Value</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of medications†</td>
<td>5.7 ± 2.8</td>
<td>7.0 ± 3.1</td>
<td>1.16 (1.04–1.30)</td>
<td>.01</td>
<td>175</td>
</tr>
<tr>
<td>Vitamin D nmol/L</td>
<td>50.0 (37.8–67.8)</td>
<td>39.5 (28.8–58.5)</td>
<td>0.13 (0.02–0.64)</td>
<td>.01</td>
<td>144</td>
</tr>
<tr>
<td>Disability§</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NHANS category score for “reach”</td>
<td>1.2 ± 1.4</td>
<td>2.2 ± 1.1</td>
<td>1.75 (1.33–2.29)</td>
<td>&lt;.001</td>
<td>160</td>
</tr>
<tr>
<td>NHANS overall disability score</td>
<td>0.9 ± 0.8</td>
<td>1.2 ± 0.7</td>
<td>1.65 (1.05–2.60)</td>
<td>.03</td>
<td>160</td>
</tr>
<tr>
<td>Number of assistive devices**</td>
<td>2 (0–4)</td>
<td>3 (1–5)</td>
<td>3.93 (1.20–12.83)</td>
<td>.02</td>
<td>165</td>
</tr>
<tr>
<td>Nondominant handgrip strength (kg)</td>
<td>19.5 ± 8.0</td>
<td>14.8 ± 5.1</td>
<td>0.90 (0.84–0.97)</td>
<td>.01</td>
<td>141</td>
</tr>
<tr>
<td>Knee extension strength fracture side (kg)</td>
<td>7.3 ± 4.0</td>
<td>5.5 ± 3.0</td>
<td>0.88 (0.78–0.99)</td>
<td>.03</td>
<td>129</td>
</tr>
<tr>
<td>Hip abduction strength nonfracture side (kg)</td>
<td>6.6 ± 3.1</td>
<td>5.3 ± 2.0</td>
<td>0.84 (0.71–0.98)</td>
<td>.03</td>
<td>135</td>
</tr>
<tr>
<td>Knee range of motion nonfracture side (°)</td>
<td>80.5 ± 8.0</td>
<td>76.8 ± 10.6</td>
<td>0.96 (0.92–1.00)</td>
<td>.04</td>
<td>143</td>
</tr>
<tr>
<td>Total static balance time (s)†</td>
<td>66.4 (61.7–79.7)</td>
<td>61.3 (49.8–69.9)</td>
<td>0.97 (0.95–0.99)</td>
<td>.003</td>
<td>131</td>
</tr>
<tr>
<td>Habitual physical activity§§</td>
<td>294.6 (36.9–1,010.5)</td>
<td>85.0 (3.6–214.2)</td>
<td>0.64 (0.45–0.90)</td>
<td>.01</td>
<td>158</td>
</tr>
<tr>
<td>Depth perception§§§</td>
<td>230.4 ± 168.0</td>
<td>310.8 ± 152.2</td>
<td>1.00 (1.00–1.01)</td>
<td>.03</td>
<td>141</td>
</tr>
<tr>
<td>Quality of life§§§§§§§</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF-36 general health</td>
<td>65.5 ± 15.4</td>
<td>59.7 ± 16.8</td>
<td>0.98 (0.95–1.00)</td>
<td>.04</td>
<td>144</td>
</tr>
<tr>
<td>SF-36 vitality</td>
<td>46.0 ± 22.7</td>
<td>37.3 ± 20.7</td>
<td>0.98 (0.97–1.00)</td>
<td>.04</td>
<td>146</td>
</tr>
</tbody>
</table>

(Table 3 Continues)
followed for 1 year (37,38), the incidence of single falls, recurrent falls, injuries, and fractures was substantially greater in the current study. Thus, our data suggest that the risk and morbidity associated with falling is notably increased in the year following hip fracture.

Approximately one third (30%) of the study participants sustained a fall-related injury (soft-tissue injury or fracture) during the 12-month follow-up. This exceeds the proportion (18%) reported for healthy older persons (38) but is less than the 48% reported for those with full history (39). As expected, most injuries involved soft tissue. However, 12% of participants sustained a fall-related fracture, similar to the incidence reported in another 1-year prospective study following hip fracture (5), but more than twice as high as seen in healthy elders (38). Importantly, recurrent hip fracture incidence (5%) was four- to eightfold greater than the incidence reported in general cohorts or fallers (0.6%–1.2%) (38–40).

<table>
<thead>
<tr>
<th>Table 3. Risk Factors for Recurrent Falls and Injurious Falls (Continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk Factors for Fall-Related Fractures</td>
</tr>
<tr>
<td>Persons sustaining</td>
</tr>
<tr>
<td>Persons sustaining a fracture</td>
</tr>
<tr>
<td>OR (95% CI)</td>
</tr>
<tr>
<td>p Value</td>
</tr>
<tr>
<td>N</td>
</tr>
<tr>
<td>Nutritional status (MNA score)††</td>
</tr>
<tr>
<td>Presence of osteoarthritis†</td>
</tr>
<tr>
<td>Disability§</td>
</tr>
<tr>
<td>NHANES category score for “hygiene”§</td>
</tr>
<tr>
<td>NHANES category score for “reach”§</td>
</tr>
<tr>
<td>Quality of life§</td>
</tr>
<tr>
<td>SF-36 mental health</td>
</tr>
<tr>
<td>SF-36 general health</td>
</tr>
<tr>
<td>SF-36 vitality</td>
</tr>
<tr>
<td>SF-36 mental component summary</td>
</tr>
<tr>
<td>52.7 ± 8.7</td>
</tr>
<tr>
<td>57.9 ± 16.1</td>
</tr>
<tr>
<td>0.97 (0.95–1.00)</td>
</tr>
<tr>
<td>0.03 146</td>
</tr>
<tr>
<td>55.3 ± 19.3</td>
</tr>
<tr>
<td>0.96 (0.93–1.00)</td>
</tr>
<tr>
<td>0.03 144</td>
</tr>
<tr>
<td>29.7 ± 15.6</td>
</tr>
<tr>
<td>0.97 (0.94–1.00)</td>
</tr>
<tr>
<td>0.02 146</td>
</tr>
<tr>
<td>51.6 ± 11.5</td>
</tr>
<tr>
<td>45.2 ± 7.6</td>
</tr>
<tr>
<td>0.94 (0.89–0.99)</td>
</tr>
<tr>
<td>0.02 143</td>
</tr>
</tbody>
</table>
| Notes: Continuous variables with normal data distributions are presented as mean ± SD. Skewed data are presented as median (25th to 75th percentile). Categorical data are presented in percent. OR and p values are from univariate logistic regression analyses, with age entered into the model. CI = confidence interval; MNA = Mini-Nutritional Assessment; NHANES = National Health and Nutrition Examination Survey; OR = odds ratio; SF = short form. 
* Number of chronic diseases listed in participants’ medical record notes from acute and rehabilitation hospitalizations for hip fracture. 
† Number of medications listed in participants’ acute hospital discharge summary. 
‡ OR and p values were calculated from log(base 10)-transformed data. OR for log-transformed data represents the OR for a 10-unit increase in raw data. 
§ OR and p values are for moderate-to-severe vitamin D deficiency (<25 nmol/L) vs normal vitamin D level (≥50 nmol/L). Cutoffs were based on Australian reference values published in a recent position statement (39). 
¶† Diagnosis recorded in participants’ medical record notes from acute and rehabilitation hospitalizations for hip fracture. 
‡‡ Data represent the mean respective category score from Part C (activities of daily living) of the NHANES I Epidemiologic Follow-Up Study 1986. Disability score = mean of eight category scores. This questionnaire asked participants how much difficulty they had (prior to hip fracture) in performing 23 activities of daily living when they were alone and without the use of an assistive device. Response choices for each question were as follows: no difficulty (0), some difficulty (1), and much difficulty (2), or unable to do (3). Data refer to the week prior to hip fracture. 
§§ Data represent the mean subscale or summary score from the Medical Outcomes Study Short-Form Health Survey (SF-36). This survey is a measure of global health-related quality of life with eight subscales and two summary scores. All SF-36 scores have a possible score of 0–100, with higher values representing better quality of life. Data are reflective of participants’ post–hip fracture status. 
** Number of assistive devices used for independent activities of daily living prior to hip fracture. 
†† Total static balance time was calculated by summing the time recorded for six individual tests (possible range = 0–90 s) (submitted, JOG 2008). Higher scores represent better static balance. 
‡‡‡ OR and p values were calculated from raw data because log transformation did not improve the normality of data distribution. 
§§§ Physical activity index representing weekly energy expenditure (27). Data refer to the week prior to hip fracture. 
††† Depth perception was assessed using the Randot Stereotest at the recommended test distance of 40 cm. Higher values represent more impaired depth perception. 
¶¶ The MNA was used to provide a global index of risk of malnutrition following hip fracture, using a combination of health status, anthropometric, psychological, and dietary intake questions and measurements at a single point in time (14). Higher scores represent lower risk of malnutrition. 

Risk Factors for Recurrent Falls

Risk factors for recurrent falls included higher number of chronic diseases and medications, higher pre-fracture disability, CHF, and lower vitamin D, handgrip strength, and quality of life. In contrast to what was expected based on studies of non–hip fracture cohorts (41–43), gender, fall history, gait velocity and endurance, physical activity level, cognition, fear of falling, and vision were not significant risk factors for recurrent falls. Notably, every 10 nmol/L increase in serum vitamin D was associated with an 87% decrease in both recurrent fall risk and “all fall-related injuries” risk, supporting recent meta-analyses suggesting that vitamin D supplementation prevents falls (44,45) and fractures (46). As others have suggested (47,48), this protective effect is perhaps mediated by vitamin D effects on muscle function as we also found that those with low vitamin D had poorer strength and balance. CHF (about 12-fold increase in risk) and quality of life related to mental health (RE subscale; 57%
Table 4. Significant Independent Risk Factors for Recurrent and Injurious Falls From Multivariate Logistic Regression Analyses

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>p Value</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Congestive heart failure*</td>
<td>.01</td>
<td>11.80 (1.79–77.80)</td>
</tr>
<tr>
<td>Quality of Life SF-36 role emotional†</td>
<td>.02†</td>
<td>0.43 (0.22–0.87)†</td>
</tr>
<tr>
<td>Injurious falls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All fall-related injuries (n = 90 in model)</td>
<td>.01</td>
<td>1.16 (1.03–1.30)</td>
</tr>
<tr>
<td>Nutritional status (MNA score)§</td>
<td>.03</td>
<td>0.82 (0.69–0.98)</td>
</tr>
</tbody>
</table>

Notes: CI = confidence interval; MNA = Mini-Nutritional Assessment; OR = odds ratio; SF = short form.
*Diagnosis recorded in participants’ medical record notes from acute and rehabilitation hospitalizations for hip fracture.
†Data represent the mean subscale score from the Medical Outcomes Study Short-Form Health Survey (SF-36). This survey is a measure of global health-related quality of life with eight subscales and two summary scores. All SF-36 scores have a possible score of 0–100, with higher values representing better quality of life. Data are reflective of participants’ post–hip fracture status.
‡OR and p values were calculated from log(base 10)-transformed data. OR for log-transformed data represents the OR for a 10-unit increase in the raw data.
§The MNA was used to provide a global index of risk of malnutrition following hip fracture, using a combination of health status, anthropometric, psychological, and dietary intake questions and measurements at a single point in time (14). Higher scores represent lower risk of malnutrition.

reduction in risk for every 10-point increase in RE score) remained strong independent risk factors for recurrent falls when controlling for other characteristics. The significant role of CHF in elevating recurrent fall risk may be related to the poorer balance found in this study or the increased gait variability that has been observed (49) in CHF. In our cohort not targeted for clinical depression, low RE scores may reflect subclinical depressive symptomatology. Because depression has been found to increase the risk of falling (50,51), perhaps due to postural instability (52), this may explain the increase in recurrent fall risk we observed with lower RE scores.

Risk Factors for Injurious Falls

Risk factors for all fall-related injuries.—Importantly, measures of pre–hip fracture impairment (disability, poor vitamin D status, and a more sedentary lifestyle), combined with strength and balance impairments persistent after surgery, identified the most vulnerable individuals in our cohort, who would go on to injure themselves again. Notably, hip abductor weakness, which has been discussed as a potential risk factor for falls to the side due to its association with increased medial–lateral sway (53), had the strongest relationship with all fall-related injuries risk of all the muscle groups tested (handgrip, knee extensor, ankle dorsiflexion, and triceps): a 16% reduction in risk for each kilogram increase in hip abductor strength. Virtually, all the risk factors identified are amenable to targeted intervention strategies (eg, strength and balance exercise, vitamin D supplementation), which may be the most effective means to target those at risk and reduce the personal and economic burden associated with fall injury.

Risk factors for fractures.—Older age, osteoarthritis, prefracture disability, malnutrition, and poor quality of life predicted fractures. Interestingly, osteoarthritis increased risk of fracture by almost fivefold in this cohort. Other recent studies (54,55) have also identified osteoarthritis as a risk factor for fracture. Nutritional status and older age remained significant in multivariate analyses. Malnutrition is linked to osteopenia as well as sarcopenia, gait and balance impairment, and neuropsychological dysfunction, all of which may underlie its observed role in fracture risk. Surprisingly, vitamin D, sarcopenia, physical performance, and current smoking were not identified as risk factors for fracture.

Although the use of different fall-related outcome variables in other post–hip fracture studies limits comparison with the present study, it is important to note that, similar to Hall (5), we have found poorer balance and disability to be significant risk factors for fall-related morbidity.

The majority of the significant predictors identified in univariate analyses (controlled for age) for both recurrent and injurious falls were no longer significant in multivariate analyses. One possible explanation for this finding is that collinearity between individual predictor variables reduced the strength of relationships in multivariate models. It is suggested that recurrent falls and fall-related injuries after hip fracture may best be conceptualized as are other “geriatric syndromes” including frailty (56) and falls in other cohorts (57), in which multiple, overlapping risk factors result in a cumulative increase in risk. Future research in this area is warranted.

Limitations

Exclusion of nursing home residents and those with severe cognitive impairment or terminal illness limits the generalizability of our findings to relatively healthy community-dwelling hip fracture cohorts. Fall events were likely underreported due to participant or proxy refusal of fall follow-up measures, research assistant noncollection of phone call data, as well as questionable reliability of proxy responses, and likely difficulties in memory recall for participants with cognitive impairment. About one third to nearly one half of participants were excluded from multivariate analyses due to those participants not having data for all measures in the model. In the majority of cases, data were missing due to participant or proxy refusal. Data for performance-based measures including mobility and balance tests were also missing due to participants’ non-weight-bearing or partial weight-bearing status. Participants who were excluded from the models (ie, those with missing data) were older, had more disability, were weaker, and had higher rates of depression and cognitive impairment. This as well as the other aforementioned limitations would likely...
serve to attenuate any observed relationships between markers of comorbidity and frailty, and falls outcomes. Thus, our results may represent a conservative estimate of the risks imposed by the characteristics identified. It is unlikely that we missed any serious injuries or fractures, however, as medical records of all hospitalizations during the 12 months were extracted. Had we attained greater compliance with our falls data collection, it is possible that additional risk factors may have been identified, or the strength of relationships we found may have been greater, but it is unlikely that the reported relationships would have been eliminated. A further limitation is the potential for identifying false-positive fall outcome predictors due to the relatively low number of events, particularly for fractures ($n = 22$), as compared with the number of potential predictors assessed. However, all predictor variables were selected through a priori hypotheses drawn from existing literature, which would tend to reduce the chances of this occurring.

It is suggested that future research examining fall-related outcomes in a post–hip fracture cohort adopt the guidelines presented in the consensus paper published by the Prevention of Falls Network Europe and Outcomes Consensus Group (ProFaNE) (58). Ultimately, this will provide greater understanding of fall-related outcomes and fall prevention strategies. Although the SHIP study was designed prior to the publication of these recommendations, the majority of this study’s data collection and reporting methods were consistent with these guidelines.

**Conclusions**

This is the first study to our knowledge to examine risk factors for recurrent and injurious falls in a post–hip fracture population. We suggest that the risk factors identified in this study may be used to (i) identify those patients after hip fracture most at risk of subsequent fall-related morbidity and 2) design robust, targeted preventive strategies. These strategies might include specific strength or balance training, treatment of depression, better management of CHF or arthritis-related mobility disorders, or improvement in support for ADL.

**Conflict of interest**

The authors of this study have no conflicts of interest.

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**Correspondence**

Address correspondence to Maria A. Fiatarone Singh, MD, Exercise, Health and Performance Faculty Research Group, Faculty of Health Sciences, University of Sydney, East Street, Lidcombe 2141, New South Wales, Australia. Email: m.singh@usyd.edu.au

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