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Impact Near the Hip Dominates Fracture Risk in Elderly Nursing Home Residents Who Fall

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Summary. Hip fractures among the elderly are a significant and rapidly growing public health problem. The prevailing view is that most hip fractures are the consequence of age-related bone loss or osteoporosis. However, because over 90% of hip fractures are the result of falls, we have undertaken a falls surveillance study to determine if factors related to the mechanics of falling are associated with increased risk of hip fracture. Case subjects with hip fracture and control subjects without hip fracture were sampled from falls recorded at the Hebrew Rehabilitation Center for Aged, a chronic care facility. Fall information was obtained by interview of the subject and witnesses if the fall was witnessed. Data were analyzed by multiple logistic regression. Increased risk of hip fracture from a fall was associated with impacting on the hip or side of the leg and potential energy associated with the fall. Quetelet, or body mass index, was inversely related to fracture risk. The adjusted odds ratio of hip fracture for a fall involving impact on the hip region was 21.7 (95% confidence interval, 8.2–58). The potential energy associated with these falls was an order of magnitude greater than the average energy required to fracture elderly, cadaveric, proximal femurs in earlier *in vitro* experiments. We conclude, therefore, that a fall from standing height should no longer be considered minimal trauma but rather trauma of sufficient magnitude to pose a high risk of hip fracture if impact occurs on the hip and if energy-absorbing processes are inadequate. These new findings suggest that fall mechanics play an important role in the etiology of hip fracture among the elderly.

Key words: Hip fracture – Falls – Osteoporosis – Biomechanics.

As measured by frequency and economic cost, hip fractures are an enormous and increasing public health problem. There are more than 250,000 hip fractures each year in the United States, with estimated annual costs of over $7 billion [1–4]. Over 90% of these hip fractures occur among the 31 million elderly over age 70 who constitute the fastest growing segment of our population [4]. If current demographic and incidence trends continue, some have suggested that the number of hip fractures may well double or triple by the middle of the next century [5, 6]. Given the ominous implications of such predictions, it is crucial that we find effective ways to reduce hip fracture incidence. However, intervention efforts are likely to be productive only if based on a sound understanding of fracture etiology.

The prevailing view is that age-related hip fractures are the direct consequence of osteoporosis, a condition associated with advanced age, female gender, white race, lack of activity, and low calcium intake [7]. Based on this view of fracture etiology, attempts to identify individuals at risk of fracture have been directed toward determining critically reduced levels of bone density. In addition, most interventions have been directed toward ameliorating or reversing age-related bone loss. These efforts have met with only moderate success. Although densitometric data indicate statistically significant differences between hip fracture patients and age- and gender-matched controls and significant inverse relationships between fracture risk and bone mass in prospective studies, there are large, unexplained overlaps in density between the two groups [8, 9]. Moreover, the use of estrogen, calcium, and other agents meant to influence bone density and reduce fracture incidence have been studied mostly in young postmenopausal women [10]. The few studies investigating the use of estrogen in older women, for example, either have been observational, with few women using estrogens at older ages [11], or have been small clinical trials using bone mineral density as the endpoint [12–14].

Given this background, some have instead suggested that it is the increased tendency for the elderly to fall and to experience falls of increased severity that explain the dramatic rise in hip fracture incidence with age. Indeed, over 90% of hip fractures are the result of a fall [15–21]. Yet, for reasons that are not well understood, fewer than 2% of all falls result in hip fracture [22–24]. In addition, as with interventions directed toward bone density, fall prevention programs have met with only limited success in preventing hip fractures in elderly populations [25, 26]. It thus appears that some unexplained, confounding factor is limiting both the ability to discriminate hip fracture subjects from controls and the attempts to reduce hip fracture incidence.

We believe this confounding factor involves the mechanics of the fall. A fall has four distinct phases: (1) an instability phase that results in a loss of balance; (2) a descent phase; (3) an impact phase; and (4) a post-impact phase during which the subject comes to rest. Previous research on falls and falling in the elderly has focused almost entirely on the instability phase, that is, on those host and environmental factors that result in a loss of balance. The work has emphasized the importance of gait disturbances, dementia, visual impairment, neurological and musculoskeletal disabilities, postural hypotension, medications, and environmental haz-

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ards [16, 18, 23, 24, 27–32]. By contrast, little is known about the mechanics of the fall itself. It might thus be said that we know a great deal about *why* people fall but very little about *how* they fall. There are also no verified definitions of fall severity or of what constitutes a high risk fall.

Cummings and Nevitt [33] have hypothesized that three conditions must be met for a fall to cause a hip fracture: (1) impact near the hip; (2) failure of active protective mechanisms (such as using the outstretched arm to break the fall); and (3) insufficient passive energy absorption by local soft tissues. Under these conditions, they believe that sufficient force can be transmitted to the proximal femur to exceed its structural capacity. Others have suggested that much more energy is available in a typical fall than is required to fracture the elderly hip [34, 35]. However, data are not available that allow these hypotheses to be tested.

We undertook this falls surveillance study in nursing home residents in an attempt to characterize fall severity and to determine which aspects of fall mechanics are associated with a high risk of hip fracture. To address these issues, we asked elderly fallers or reliable witnesses several open-ended questions about their falls, and we examined medical records and performed brief physical exams to obtain additional information. We found that fallers who fractured were distinguished from fallers who did not quite simply by whether they landed on their hips. We also found that the energy available in these simple falls among nursing home residents is on average more than 15 times greater than the energies required to fracture the elderly hip.

Methods

Study Design

The design was a case-control observational study; case subjects sustained a hip fracture after a fall and control subjects did not fracture the hip after a fall. A fall was defined as a sudden, unexpected descent from a standing, sitting, or horizontal position that ended on the floor or ground.

Subjects

The source of the study subjects was the Hebrew Rehabilitation Center for Aged (HRCA), a life care environment at all levels of care for approximately 720 patients. The average resident age at the HRCA is 87 years, and the female to male ratio is 3 to 1. Falls at the HRCA were surveyed consecutively from December 30, 1986 to July 29, 1990. During this period, approximately 1174 residents were under observation for falls. All ambulatory residents of age 65 years and older were eligible for the study. A subject was entered into the study if an examination of the HRCA computerized reports and daily logs from each nursing unit revealed that the subject had fallen. Multiple fallers were entered only once during the time period of the study by entering the first fall of each subject (the maximum recorded number of falls was 13). Subjects with falls that occurred over weekends and holidays were excluded if the research assistant was unable to obtain information about the fall within 24 hours. If an individual was included in the control group and then fell and fractured the proximal femur, the subject was switched to the case group and deleted from the control group. A total of 395 subjects who fell during the study period was included; 82 of these fell and fractured a hip and 313 fell and did not sustain fracture. This includes all patients who sustained a fracture, but only about one-half of the residents who experienced a fall during the study period (n = 764 fallers).

Evaluation of Subject and Fall Characteristics

All subjects provided verbal informed consent for a brief physical examination, chart review, and personal interview by a research assistant at the HRCA. Subject height, weight, gender, and injuries resulting from the fall were ascertained by the brief physical examination. The chart review was used to determine the patient's age and to assign a mental status to the subject (see definition below). Characteristics of the fall were determined by personal interview with the faller and with any witnesses to the fall. The following variables were assessed in the interview: date and time of the fall, height of the fall, fall direction, impact location on the body, and activity and location of the subject at the time of the fall. Information on the 82 falls that resulted in hip fracture was gathered from witnesses in 24 cases (29%) and from the subject in 58 cases (71%). Of the 313 falls that did not result in hip fracture, 33 (11%) were witnessed by sources who were able to describe the characteristics of the fall, and the remaining 280 (89%) falls were described by the subject.

When possible, the interviews were conducted by the research assistant at the HRCA within 24 hours of the event. The HRCA research assistant could not always interview the patients with hip fracture within 24 hours, however, because they were taken to Boston's Beth Israel Hospital (BIH) for treatment. Consequently, those individuals with hip fracture were interviewed at the BIH by a physical therapist. The research assistant and the physical therapist were blinded to the study hypotheses.

Definition of Variables

The Quetelet, or body mass index (BMI), was determined by dividing the subject weight (in kg) by the height squared (in m^2). Mental status was assigned to each resident based on the standardized assessment made by HRCA staff. This assessment graded the degree to which a resident's memory interfered with his/her ability to reason, plan, and organize daily activities, according to a 4-point scale: normal, mild impairment, moderate impairment, and severe impairment [36]. Mental impairment was then defined as being in any of the three impaired categories of mental status. Fall height was assessed during the interview as one of the following categories: fall in a horizontal position from a bed, fall from a seated position, fall from standing height, fall from height of one step, fall from height of two steps, standing fall from a chair, and fall from height greater than a chair. The fall height was then used to estimate the potential energy of the fall, which was calculated by multiplying patient mass times height of the center of gravity immediately prior to the fall times gravational acceleration ($g = 9.8\ m/s^2$). The height of the center of gravity for the subject before a fall was assumed to be 0.58 times the subject's height [37] for subjects falling from a standing position. The height of the center of gravity for falls other than falls from standing height was calculated using the distance between the subject and the ground. The fall height was also used to derive the dichotomous variable called standing height or higher.

Each subject was asked an open-ended question about the direction of the fall and the response was recorded as forward, sideways, backward, or straight down. The direction of the fall was then dichotomized into either a fall to the side or a fall in another direction. Impact location on the subject's body was recorded according to the description of the area of greatest impact by the subject or a witness. A variable describing impact on the hip or side of the leg was then derived from the impact location. The activity at the time of the fall was divided into four levels: sedentary behavior (sitting or lying down), standing still, changing position (i.e., going from a sitting position to a standing position), and walking.

Data Analysis

Mean differences in continuous variables (subject age, height, weight, Quetelet index, and potential energy content of the fall) between subjects with hip fracture and those without fracture were compared by Student's *t*-test in the preliminary data analysis. Chi-square analysis was used to test the null hypothesis that there was no association between the categorical variables assessed for each fall (gender, mental impairment, falling from standing height or higher, falling to the side, impacting on the hip or the side of the leg, and walking at the time of the fall) and the presence of hip fracture.

Table 1. Mean values and standard deviations of characteristics of cases with hip fracture and controls without hip fracture

Property	Fracture cases	Fall controls	Significance (t test)	Number of missing (%)
Age (years)	88.9 (6.2)	87.8 (5.9)	0.13	0
Weight (kg)	53.3 (10.7)	56.9 (11.1)	0.01	3 (1%)
Height (m)	1.57 (0.08)	1.52 (0.08)	<0.001	13 (3%)
BMI (kg/m^2)	21.5 (3.5)	24.7 (4.4)	<0.001	15 (4%)
Potential energy of fall (Joules)	442 (149)	424 (143)	0.38	43 (11%)

Odds ratios and the 95% confidence intervals were determined for each dichotomous risk factor. To examine the potential confounding influence of dementia in these elderly subjects, the Mantel-Haenszel (MH) statistic was calculated and the test of homogeneity of odds ratios was applied to mentally impaired versus cognitively intact subjects. Because some of the risk factors could be intercorrelated, the data were also analyzed by stepwise logistic regression in a main-effects model with hip fracture as the dichotomous outcome variable.

Results

The average age of the nursing home residents at the time of the first recorded fall was 88 ± 6 years (mean ± standard deviation [SD]). The falls resulting in hip fracture occurred in subjects with a significantly greater body height (1.57 m versus 1.52 m), lower body weight (53.3 kg versus 56.9 kg), and lower BMI (21.5 kg/m^2 versus 24.7 kg/m^2) than in those falls without fracture (Table 1). Estimated potential energies were 442 ± 149 SD Joules for those falls that resulted in hip fracture and 424 ± 143 Joules for those falls that did not; these energies were not significantly different (Table 1). There was no difference in the gender of the cases compared with the gender of the controls; both groups were 23% male and 77% female, resulting in an odds ratio of 1.0 (Table 2). From the univariate analysis, the following factors were associated with hip fracture from a fall: walking at the time of the fall, mental impairment, falling to the side, and impacting the body in the region of the hip (Table 2). In particular, impacting the hip or side of the leg was associated with an odds ratio of 21 (95% confidence interval, 9.1–48).

Up to 20% of the responses were missing for some of the fall variables such as fall direction and impact location (Tables 1 and 2). When mental status of the subject was cross-tabulated with the presence or absence of missing data for each variable, significant associations ($P < 0.001$) with missing responses were found for the variables with a large percentage of missing data. Over three times the number of responses were missing in falls in which the faller was graded as mentally impaired than in falls where the mental status was designated as normal. Therefore, the relationships between hip fracture after falling and the characteristics of the fall were investigated further by controlling for mental impairment with the use of MH statistics. There was overlap in the confidence intervals of all odds ratios between the mentally impaired versus the cognitively intact (Table 3). The MH adjusted risk estimates, with mental impairment as the confounding variable (Table 3) remained within the 95% confidence intervals (CI) given in Table 2. The test for homogeneity of risk ratios was not rejected for each variable (Table 3), indicating that mental impairment was not confounding the associations.

The magnitude of the odds ratio was very sensitive to substitutions for the missing values. When the known distribution of the binary variable, impact site, was substituted for the 79 missing responses (Table 2), the odds ratio dropped from 21.0 to 6.1 with a 95% CI of 3.3–11.6. This decrease in odds was because the majority of subjects (88%), regardless of case status, were not witnessed to land or did not report landing on the side of the leg or the hip. If we assumed that the subject did not land on the hip for *all* missing responses, the odds ratio dropped only slightly more to 5.3 (95% CI; 2.7–10.5). In a similar manner, if the known distribution for fall direction was used to substitute for the 78 missing answers, the odds ratio for falling sideways became 2.3 (95% CI: 1.4–3.8). Although the value of odds ratios changed with perturbations in the responses, the associations of hip fracture with impact site and fall direction remained strong and highly significant.

To further address the question of the reliability of the fall direction and impact location in fracture patients, we analyzed, witnessed and unwitnessed falls separately. The basic assumption was that witnesses to the fall would have no reason to bias their responses. Analysis of witnessed falls, for which the cell frequencies were low, gave odds ratios well within the CIs displayed in Table 2 for falling to the side, walking, and falling from standing height. For impact location, however, the cell describing nonfracture falls with hip impact was empty, precluding calculation of a ratio (0% of fall controls and 55% of fracture cases had impact on the hip or side of the leg). If each cell frequency was incremented by 0.5, the odds ratio was calculated to be 81, with a large 95% CI of 4.4–1500. This CI obviously overlaps that for hip impact using all falls and does not overlap one. The test for equality of odds ratios between witnessed and unwitnessed falls was not rejected for all of these variables.

Independent variables associated with the occurrence of a hip fracture during a fall by the multiple logistic regression model are shown in Table 4. Only 292 of 395 falls were used in the multiple regression because of the large number of missing values for some of the effect variables. Associations of hip fracture with impact location on the hip, Quetelet index, and potential energy content of the fall were significant in the stepwise multiple regression. The odds ratio for having a hip fracture given that impact was on the hip or side of the leg was 21.7 (95% CI, 8.2–58) after adjusting for the linear effects of the other variables in the model, which is the same value as that in the univariate analysis. Low Quetelet index and high energy content of the fall were also found to be independent predictors of hip fracture. The univariate associations of hip fracture with mental impairment, falling to the side, and walking at the time of the fall (Table 2) did not result in significant associations in the multiple regression.

Discussion

We undertook this study to characterize fall severity and to

Table 2. Frequency distributions of subject and fall characteristics for case subjects with hip fracture and control subjects without fracture

Characteristic	Fracture cases (%)	Fall controls (%)	Odds ratio	95% CI	Significance (χ-square)	Number of missing (%)
Female	77	77	1.0	0.6–1.8	0.98	0
Fall from standing height or higher	81	73	1.5	0.8–2.9	0.21	34 (9%)
Walking	59	35	2.6	1.5–4.4	<0.001	33 (8%)
Mental impairment	74	43	3.6	2.1–6.2	<0.001	1 (<1%)
Fall to side	60	23	4.9	2.4–10	<0.001	78 (20%)
Impact hip or side of leg	59	6	21.0	9.1–48	<0.001	79 (20%)

Table 3. Odds ratios for mentally impaired subjects versus cognitively intact subjects

Characteristic	Odds ratio mental impairment	Odds ratio no impairment	MH ratio	Significance of homogeneity test
Fall from standing height or higher	1.3 (0.6–2.9)*	3.1 (0.7–14.0)	1.6 (0.8–3.2)	0.35
Walking	2.3 (1.1–4.6)	3.4 (1.3–8.9)	2.6 (1.5–4.7)	0.52
Fall to side	7.0 (2.3–21.0)	3.7 (1.4–10.0)	5.0 (2.3–10.5)	0.40
Impact hip or side of leg	40.7 (10.7–155)	13.2 (4.4–40.1)	20.9 (8.8–50)	0.21

* 95% confidence interval

Table 4. Multiple logistic regression: Coefficients and adjusted odds ratio

Property	Coefficient	Standard error	Adjusted odds ratio	95% CI
Impact hip or side of leg	3.1	0.50	21.7	8.2–58
BMI (kg/m^2)	−0.34	0.088		
Potential energy of fall (Joules)	0.0082	0.0024		

determine which aspects of fall mechanics are associated with a high risk of hip fracture. We found that the risk of hip fracture from falls among nursing home residents was associated independently with impact site, BMI, and potential energy content of the fall. Fracture of the hip was not associated with gender or age in this elderly sample residing in a long-term care facility. Impact on the hip or side of the leg was the strongest determinant of hip fracture compared with the other variables measured, raising the risk by about 20-fold. The value of the odds ratio for impacting the hip was a function of two effects: the increased odds of hip fracture occurring when the subject impacts the hip and the decreased odds for fallers without fracture to impact the hip. Over half of the fracture subjects recalled landing or were witnessed to land on the hip or the side of the leg, whereas only 6% of fallers without fracture landed on the hip.

The most common impact location of fallers without hip fracture was the buttocks (44% of fallers without fracture reported landing on the buttocks). Falling onto the buttocks seemed to offer protection from hip fracture and was found to decrease the odds that a hip fracture would occur. In contrast, Nevitt et al. [38] considered that impact on the buttocks or the hip increased the risk of hip fracture. When they grouped buttocks together with hip as a high risk impact site for hip fracture, they found a significant association with hip fracture and an odds ratio of approximately 20. We expect this difference in results is a consequence of our use of impact on the buttocks to refer to the impact site associated with a backward fall. In our data, 87% of falls with impact on the buttocks were falls to the back or straight down. We suspect that Nevitt et al. [38] referred to oblique impacts as impacts on the hip and buttocks. This distinction is clearly a subtle but important difference in definition of impact location that should be evaluated in greater detail in future studies.

We found a negative relationship between BMI and hip fracture in elderly nursing home residents who fall. Body mass, or Quetelet index, has been shown to be a reliable indicator of obesity and relative amount of body fat [39]. Low BMI and low body weight have both been found to be significant risk factors for hip fracture in previous studies that did not use fallers as controls or used a prospective cohort design [15, 18, 40–46]. When fallers were used as controls in the study by Nevitt et al. [38], a weak association between reduced Quetelet index and hip fracture was found in women, but the significance of the association was lost after adjusting for other variables including bone mineral density (BMD). The reason for the association between hip fracture risk and reduced body fat is unknown. We hypothesize that reduced fat thickness over the greater trochanter diminishes the absorption of energy during impact, causing more energy to be transmitted to the femur in fallers with low BMI than in fallers with high BMI. A second explanation for the negative relationship between BMI and hip fracture is that BMI could be related to other unmeasured variables, such as femoral BMD, that have an impact on fracture status. Several cross-sectional studies have measured the strength of the linear relationship between BMI and BMD of the femoral neck. The results vary from no significant correlation in healthy female volunteers aged 17–82 years [47] or in males aged 20–89 years [48] to a weak but significant relationship in postmenopausal women ($r^2 = 0.13$) [49]. Because of this weak correlation, it seems unlikely that the inverse relationship between hip fracture and BMI is actually a reflection of an inverse relationship between hip fracture and femoral BMD. However, it remains to be determined if BMI is a significant effect variable that is independent of femoral BMD.

Comparison of the potential energies available in these falls with the energies required to fracture the elderly cadaveric femur *in vitro* indicates that much less energy is needed to fracture the proximal femur than is available in simple falls from sitting or standing height. Fracture energies required to break elderly cadaveric hips loaded on the lateral greater trochanter range from 5 to 51 Joules [50]. In contrast, the potential energies associated with falls among elderly nursing home subjects were on average greater than 400 Joules, which is an order of magnitude greater than the fracture energy needed to break the femur *in vitro*. Although direct extrapolation from *in vitro* fracture data to expected *in vivo* fracture forces must be made with a clear understanding of the limitations of *in vitro* testing with cadaveric specimens, we believe there are two important implications of this finding. First, a fall from standing height should no longer be viewed as representing "minimal trauma" and used as an operational definition of an osteoporotic hip fracture. Instead, our data indicate that a fall from standing height, especially if impact occurs near the hip and energy-absorbing mechanisms are inadequate, provides more than sufficient energy to fracture the hip in elderly fallers. Second, for falls from standing height which involve impact near the hip but do not result in hip fracture, significant energy-absorption mechanisms must reduce the force actually delivered to the femur. In probable order of importance, these are likely to include eccentric contraction of the muscles of the lower extremities, the use of the outstretched arm to break the fall, and the absorption of energy by soft tissues at the site of impact. We believe that the combined effects of these energy-absorbing mechanisms and the relatively low probability of impact near the hip account for the fact that fewer than 2% of all falls result in hip fracture [22–24].

Although energy-dissipation processes may determine the kinetic energy level actually transferred to the proximal femur in a fall and therefore may obscure the influence of initial potential energy, we found the magnitude of the potential energy available in the fall to be a risk factor for hip fracture. The potential energy became a highly significant factor in the prediction of hip fracture after adjusting for impact site and BMI in the multiple logistic model. A modest increment in potential energy resulted in a significant increase in the adjusted odds that a subject had a hip fracture. For example, using the coefficient for energy from the multiple regression (Table 4), a 50-Joule increase in potential energy would give an odds ratio of 1.5 (95% CI: 1.2–1.9); such an increase could result from an increase in fall height of only about 9 cm. This finding agrees with the results of Grisso et al. [18] that subjects with hip fracture were more likely than controls to have fallen from standing height or higher.

Our study has several important limitations, the first of which is the reliability of the variables describing fall height, fall direction, impact site, and activity at the time of the fall. In approximately 85% of falls, we relied on self-reporting from elderly subjects (average age 88 years) who had just experienced a life-threatening, traumatic event. The inability of elderly fallers to describe the circumstances of the fall or even to recall that a fall has occurred within 3 months prior to contact is well known [51]. We thus made certain to obtain information within days of the fall, to ask the open-ended questions in a manner that was not directed at particular answers, and to record as unknown all information about which the subject or the witnesses were uncertain. This attempt to be rigorous in excluding uncertain responses accounts for the high percentage of missing values for fall direction and impact site. Despite the high percentage of missing values for these variables, our substitution of conservative estimates for these variables based on the distribution of values for the remaining population still resulted in a highly significant association with hip fracture occurrence. In addition, witnessed falls gave similar results to all falls considered together.

We were also concerned that fallers with fractured hips would bias their responses on fall direction and impact site due to pain at the affected hip or to a preconceived bias that impact near the hip would be associated with fracture. In particular, subjects with mental impairment, who may have had impaired abilities to recall the events of the fall, could bias their responses due to the immediacy of the pain after hip fracture. The increase in the odds ratio for impact location with mental impairment (13.2 for cognitively intact subjects compared with 40.7 for impaired patients; Table 3) indicates that this could be the case, but the CIs show a large amount of overlap, and the null hypothesis of equal odds ratios for the two groups could not be rejected ($P = 0.21$; Table 3). Consequently, any potential bias introduced by pain at the affected hip does not seem to be more prevalent in the memory-impaired subjects than in those designated as normal. In addition, it should be noted that 29% of the falls with fracture were witnessed and that, among the unwitnessed falls for which the subject was unable to recall the impact location (and therefore the impact site was coded as unknown), one-third was found by HRCA nursing staff to be lying on the side of the body. In only 9% of unwitnessed falls without fracture and with unknown impact site was the subject found on the side. We did attempt to improve the reliability of the measurement of impact site by examining patients for bruises but were unsuccessful. It should also be noted that the odds ratio of having hip fracture given that impact occurs near the hip is not only a function of the increased odds for fracture subjects to impact the hip but also the decreased odds for fallers without fracture to impact the hip. Fallers without fracture would have no apparent reason to give biased responses to the question concerning impact location on the body.

Another limitation is that the study was conducted in a long-term care facility and therefore does not identify factors that could be associated with hip fracture from falls in community-based elderly subjects. Several characteristics may be enhanced in a nursing home sample compared with community dwellers, such as delayed reaction times, reduced lower extremity strength, and slow gait, which would increase the likelihood of falling to the side and impacting the hip or side of the leg [33]. As a result, other factors that were not significant in this study or were not assessed could prove to be important factors in the etiology of hip fractures outside the nursing home.

Based on the strong association between impact site and hip fracture, simple falls from standing height or from beds and chairs should not be considered minor if impact is likely to occur near the hip. In addition, a modest increment in potential energy of the fall or a decrease in body fat both seem to increase the risk of hip fracture. These results support two potential directions for hip fracture intervention: maintenance of femoral bone strength by nutrition, exercise, or therapeutic interventions so that the femur will not break under small fluctuations in energy content of the fall, and padding of the hip so that the loads and energies transmitted to the bone will be decreased in the event of a fall with impact near the hip.

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