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Bone Mineral Density, Soft Tissue Body Composition, Strength, and Functioning After Hip Fracture

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Background. Although substantial decrements in bone, muscle, and functional ability have been reported to follow the occurrence of hip fracture in elderly women, little is known about the interrelation of these consequences. The authors evaluated the associations among physiologic and functional factors during recovery from hip fracture to determine whether any consistent sequence of events followed and whether markers of functional outcomes could be identified.

Methods. Two hundred five community-dwelling women aged 65 years and older who sustained hip fracture between 1992 and 1995 and were admitted to one of two acute care hospitals in metropolitan Baltimore, Maryland, participated in a 1-year prospective cohort study. Bone mineral density, lean mass, and fat mass were measured by dual-energy X-ray absorptiometry during the hospitalization and 2, 6, and 12 months later. Functional limitations were self-reported and grip strength was measured during interviews at the same time points. Correlation coefficients were calculated for all possible pairs of measures and time points.

Results. Losses of femoral neck bone mineral density and lean body mass and gains in fat mass were observed. Grip strength showed early improvement but declined by 1 year to levels close to those seen during hospitalization. Functional outcomes showed minimal correlation with bone or body composition and only moderate correlation with strength.

Conclusions. Physiologic and functional declines follow hip fracture in elderly women. These are largely independent of one another and suggest that interventions to maximize recovery must simultaneously target multiple areas, including bone, muscle, strength, and function.

HIP fracture has important consequences for elderly women. The subsequent increased risk for mortality is well known and may persist for several years (1). Postfracture morbidity is also a substantial concern. During the year after hip fracture, women lose 4% to 7% of bone at the contralateral hip and approximately 5% to 6% of lean body mass, while they gain 3.6% to 11% of total fat mass (2–4). Functional recovery is incomplete as well: Only about one third of patients regain prefracture levels (5). By 1 year after the fracture event, only 60% of women can walk independently without equipment and only 40% require no assistance with activities of daily living (ADLs) (6–9). Decrements that follow hip fracture may add to age-related changes in bone, lean and fat body composition, function, and performance.

The interrelation of these hip fracture consequences is not well understood. Although disuse can produce losses of both muscle and bone and lead to functional decrements in the early postfracture period, the relationships among these elements during the recovery process have not been evaluated. It is unknown whether recovery in one area is a prerequisite to recovery in another, or whether structural and functional courses are independent of one another. The design of interventions to optimize recovery from hip fracture requires an understanding of the mechanisms underlying change, and clarification of the correlations or interdependence over time of bone, muscle mass, muscle strength, and function is a preliminary step in this process.

The Baltimore Hip Studies comprise a series of cohorts of older persons who have sustained a hip fracture. In this report, we use information collected from participants in a prospective study of hip fracture consequences to determine whether anatomic measures of body composition (bone mineral density [BMD], lean body mass, and fat mass), strength, and functional ability correlate with each other cross-sectionally and over time, and to what extent a measure at one time can predict a subsequent value.

Methods

Participants

A prospective study of hip fracture consequences was conducted from 1992 through 1995 in the Baltimore, Maryland, metropolitan area as part of the Baltimore Hip Studies. Details of the study cohort have been published (2,10). Briefly, community-dwelling white women aged 65 years and older who were admitted to one of two acute care teaching hospitals with new hip fractures were eligible to participate. Baseline evaluations were performed on 205 women, who represented 50% of eligible patients ($n = 407$) identified. All participants underwent surgical repair of their hip fractures. Those enrolled did not differ from those not enrolled in age, fracture type, surgical procedure, or prevalent comorbidity. Participants were followed for 1 year, with evaluations in the hospital within 10 days of admission and at 2, 6, and 12 months after the fracture. Any information a participant could not provide was collected from a proxy respondent. Informed consent was obtained from the participant or a designated proxy, and all study protocols were approved by the institutional review boards of participating facilities.

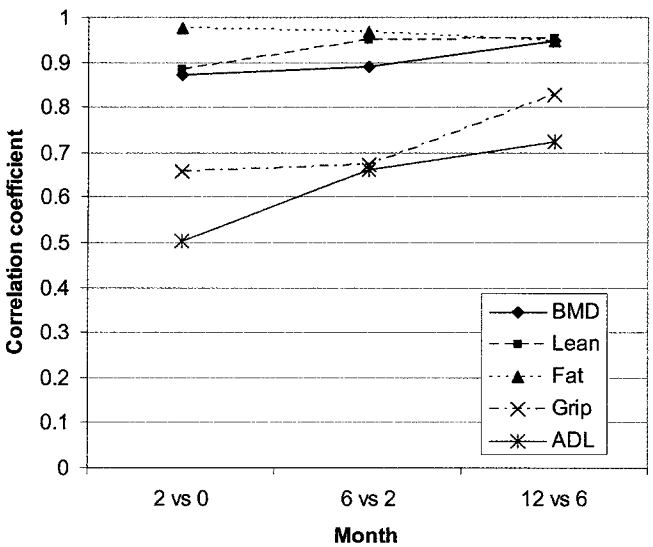

Figure 1. Within-measure correlation of measures during the year after hip fracture. BMD = bone mineral density; lean = lean body mass; fat = fat body mass; grip = grip strength; ADL = activities of daily living, self-reported.

Body Composition: Bone and Muscle

The BMD of the nonfractured hip and total body were measured using dual-energy X-ray absorptiometry, with either Hologic QDR-1000W or QDR-1500 equipment (Hologic, Waltham, MA). System software (version V5.47P) generated other body composition information, including lean and fat mass, for the entire body. Subsequent tests for each participant were conducted using the same machine used at baseline, and quality control of scans was maintained by daily use of a standard spine phantom. The coefficient of variation of phantom measurements during a 7-month period was 0.31%. Baseline measurements were performed, if possible, 3 days after admission. If this was not possible, testing was performed approximately 1 week later or 10 days after admission. If measurements were made at both times, the average was used as the baseline value.

Muscle Strength

Muscle strength was measured as grip strength, using a hand-held dynamometer (Jamar, Clifton, NJ). Testing was conducted with the participant in the sitting position, with the forearm supported and parallel to the floor. The better performance of two trials with the right arm was used, with maximum strength measured in kilograms. Grip strength has previously been shown to correlate well in older women ($r > 0.5$) with both knee extension strength (11) and quadriceps strength (12).

Function

Physical ADLs were assessed by participants' self-report of their ability to perform, with or without assistance, 15 tasks. These included 11 activities related to lower extremity function: walking 10 feet; walking one block; climbing 5 stairs; getting into a car; getting into and out of bed; rising from an armless chair; putting on pants; putting socks and shoes on both feet; getting into and out of a bath or shower; taking a bath, shower, or sponge bath; and getting on and off the toilet. Activities relating to upper extremity function included putting on a shirt or blouse, buttoning a shirt or blouse, feeding oneself, and grooming oneself (brushing hair, brushing teeth). Baseline scores reflected prefracture function.

Statistical Analyses

All statistical analyses were performed using SAS software, version 6.12 (SAS Institute, Cary, NC). The longitudinal course for postfracture measurements of BMD, muscle mass, grip strength, and ADL ability was modeled using linear mixed models, with an unstructured covariance matrix specified. This procedure accommodates missing values at some time points during the observation period. For each measure, Pearson product-moment correlations were determined to establish the association of that measure for a given time point with the same measure at another time point. "Tracking" refers to the extent to which the value of a measure at one time predicts the value at another time. Correlation coefficients were also used to establish the association between different measures at a given time point and to determine the extent to which a measure could predict the future value of another measure.

Results

The mean age of participants was 81 (±7.8) years. More than one half (52.5%) had intracapsular fractures. Mean femoral neck BMD, as measured within 10 days of the hip fracture, was 0.547 (±0.094) g/cm^2, mean fat mass was 16.29 (±6.85) kg, and mean lean body mass was 39.33 (± 0.43) kg. Average self-reported functional ability before the fracture was 1.97 (±0.13). During hospitalization, mean grip strength was 15.15 (±0.44) kg.

On average, during the postfracture year femoral neck BMD decreased 4.4%, lean body mass decreased 6%, and ADL performance decreased 73.4%. Grip strength was initially measured during the hospitalization, so the baseline value reflected acute weakness and functional limitations as a consequence of the injury, surgery, anesthesia, and medical restrictions. Despite this, and despite higher scores 2 months after the fracture, by 1 year after fracture grip strength was only marginally improved (0.4%).

Tracking performance of the measures is shown in Figure 1, with each point representing the correlation between two successive measurements. Characteristics that were precisely measured, for example, BMD, lean body mass, and fat mass, tracked well; that is, measurements at two successive time points were highly correlated. Grip strength tracked moderately well. Limitations of ADLs, which were less precisely measured and involved subjective assessment, showed weaker tracking.

Because functional outcomes are of primary interest after hip fracture, the associations of ADL limitations with concurrent and previous measures of other characteristics were also evaluated, as shown in Figures 2 and 3. Moderate associations were seen between concurrent measurements of grip strength and ADL function, ranging from 0.37 to 0.42; associations with bone, muscle, and fat were minimal, in no case more than 0.12 (Figure 2). Subsequent ADL function

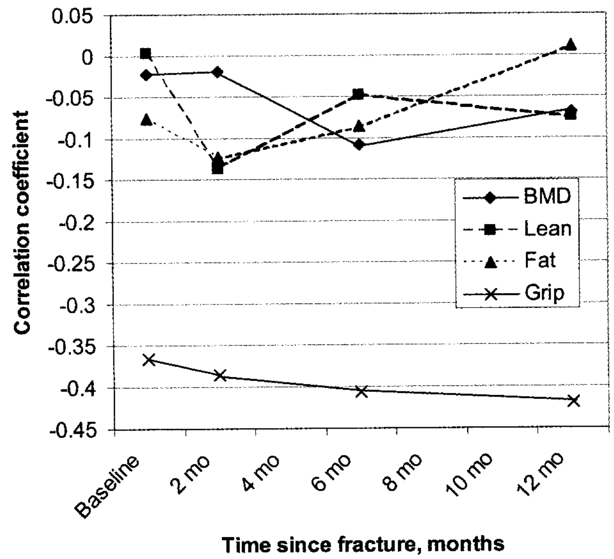

Figure 2. The correlation of ADL function with concurrent measures of BMD, lean mass, fat mass, and grip strength. BMD = bone mineral density; lean = lean body mass; fat = fat body mass; grip = grip strength; ADL = activities of daily living, self-reported.

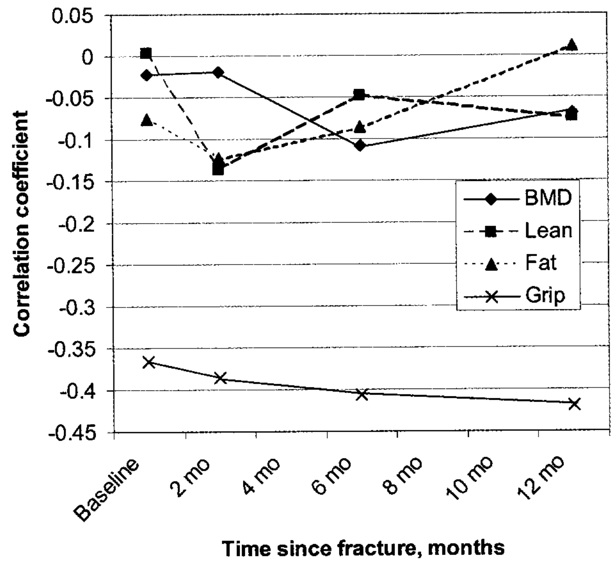

Figure 3. The correlation of ADL function at 2, 6, and 12 months after fracture with measures of BMD, lean mass, fat mass, and grip strength as measured at the previous time point (baseline, 2, and 6 months, respectively). BMD = bone mineral density; lean = lean body mass; fat = fat body mass; grip = grip strength; ADL = activities of daily living, self-reported.

showed strongest correlations with previous measures of grip strength, ranging from 0.32 to 0.43 (Figure 3). Previous measures of BMD, lean body mass, and fat mass correlated only weakly with subsequent ADL function. As an additional measure of functional outcomes, timed performance of 9 lower extremity activities (walking 10 feet, reaching for an item on the ground, rising from an armless chair, putting on socks, putting on shoes, going up and down stairs, getting on and off a toilet) was measured in these patients, using the Lower Extremity Gain Scale, an instrument developed by Baltimore Hip Studies investigators (unpublished data). Correlations of the Lower Extremity Gain Scale scores with other measures were almost identical to those seen with self-reported ADL function.

Discussion

Hip fracture is a momentous health event in elderly women and appears to be associated with substantial permanent physiologic and functional losses. The current analysis substantially extends earlier reports. We have previously reported losses of BMD and lean body mass and gains in fat mass after hip fracture (2), and other investigators have made similar observations (4,13). We have also reported that lower extremity physical functioning, as measured by self-reported limitations, shows some improvement until 6 months after fracture, but fails to recover to prefracture levels even 2 years later (9). Neither the trajectory of grip strength nor the extent of association among physiologic and functional measures during the year after hip fracture previously has been shown. Grip strength showed improvement between in-hospital and 2-month testing; however, by 12 months after fracture, grip strength had decreased almost to the levels seen immediately after fracture. Collectively, these findings suggest a pattern of increasing frailty and fragility.

Remarkably, post-hip fracture changes in body composition (bone, lean mass, and fat mass), strength, and physical functioning are largely independent of one another in this study. No element reliably predicts any other element, either contemporaneously or over time. Self-reported function showed a negligible correlation with BMD and body composition. In other words, function was almost entirely unrelated to musculoskeletal parameters measured by dual-energy X-ray absorptiometry, both cross-sectionally and over time. Grip strength, however, was moderately correlated with both function and body composition, although only modestly with BMD. The latter finding is consistent with earlier reports, in which grip strength had been shown to be associated with hip BMD in older women who exercised moderately at least three times per week (14). Strength has been observed to be determined by muscle mass independently of age and sex (15), and site-specific strength (e.g., grip strength) can reasonably be expected to depend on general lean body mass. In turn, skeletal muscle strength is an important determinant of function and performance (16–19).

In persons without fractures, muscle strength decreases with advancing age, but age-related bone loss is largely independent of this (20), and lower extremity strength has been shown to play a limited role in performing functional activities (16). Grip strength has been considered to be a marker of general frailty (14) and, in men, midlife grip strength has been a predictor of both disability (21) and mortality (22) in old age. However, grip strength, despite showing the strongest correlations with all other measurements, explains only about 17% of the variation in lean body mass and function and less than 10% of variation in BMD during the year after hip fracture.

Although associations among BMD, muscle mass, fat mass, grip strength, and functional ability would be biologically plausible in patients recovering from hip fracture, the magnitude of observed correlations was small. Each of the parameters measured in this study explains little of the variation in other parameters, both cross-sectionally and longitudinally. This implies that many important factors are not accounted for, or that influences responsible for the variation occur before the fracture. For example, might specific comorbid disease conditions not only predispose a person to hip fracture but also condition subsequent BMD, muscle mass and strength, fat mass, and ADL ability?

Recovery from hip fracture is generally defined in terms of functional outcomes: regaining the ability to walk, regaining self-sufficiency in the performance of a variety of tasks, and living independently (6,7,9). The recovery process after hip fracture is complex. It has been suggested that the recovery process necessarily proceeds sequentially, at least to the extent that affective function, cognition, balance, and gait recover before social, instrumental, and lower extremity physical function (9). Optimizing recovery, given the limited reserves of any older person who has sustained a hip fracture, may entail an understanding of other necessary correlates or prerequisites of each facet of recovery and the biologic mechanisms underlying them.

This study has important limitations. Bone mineral density, lean mass, and fat mass showed the greatest correlations, or best tracking, across time. These measurements are highly objective and repeatable. The lesser magnitude of correlation for strength and function may relate to measurement with relatively less precision and with greater subjectivity than bone and body composition and, therefore, greater variability. This variability would diminish correlations with all other measurements and may not reflect the "true" magnitude of association. Muscle strength was not measured in the lower extremity, although that might be expected to be most pertinent for walking ability, because of the greater degree of variability and subjectivity associated with quadriceps measures (relative to grip strength measures) in this population. Direct, reliable measure of quadriceps strength may, indeed, show stronger correlations with function. Furthermore, although the patients with hip fracture included in the study were frail, they were sufficiently well and cognitively intact to participate. Despite the similarity between enrolled patients and all eligible patients entering the two study hospitals, those included in this study likely represent a relatively healthy subset of all persons sustaining hip fracture; thus, their experience may not reflect that of all patients with hip fracture. Consistent with this possibility, although excess mortality is very high in frail populations after hip fracture, only 27 of the 205 (13.2%) participants died during the year after the fracture. Most importantly, the data are observational and descriptive: Cause-and-effect associations cannot be inferred.

A person's status at the time of the fracture event is of important prognostic value for the clinical course during the next year, whether the measure of interest is anatomic (bone, muscle mass), physiologic (strength), or functional (self-reported limitations). The magnitude of correlation, whether within or between areas of measurement, is consistent over time. Increasing BMD with a targeted antiresorptive agent is not likely to affect functioning, but it may reduce the risk for subsequent fracture. In addition, improving functional ability will not directly affect BMD, although it could be expected to improve quality of life and might decrease the risk for future fracture by reducing the risks for falling or fall-related injury. Increasing strength, which appears to be intermediate between anatomy and function, may affect both BMD and functional ability and, if focused on muscle groups adjacent to the hip, may also decrease the risk for fall-related injury.

Conclusion

We found little association among several anatomic and functional measures during the year after hip fracture. In particular, knowledge of functional status provides little information about anatomic parameters; conversely, anatomic measures explain little of the observed variation in function. Interventions to optimize recovery after hip fracture must increase BMD, improve body composition by increasing lean mass, increase strength, and improve function. Targeted interventions after hip fracture will, therefore, need to be multidimensional and individualized, based on specific deficits or risks for limited recovery in those areas. Our observational results, which are derived from a population in whom interventions were not formally tested, do not exclude the possibility that certain interventions may affect more than one target. In fact, some investigational agents, including the anabolic compounds growth hormone and insulin-like growth factor-1, have shown, in small preliminary studies, promising effects simultaneously on bone, muscle, and strength (23,24). In particular, in a study of patients with hip fractures, insulin-like growth factor-1 increased grip strength, improved functional recovery, and attenuated BMD losses in the early postfracture period (24). Future clinical trials need to investigate these agents more completely and identify and test other interventions, individually and in logical groupings, to maximize recovery and minimize adverse sequelae of hip fracture.

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