Methodology and Baseline Characteristics for the Sarcopenia and Hip Fracture Study: A 5-Year Prospective Study

Maria A. Fiatarone Singh,1,2,3 Nalin A. Singh,4,5 Ross D. Hansen,6 Terence P. Finnegan,7 Barry J. Allen,8 Terrence H. Diamond,9 Ashish D. Diwan,10 Bradley D. Lloyd,1 Dominique A. Williamson,1 Emma U.R. Smith,1,11 Jodie N. Grady,1 Theodora M. Stavrinos,1,4,5 and Martin W. Thompson1

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

Background. Age-related hip fractures are associated with poor functional outcomes, resulting in substantial personal and societal burden. There is a need to better identify reversible etiologic predictors of suboptimal functional recovery in this group.

Methods. The Sarcopenia and Hip Fracture (SHIP) study was a 5-year prospective cohort study following community-dwelling older persons admitted to three Sydney hospitals for hip fracture. Information was collected at baseline, and 4 and 12 months, including 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, vision, and fall-related data, with residential status, disability, and mortality reassessed at 5 years.

Results. 193 participants enrolled (81 ± 8 years, 72% women). High levels of activities of daily living, disability and sedentariness were present prior to fracture. At admission, the cohort had high levels of chronic disease; 38% were depressed, 38% were cognitively impaired, and 26% had heart disease. Seventy-one percent of participants were sarcopenic, 58% undernourished, and 55% vitamin D deficient. Mobility, strength, and vision were severely impaired. There was little evidence that these comorbidities were either recognized or treated during hospitalization. Disability, sedentariness, malnutrition, and walking endurance predicted acute hospitalization length of stay.

Conclusions. The complex comorbidity, pre-existing functional impairment, and sedentary behavior in patients with hip fracture suggest the need for thorough screening and targeting of potentially reversible impairments. Rehabilitation outcomes are likely to be highly dependent on amelioration of these highly prevalent accompaniments to hip fracture.

Key Words: Body composition—Disability—Hip fracture—Sarcopenia.
ulcers, and postoperative pain (5). Moreover, Eastwood and associates (6) and later Penrod and associates (7) have classified patients after hip fracture into specific subgroups based on pre-fracture functional status, age, and comorbidity that predict 6-month outcomes. However, the majority of studies in which these predictors have been identified are limited by single-study site designs, collection of only a limited set of patient characteristics in a single cohort, lack of performance-based measures, or short follow-up periods.

To develop clinical management practices that implement rational treatment initiatives in the hip fracture cohort, there is a need to better identify reversible etiologic predictors of poor functional recovery and to understand their relationships to each other. A comprehensive study examining potential predictors of functional recovery from multiple domains with robust assessment of these factors within the same cohort must be done to achieve this. We were able to identify only one recent large multisite prospective study that has collected prospective patient data after hip fracture across multiple functional domains with inclusion of performance-based measures (8). Further, few studies have followed persons after hip fracture beyond 2 years, and none to our knowledge have examined predictors of functional status at 5 years after hip fracture. Therefore, we designed and implemented the Sarcopenia and Hip Fracture (SHIP) study as a means to explore these factors in detail for a period of 5 years following an index hip fracture in all eligible consenting patients in three hospitals. This article details the data collection methods of the SHIP study and describes the baseline characteristics and predictors of acute hospital outcomes in this cohort. Follow-up data will be presented in future publications.

METHODS

Recruitment

Participants were 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 a presenting diagnosis of “hip or femur fracture,” “hip or pelvic pain,” or “fall” were identified by emergency and operating room lists. Patients were eligible for study inclusion if aged 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 the inability to 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.

Study Design

In-person assessments were undertaken at baseline, one-month period following hip fracture, and 4 and 12 months after hip fracture. These assessments included interview and performance-based tests and were performed at the participants’ place of residence at the time of assessment. Monthly phone calls were conducted during the first year of follow-up to collect subsequent falls data and information about subsequent hospitalizations and visits to health care providers. At approximately 5 years following hip fracture, participants were contacted through phone to collect information about mortality status, disability, and residence type. Proxy reporting was permitted for cognitively impaired participants.

Baseline Measures

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 (9).

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 (10). An energy intake less than 30 kcal/kg/d was considered inadequate. Serum albumin level of less than 35 g/L was considered low (11). 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 (12). 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 (13). Creatinine clearance was calculated from serum creatinine using the Cockcroft–Gault formula and considered “low” if less than 65 mL/min (14). 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 (15) 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) (16) and fat-free mass (FFM) (17). Fat mass was calculated by subtracting FFM from fasting body weight. Skeletal muscle index (SMI) was calculated as SMM (kg)/height (m²) (18). Sarcopenia was defined as SMI less than 7.0 kg/m² for women and less than 9.5 kg/m² for men (18). Standing height was predicted from measured knee height for non-weight-bearing participants using the formula provided by Chumlea and associates (19). 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) Mini-nutritional Assessment (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; Ametek 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 a 6-minute walk test. Habitual and maximal gait velocities were assessed for 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 range of motion were measured with a Plurimeter-V (Australasian Medical & Therapeutic Instruments, Brisbane, Australia). Visual capacities including reading visual acuity (Vocational Near Vision Test Type from 38 cm; HS Clement Clarke International, Harlow, Essex, UK), depth perception (Randot Stereotest; Stereo Optical Co. 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 (20). Contrast sensitivity was considered impaired if less than 1.65 log units (21). 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 [ADLs]) of the National Health and Nutrition Examination Survey (NHANES) I Epidemiologic Follow-Up Study 1986 (22). 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 (23) was also used to reflect pre-fracture functional status. Pre-fracture habitual physical activity level was assessed by the Harvard Alumni physical activity index (24) and the Physical Activity Scale for the Elderly (PASE) (25). The Mini-Mental State Examination, Geriatric Depression Scale, Tinetti Falls Efficacy Scale (26), Self-Efficacy Gauge (27), and the 11-item Duke Social Support Index (28) 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) (29).

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, range of motion [ROM], strength) tests were reflective of participants’ status at the time of interview.
RESULTS

Flow of Participants

Of 303 participants eligible for study inclusion, 193 enrolled, representing a response rate of 64% (Figure 1).

Baseline Participant Characteristics

Baseline characteristics of participants are shown in the supplemental Appendix Tables 1–5 (see supplementary materials online). Recruited participants were not different in age nor gender compared with all patients tracked with hip fracture, but were younger (80.6 vs 84.8 years, \( p < .001 \)) than patients with hip fracture who were ineligible (due to illness, cognitive impairment, nursing home residence, non–English-speaking background, or death). Among all eligible patients, the 64% who consented were of similar age (80.6 vs 82.3 years, \( p = .10 \)) but more likely to be men than those who refused (28% vs 18%, \( p = .05 \)).

Demographic Characteristics

The 193 participants were 81 ± 8 years old (range = 60–97 years) and 72% were women. Prior to hip fracture, 92% of participants were living independently and 8% lived in hostel accommodation.

Pre-fracture Characteristics

Nearly half (42%) of the cohort reported falling in the year prior to hip fracture, and 20% reported recurrent falls.

Participants had ADL disability prior to hip fracture as shown by the NHANES disability score reflecting “some difficulty.” About 1 in 5 participants were using home care services prior to hip fracture. Pre-fracture physical activity levels were very low, with 94% of participants expending less than the desirable 2,000 kcal/wk (30).

Circumstances and Treatment of Hip Fracture

Most commonly, hip fractures occurred while walking at home. All patients were treated on orthopedic wards, with consultations from geriatricians and psychiatrists as requested by the surgical team. The most common site of hip fracture was pertrochanteric, and the most commonly used surgical hip prosthesis was a pin and side plate (dynamic hip screw). Three participants required a revision of their original hip prosthesis during acute hospitalization. Ninety percent of participants received intravenous antibiotics, whereas only 61% received anticoagulation medication. Only 4 people were seen by a psychiatry team, and not one person received enteral or parenteral nutritional support. Eighteen percent of participants were prescribed vitamin D supplementation. Most participants were discharged from the acute care hospital to a rehabilitation hospital; however, 12% were discharged home into the community and 4% to a nursing home.

In-hospital Complications

One hundred eleven (59%) participants had at least one in-hospital complication, the most prevalent being delirium (17%), anemia (10%), urinary retention (8%), and electrolyte or fluid imbalance (8%). Two people suffered an acute myocardial infarction. Four people suffered deep venous thrombosis, and 1 person had an infection at the site of hip prosthesis. Eight people fell during the hospital admission.

Comorbidity at Time of Hip Fracture

Nutrition.—Fifty-eight percent of participants were sarcopenic, a further 12% had sarcopenic obesity, and 19% were overweight or obese (and not sarcopenic), whereas only 11% had normal body composition. More than half (58%) of the participants were undernourished or at risk of malnutrition (31), and 55% were deficient in vitamin D (12). Lymphopenia (<1,500 cells/mm³), consistent with protein calorie malnutrition, was present in 68% of participants. Forty-five percent of the cohort had inadequate energy (<30 kcal/kg/d) and protein (<1 g/kg/d) intakes. Dietary intake of vitamin D was only one fifth of the adequate intake recommended for healthy elderly population (32), and calcium intake was also much less than the recommended dietary intake (32). Ninety-nine percent of patients were at “nutritional risk” based on a below-normal result for MNA, vitamin D, albumin, total lymphocyte count, body composition, or some combination of these factors.
Figure 1. Participant recruitment flowchart.

Disease.—The cohort had high levels of chronic disease, with the most prevalent being depression, cognitive impairment, heart disease, respiratory disease, and osteoarthritis.

Psychological function or quality of life.—Quality-of-life scores were substantially worse for physical functioning, role physical, bodily pain, vitality, social functioning, and physical component summary, and similar for general health, role emotional, mental health, and mental component summary compared with the Australian norms for women aged 70–74 years (33). Fear of falling was much higher than that reported for community-dwelling older persons not selected for hip fracture (34).

Physical Function Post-fracture

In the month following hip fracture, mobility was impaired, with habitual walking velocity and 6-minute walk distance less than one third of norms for older persons (35). Based on normative data for “healthy older persons,” men and women’s handgrip strength was only about 60% and 80%, respectively of normal (36). As expected, participants were weaker and had reduced joint range of motion for measures on their hip fracture leg as compared with their “good leg.” At the time of discharge from the acute care hospital, 76% of patients were full weight-bearing; however, half the cohort still required a four-arm support frame to mobilize and 70% required at least one person for assistance during transfers or mobilization.

Predictors of Acute Hospitalization Length of Stay

The median length of acute hospitalization stay was 9 days (range = 2–53 days). Length of stay (less than or equal to median vs greater than median) was significantly longer for patients at one hospital (median = 17 days) compared with patients at the other two hospital sites (median = 8–9 days; \( p < .001 \)), despite no difference in age or pre-fracture disability between sites (\( p = .56 \)). Age (controlling for hospital site) did not predict length of stay (\( p = .58 \)). Among the most prevalent comorbidities (malnutrition, depression, cognitive impairment, heart disease), pre-fracture disability, pre-fracture physical activity level, post-fracture walking endurance (6-minute walk distance measured within 1 month of hip fracture), and post-fracture strength (handgrip strength, total lower limb strength), the only significant predictors (controlling for age and hospital site) of acute hospitalization length of stay were malnutrition (MNA score) (odds ratio [OR]: 0.90, 95% confidence interval [CI]: 0.82–0.99, \( p = .02 \)), lower pre-fracture physical activity level (PASE score) (OR: 0.99, 95% CI: 0.98–1.00, \( p = .02 \)), and walking endurance (OR: 1.00, 95% CI: 0.99–1.00, \( p = .046 \)).
Pre-fracture disability (NHANES disability score) tended to be higher in those with increased length of stay (OR: 1.56, 95% CI: 1.00–2.45, p = .053).

**Discussion**

We found that older persons present with an extraordinary burden of malnutrition, disability, neuropsychological impairment, and comorbid diseases at the time of hospitalization for hip fracture, some of which has been noted in other hip fracture cohorts (8,37,38). Most notably, these included depression, cognitive impairment, ADL disability, inactivity, poor nutritional status, sarcopenia, and reduced gait velocity and endurance, strength, and vision. Many of these problems, including poor nutrient intake and body composition, ADL disability, and inactivity, were present before hip fracture and may have actually contributed to the admission hip fracture. We identified that poorer nutrition and walking endurance, and greater levels of pre-fracture disability and inactivity, predicted a longer acute hospitalization stay. Importantly, left untreated, studies after hip fracture have shown that these comorbidities and impairments lead to poor functional outcomes, a reduced level of independence, and ultimately nursing home admission, and death (5). Moreover, a longer acute hospitalization stay by itself has been found to predict poor functional recovery after hip fracture (38). Therefore, it is crucial to identify and target these impairments early at the time of hip fracture.

There was little evidence that any of these problems were diagnosed or treated during the hospital admission in this cohort. For example, only 4 people (2%) received a psychiatry consult, and not one person received enteral or parenteral nutritional support despite the high prevalence of cognitive impairment (38%), depression (38%), in-hospital delirium (17%), and nutritional risk (99%).

Dietary intake of vitamin D in the month prior to hip fracture was substantially below reference values recommended for healthy older Australians (32), and more than half of the participants were deficient in vitamin D. Considering the risk of falls and fracture associated with vitamin D deficiency (39–41), it is notable that only 18% of patients were receiving vitamin D supplementation.

This study is unique with respect to the number of different physiological, functional, medical, and psychosocial domains assessed within the same cohort, as well as the inclusion of performance-based measures (rather than reliance on self-report or proxy report), and its multisite 5-year prospective design. Only one other study (8) was identified that was comparable in design and breadth of domains assessed. Magaziner and associates prospectively followed 674 patients in the United States for 2 years after hip fracture and proposed that recovery after hip fracture follows a function-specific sequence such that affective function, balance, gait, and cognition reach peak recovery before social, instrumental, and lower extremity physical function. It will be interesting to see whether this same pattern of recovery is observed within the Australian SHIP cohort. In addition to sequence of recovery, future SHIP publications will examine predictors of functional recovery (as well as their relationships to each another) at 1 and 5 years after hip fracture.

**Limitations**

There are several potential limitations to our study, which should be acknowledged. As we excluded nursing home residents, and those with severe dementia or terminal illness, our results may not be applicable to these cohorts. Had we included these persons, it is likely that a higher mortality and disability rate would have been observed. In addition, incomplete data collection, especially of physical performance measures such as balance and walk tests, may have attenuated the degree of impairment already reported for these measures as the majority of those unable to perform such tests due to weight-bearing status or refusal were likely to be at a lower level of functioning than those tested. There is also the potential for recall bias for pre-fracture measures because the questionnaires used to obtain these data were administered after hip fracture, but the use of proxy reporting for those with cognitive impairment minimized this bias.

**Conclusions**

Older persons presenting at hospital for surgical repair of minimal-trauma hip fracture have a high burden of comorbidities and impairments, many of which existed before fracture. Medical management that focuses solely on successful surgical treatment of hip fracture is therefore insufficient for these patients. Poorer nutrition and walking endurance, as well as greater levels of pre-fracture disability and inactivity, predicted increased length of acute hospital stay, delaying transfer to rehabilitation settings. Thorough multidisciplinary screening for potentially reversible impairments is needed, followed by a coordinated multidisciplinary rehabilitation treatment approach targeting these impairments. Acute hospital complications as well as long-term functional patient outcomes are likely to be highly dependent on the ability to ameliorate these highly prevalent accompaniments to hip fracture. Future SHIP publications will provide greater understanding of the predictors and sequence of recovery for the 5-year period following hip fracture.

**Supplementary material**

Supplementary material can be found at: http://biomedgerontologyjournals.org/.

**Acknowledgments**

This study was funded by the Australian National Health and Medical Research Council, project grant 107472, and supported by the University of Sydney. We thank Peter Smerdely and Tom Gwinn for their contribution to the study’s design. We thank all hospital personnel who assisted in the recruitment of participants, and the participants and their families for their generous commitment to this project.
CONFLICT OF INTEREST

The authors of this study have no conflicts of interest.

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

REFERENCES


