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Article *in* Ageing Research Reviews · February 2003

DOI: 10.1016/S1568-1637(02)00045-4 · Source: PubMed

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Ageing Research Reviews
2 (2003) 57–93

ageing research reviews

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Hip fractures among the elderly: causes, consequences and control

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Received 31 July 2002; accepted 5 August 2002

Abstract

This review examines all pertinent literature sources published in the English language between 1966 to the present concerning hip fracture epidemiology, hip fracture injury mechanisms, and hip fracture management strategies. These data reveal hip fractures have several causes, but among these, the impact of falls and muscle weakness, along with low physical activity levels seems to be the most likely explanation for the rising incidence of hip fracture injuries. Related determinants of suboptimal nutrition, drugs that increase fall risk and lower the safety threshold and comorbid conditions of the neuromuscular system may also contribute to hip fracture disability. A number of interventions may help to prevent hip fracture injuries, including, interventions that optimize bone mass and quality, interventions that help prevent falls and falls dampening interventions. Rehabilitation outcomes may be improved by comprehensive interventions, prolonged follow-up strategies and ensuring that all aging adults enjoy optimal health.

Keywords: Hip fractures; Etiology; Prevalence; Disability

1. Introduction

Fractures of the neck and trochanteric regions of the femur, the major bone in the hip joint, are currently one of the most serious health care problems facing aging populations. Not only is the acute injury accompanied by severe hip pain, and an inability to stand or walk on the fractured leg, but there may be significant vascular damage to the femoral head ultimately leading to avascular necrosis and secondary osteoarthritis. Further, even after

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1568-1637/03/$ – see front matter © 2003 Published by Elsevier Science Ireland Ltd.
PII: S1568-1637(02)00045-4

passive realignment of the femoral bone fragments, or surgery to replace the fragmented bone with a new femoral head and/or hip socket, poor healing, considerable functional disability, and a decreased capacity for managing activities of daily living independently may prevail, despite advances in anesthesia, nursing care, and surgical techniques. Because hip fractures are difficult to prevent without precise knowledge of the causative factors that underlie them, and their incidence is rising as the population ages, hip fractures pose a significant health care problem and source of morbidity and mortality for the aging populace. A better understanding of why hip fractures occur, and how treatment of these injuries can maximally restore function and prevent further injuries, in face of their rising incidence is a major challenge of considerable socioeconomic import and is the focus of the present article. However, this review will not deal with the pharmacological treatment of osteoporosis. For a review of this topic, the reader is referred to Crandall (2002), Lark and James (2002) and Mundy (2002).

1.1. Epidemiology

The English language literature published since the beginning of the 1980s describing the incidence of hip fractures in several countries has generally shown that while this is variable, with few exceptions, the age-adjusted incidence of this injury is increasing (Dargent and Breart, 1993; Lyons, 1997). In the United States, for example, the number of frail elderly at risk for hip fracture is expected to double in the next 15 years as the number of residents over age 85 years increases (Suzman, 1992). As well, even in the People's Republic of China where hip fracture rates have been amongst the lowest in the world compared with more affluent countries (Yan et al., 1999), hip fracture rates in Beijing were found to have increased by 34% for women and 33% for men between 1988 and 1992 (Xu et al., 1996). Similarly, in Finland, the whole population incidence rate approximately tripled between 1970 and 1991 with respect to both genders (Kannus et al., 1996), and the age-specific incidence of hip fractures increased in all age groups between 1970 and 1997 (Kannus et al., 1999). Likewise, linear increases of age-adjusted fracture incidences for men and women were found in The Netherlands over the period 1972–1987 (Boereboom et al., 1992) and in Sweden from 1966 to 1986 where the proportional increase was greatest in men and in city dwellers (Jarnlo, 1991).

Indeed, as people live longer, the number of hip fractures in the world, estimated at 1.7 million in 1990 is expected to rise exponentially to 6.3 million by the year 2050 (Cooper et al., 1992). The increase in hip fracture incidence is expected to be seven-fold between the present time and 2050 in Belgium (Reginster et al., 2001), and will be greater in men, and in Asia where the highest absolute increment in the elderly population will be observed (Gullberg et al., 1997; Melton, 1993). Highest incidences, however, are currently described for Northern Europe and North America (Johnell et al., 1992a; Melton, 1993), and in Australia, the number of hip fractures is expected to double over 29 years and quadruple in 56 years (Sanders et al., 1999).

Of the nearly 300,000 hip fractures that occur each year in the United States (Apple and Hayes, 1994; Zuckerman, 1996), data by Michelson et al. (1995) suggests that 49% of these hip fractures will be intertrochanteric, 37% will be intracapsular, and 14% will be subtrochanteric; each have potentially different risk factor profiles, which have yet to

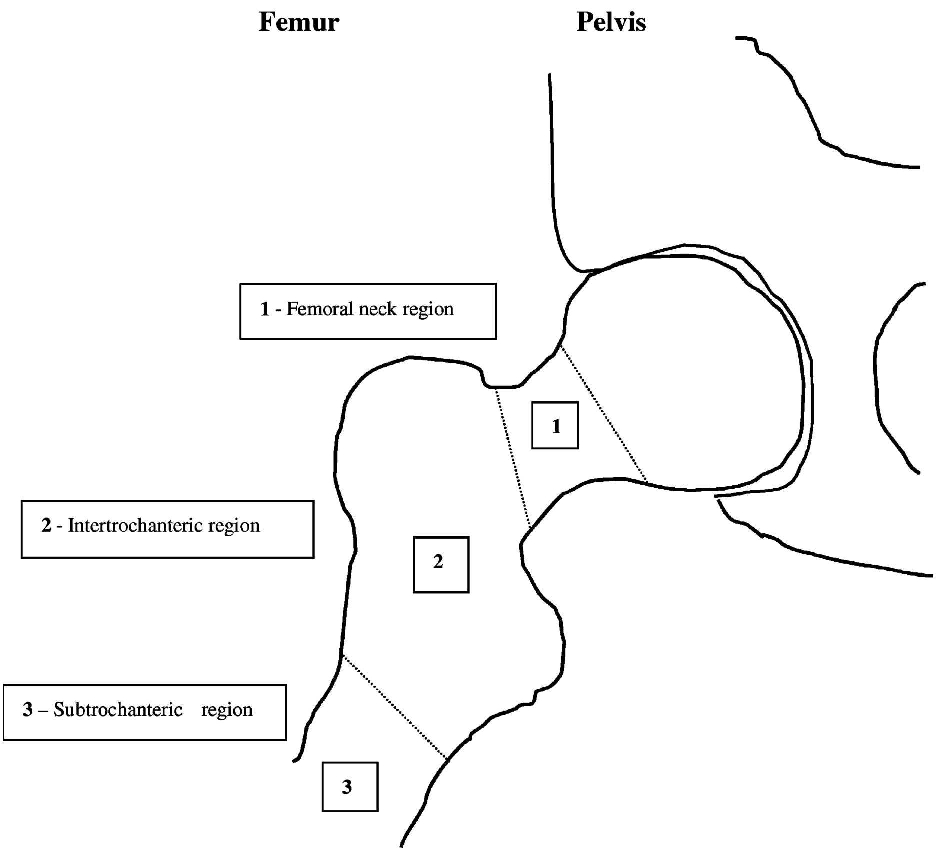

Fig. 1. Hip fractures as classified on basis of their location.

be clearly delineated (see Fig. 1). Cummings et al. (1990) estimate that by the year 2040, a total of 512,000 hip fractures can be expected annually, but if the elderly populace in America grows more rapidly than predicted, the number of hip fractures in the year 2040 could be as high as 840,000 (Schneider and Guralnik, 1990). Contrasting these rates, if the number of trochanteric fractures per se increases relative to the number of femoral neck or intracapsular fractures, which is expected for males up to 2010 (Lofman et al., 2002), this may have direct public health implications since mortality, morbidity, and costs caused by these are higher than those of femoral neck fractures (Fox et al., 1999; Keene et al., 1993), as is disability (Michelson et al., 1995). This may be because intertrochanteric fracture patients are older with poorer health status (Fox et al., 1999), or because the mean age of women with trochanteric hip fractures seems to be rising (Martinez et al., 2001).

Arguably, most of the published data pertaining to hip fracture prevalence projections are dated. This is because they do not take into account more recent interventions with drugs such as alendronate and risedronate, calcitonin, conjugated equine estrogens (CEEs), selective estrogen receptor modulators (SERMS), parathyroid hormone (PTH), statins and other experimental therapies that may prevent bone loss at the hip (Crandall, 2002; Lark and James, 2002), or data from developed countries that the age-specific incidence of hip fractures is flattening out or even static (Huusko et al., 1999; Lau et al., 1999). Nonetheless, given the anticipated growth of the older population, and that falls, which are difficult to prevent are implicated in most hip fractures, it is anticipated that the overall incidence of hip fractures will continue to rise by 1–3% per year in most areas of the world for both men and women (Cummings and Melton, 2002; Koeck et al., 2001; Lauritzen, 1997; McColl et al., 1998). In Greece, there was an 81% rise in hip fracture incidence between 1977 and 1992, an increase, which was greater than expected due to population aging, also suggested the existence of other factors influenced this increase (Paspati et al., 1998). Estimates of the risk for hip fractures, said to range from 10 to 17% in women at age 50 years, are about a third of these values in men (Lips, 1997). By the age of 90 years, one in four women and one in eight men will probably sustain a hip fracture (Armstrong and Wallace, 1994), although there may be a trend-break for New Zealand men and women (Fielden et al., 2001) and Swedish women due to current therapeutic and/or preventive measures (Lofman et al., 2002). The estimated lifetime risk of a hip fracture is said to be 15.6–17.5% in women, and 5.2–6.99% in men (Boonen et al., 1996), although in the Peoples Republic of China Shenyang Province and in Turkey, where men do heavy physical labor, the normal female/male ratio is found to be reversed (Lyritis, 1996; Yan et al., 1999). For very old women and men, there exists nearly the same risk of hip fracture in these countries (Lauritzen, 1997).

Hip fracture rates among whites are said to be greater than those of nonwhite populations (Baron et al., 1996; Melton, 1996; Wolinsky and Fitzgerald, 1994) with a two to three times higher incidence in white than in nonwhite women (Zuckerman, 1996), although this gap seems to be narrowing (Lauderdale et al., 1997). Among nonwhites, the incidence is lower in Asian races than in black races, although the lowest incidence described has been that of the South African Black (Boereboom et al., 1992). In comparing Asians, however, it seems noteworthy that in Singapore where hip fracture rates are the highest in Asia, significant racial differences occur within the same community and time trends in hip fractures differ among the races. However, Koh et al. (2001) report that Kuwaiti nationals have higher hip fracture rates than those observed in other Asian countries, including Singapore. Rates among Kuwaiti females were also similar to those observed in some European countries and in Asian females in the United States. Rates in Kuwaiti males were high and equal to those of white males in the United States (Memon et al., 1998).

To explore potential etiologic differences in the two major types of hip fracture, Karagas et al. (1996) computed the incidence rates of fractures of the femoral neck and trochanteric region using a 5% sample of the United States Medicare population aged 65–99 years. For the period from 1 July 1986 to 30 June 1990, the rates of both hip fracture types increased with age in all race and gender categories. The proportion of hip fractures that occurred in the trochanteric region rose steeply with age among white women, but not among black women, white men, or black men. Within the United States, a north-to-south gradient in rates of both fracture types was observed among women, while no clear pattern was found for men. These findings raise the possibility of etiologic differences in the two fracture types, and provide further evidence of gender and racial differences in the risk of osteoporotic fractures.

Yet, regardless of hip fracture subtype, ethnicity, gender and uncertainty about predicted incidence rates, hip fractures in the United States remain a major cause of excess mortality and substantial disability (Melton, 1993) and involve enormous medical and rehabilitation costs ranging from seven to ten billion dollars annually (Hayes et al., 1996). This estimated figure assumes no complications to the standard treatment and outcome of any individual hip fracture incident and no indirect costs of lost productivity for those still gainfully employed. It is, therefore, likely an underestimate of the true costs.

Further, given that most hip fracture patients are elderly, report more signs of diseases than controls (Jarnlo, 1991), and suffer comorbidities that pose a high risk for complications, the direct costs of a hip fracture could be at least three-fold higher than those basic estimates previously mentioned (Holmberg and Thorngren, 1988). For example, while the excess mortality from a hip fracture is said to be between 10 and 20%, of those who survive, half will have longstanding disability (Meunier, 1997). As well, in addition to having an average stay of a total of 19–24 days of short-term hospital care which is almost double that for any other diagnosis (Baker, 1985; Dolk, 1989; Lyritis, 1996; Varney et al., 1992), length of hospital stay after a hip fracture may actually exceed 65 days as reported by Kitamura et al. (1998). Additionally, hip fracture patients are said to occupy 20–25% of all orthopedic beds, and this percentage could rise, given the increasing rate of the incidence of hip fractures (Lyritis, 1996). In addition, rehabilitation in this condition is slow, and of survivors only two-thirds will return home (Armstrong and Wallace, 1994), while 19–27% will require long-term institutional care (Chrischilles et al., 1991; Cumming et al., 1996).

A second fracture, which may be in the same location with a tendency to greater displacement or instability occurs about six percent of the time and within a 4-year period postfracture (Dretakis et al., 1998). Further, Dolk (1989) predicts the frequency of sustaining two hip fractures over the course of an individual's lifetime could reach 20%. In addition, because new hip fractures may occur on the same side as well on the opposite side to an initial fracture, it may be possible to sustain three hip fractures over time. According to Schroder et al. (1993), the risk of incurring a third hip fracture per 1000 men is 8.6 and 9.8 per 1000 women, per year.

Ipsilateral second hip fractures may include trochanteric fractures that are not operated on, or in the case of internally fixated hips, these may be attributable to suboptimal placing of the screw(s). Rarely, they may also occur after removal of internal fixation. In their study, Shroder et al. found 8% were ipsilateral, while 92% were contralateral, and that 62% of those with femoral neck fractures and 72% of those with trochanteric fractures had a preceding contralateral fracture of the same type. The mean time interval between the two fractures was 3.3 years (range 5 days–14 years); 20% occurred within 1 year, regardless of gender or fracture type. In calculating the risk of incurring a second hip fracture, the investigators found this rose about nine times over the risk of the first hip fracture for men, and six times for women with a first hip fracture. This increased risk of a second hip fracture was highly significant for both genders, but was significantly higher for men than for women.

In the light of these findings, and the severe individual and economic consequences of hip fractures, as measured by their frequency, and influence on health care utilization, premature mortality, independence and life quality, there is currently an urgent need to prevent the anticipated rise in hip fracture incidence observed in most countries and especially to investigate the underlying causes of this condition. There is also a strong need to investigate whether it is possible to improve upon current rehabilitation strategies for restoring functional recovery post-hip fracture surgery and particularly for preventing further joint injuries, including second and third hip fractures and certain types of articular degeneration. In the following discourse, some of the primary risk factors for hip fractures, plus aspects of the remediation process and the determinants of this are discussed.

1.2. Risk factors

1.2.1. Falls

Of the 300,000 hip fractures that occur each year (Apple and Hayes, 1994), over 90% of them are associated with falls (Grisso et al., 1994; Hedlund and Lindgren, 1987; Melton, 1993; Varney et al., 1992). Although fractures at the hip may be caused by a sudden muscle contraction prior to impact (Gardner et al., 1998; Smith, 1953), falls and bone impact seem to precede the hip fracture, rather than vice versa (Grisso et al., 1991a). Frequently, a fall that impacts the lateral aspect of the hip may strike the greater trochanter and fracture the neck of the femur (Cummings et al., 1995; Greenspan et al., 1994; Lauritzen, 1997; Parkkari et al., 1999). Research by Hayes et al. (1993), who have begun to examine precisely what constitutes a fall with a high risk for hip fracture, has shown that an impact on the hip or side of the leg raises the risk of a hip fracture over 20-fold in nursing home fallers, and 6-fold in community-dwelling men and women. It has also been shown that a decrease of one standard deviation in femoral neck bone mineral density, a similar decrease in body mass index, and an increase of one standard deviation in the potential energy associated with a fall, are all significant and independent risk factors for hip fractures of both genders (Greenspan et al., 1994), as are impairments in balance, neuromuscular functioning and musculoskeletal impairments (Myers et al., 1996a) (see Fig. 2). These findings, plus findings that falls to the

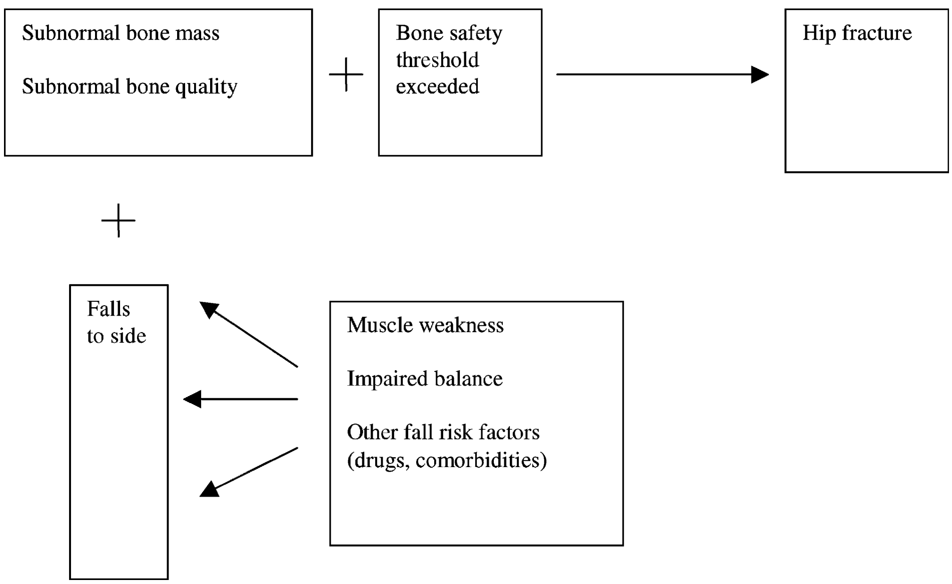

Fig. 2. Model of key factors implicated in hip fracture injury.

side coupled with high impact velocity are more likely to result in hip fracture than other falls (Cummings et al., 1995; Greenspan et al., 1994, 1998) suggest factors related to both the mechanics of loading and bone fragility, as well as fall speed play important roles in hip fracture etiology (Hayes et al., 1996). The decreased effectiveness of protective responses, due to increases in reaction time, along with decreases in strength with age may also explain why hip fractures occur to a greater extent in elderly people who fall than in younger people (Sabick et al., 1999).

Interestingly, Hayes et al. (1996) found that during a relaxed fall, impact occurred earlier, and was usually located at the knee or at the side of the leg, before any impact fell on the hip. This suggested a larger portion of the energy available at impact dissipated in the surrounding soft tissue. In further findings they noted that the state of muscle activation predicted average peak forces, at least in men. While neuromuscular control in the descent phase of the fall may reduce the velocity of impact and allow the 'faller' to adjust the body into a safe landing configuration, striking the ground in a stiff state was actually found to increase the impact forces. This was an intriguing finding and somewhat counter-intuitive, as the generation of submaximal or maximal muscular contractile forces would seem to afford a joint exposed to impact more protection than a muscle in its relaxed state, as indicated by findings of Sabick et al. (1999) and Sandler and Robinovitch (2001). The findings also fail to explain why older persons with decreased leg and arm strength fall and sustain injuries to a significantly greater extent, than those with stronger arm and leg muscles (Tinetti et al., 1995a).

However, the following explanation by Luukinen et al. (1997) seems plausible and in line with the hypothesis generated by Hayes et al. That is, fear of falling, a serious disorder in older people, resulting in their limited physical activity and reduced functional ability, may have the effect of inducing a co-contraction, or tenseness rather than a graded contraction of muscle agonists and antagonists during a postural perturbation. By increasing the lever arm, the resultant stiffening reaction of the musculature might contribute to, rather than absorb, the impact experienced during a fall, and accordingly, the risk of fracturing a bone such as the hip.

1.2.2. Decreased bone mineral density and bone mass

Cummings (1985), Birge (1993) and Greenspan et al. (1994) report that while several studies have found low bone mass to be associated with an increased risk of fracturing a hip prior to age 70 years, virtually all have found a considerable overlap in bone densities between hip fracture patients and age- and gender-matched controls after the age of 70 years. Low calcium intake, thought to impact detrimentally upon peak bone mass, is also not a risk factor for hip fracture (Cooper et al., 1988; Cummings et al., 1995; Farmer et al., 1989; Nieves et al., 1992; Wickham et al., 1989a). As well, the propensity to fall and fall mechanisms is more important in the pathogenesis of hip fracture than bone mineral density (Runge and Schact, 1999). Wei et al. (2001) found the effect of risk factors for hip fracture among community-dwelling ambulatory elderly to remain the same, regardless of femoral neck bone mineral density. It has also been observed that bone mineral density is a weaker predictor of intertrochanteric hip fractures than femoral neck fractures (Fox et al., 2000) and osteoporotic indices were found to be comparable between cases and controls in a recent study (Fitzpatrick et al., 2001). In addition, several studies have concluded that hip fracture patients are not more osteopenic than age and gender-matched controls (Cummings et al., 1985), and Asians, who have similar, or lower bone mineral densities than whites, and partake in diets low in calcium, have a low incidence rate of hip fracture, especially in women (Yan et al., 1999). Mathematical models too, cannot account for the exponential rise in hip fractures with age solely on the basis of bone density levels (Cummings and Nevitt, 1989; Melton et al., 1988). Further, individuals with osteoarthritis and higher bone density levels than the norm are not protected against hip fractures (Arden et al., 1996; Jones et al., 1995).

Such findings strongly suggest factors other than having a low bone mineral density and peak bone mass may contribute to the risk of fracturing a hip, and that an examination of factors unrelated to bone mass must merit consideration in establishing the causes of hip fractures. These factors include: environmental hazards, lifestyle habits, factors that are related to or increase the risk for falling, the location of the fall impact, the mode of falling, the property of the fall surface, the geometry of the hip, the distance to impact, the height and weight of the moving body parts, body size, the degree of soft tissue coverage over the hip bone, reduced agility and motor function, and muscle weakness (Cumming and Klineberg, 1994a; Cummings and Nevitt, 1989, 1994; Dargent-Molina et al., 1999; Farmer et al., 1989; Fitzpatrick et al., 2001; Fujita, 1994; Jones et al., 1995; Nevitt et al., 1989; Lauritzen, 1997; Luukinen et al., 1997; Parker et al., 1996; Runge and Schact, 1999; Slemenda, 1997; Wolinsky and Fitzgerald, 1994) (see Table 1).

1.2.3. Body size characteristics

In terms of body size characteristics, it has been argued that body height greater than 65 in. may be a predictor variable for hip fracture (Birge, 1993; Greenspan et al., 1998), because the impact energy from the increased fall height of taller subjects is equal to the square root of the falling height of a body (Gardner et al., 1998). Indeed, Joakimsen et al. (1997) report that high body height is a risk factor for fractures, and estimate one in four low-energy fractures among women today might be ascribed to the increase in average

Table 1
Selected studies describing factors other than bone mineral density and bone mass as risk factors for hip fracture

Authors	Risk factors for hip fracture
Cummings and Nevitt (1989)	Neuromuscular dysfunction
Cummings and Nevitt (1994)	Fall mechanics
Dargent-Molina et al. (1999)	Walking speed, impaired mobility
Farmer et al. (1989)	Too little recreational exercise
Fitzpatrick et al. (2001)	Factors related to falls, sleeping tablets, health perception, lower mental score
Fujita (1994)	Lifestyle and physical activity
Jones et al. (1995)	Postural instability
Lauritzen (1997)	Deficient soft tissue covering hip, deficient protective responses, falls
Parker et al. (1996)	Environmental factors
Runge and Schact (1999)	Falls and fall mechanisms, age-related gait and balance disorders
Slemenda (1997)	Neuromuscular impairment, fall mechanics
Wolinsky and Fitzgerald (1994)	Prior falls, leaner body mass

stature since the turn of the century. Owusa et al. (1998) similarly report that having a high body height is positively associated with significant elevations in the incidence of hip fractures among men, as do Lau et al. (2001) for Asian men and women, and Farahmand et al. (2000) for postmenopausal Swedish women.

Another body size feature, namely a low body mass, has been found associated with a higher risk of fractures, especially in white men (Mussolino et al., 1998), after the age of 50 years (Langlois et al., 1998) (see Table 2). Weight losses of 10% or more from maximum weight are also associated with an increased risk of hip fracture (Farahmand et al., 2000; Langlois et al., 2001). Older women with smaller body size are potentially at increased risk for a hip fracture because of their lower bone mineral density levels (Ensrud et al., 1997). It is equally likely that women with a low body mass have less soft tissue covering the hip than women of normal body weight (Lauritzen, 1997). According to Gardner et al. (1998), having a low body mass that reduces the extent of soft tissue padding and energy absorption over the greater trochanter, might explain the observed tendency of underweight individuals towards incurring a hip fracture if they fall on their side. The interaction between low body mass, low muscle mass and muscular weakness leading to failure of protective responses, could also be expected to heighten the risk of incurring a hip fracture, regardless of femoral bone density status (Meunier, 1997).

However, although many people who fracture their hips could be classified as being thin, and high body weight has been deemed protective (Farahmand et al., 2000), in accord with Cumming and Klineberg (1994b) and Maffulli et al. (1999) that one risk factor for hip fracture could be excessive body weight, or an elevated waist-to-hip ratio (Owusa et al., 1998) we recently noted that among 35 elderly community-dwelling elders hospitalized with acute hip fractures and a mean age of 76.2 ± 7.6 years, 51.4% were overweight or obese, and only 2.9% were underweight, as indicated by their body mass index. Dretakis and Christadoulou (1983) too, noted similar rates of overweight and underweight hip fracture cases among their 373 patients. This may suggest, that even though overweight individuals would be expected to have a relatively higher proportion of body fat than average to dissipate a fall, it is possible that if they fall on their hips, their restricted mobility, plus the direct impact sustained by their high body and leg weights, along with their potentially inferior muscle mass, which may constituted by a large fat mass, could cause the safety threshold of the hip to be exceeded, even if their bone mass is within normal limits. Similarly, when patients with severe dementia were excluded, Bean et al. (1995) found thinness was not necessarily associated with hip fracture. However, their observations of differences in handgrip strength among hip fracture patients and controls of comparable body mass indices, supported the view that some hip fracture cases might have muscles constituted by a high proportion of fat.

In this context, it is especially noteworthy that although body weight is considered to affect bones of children and adults positively, recent studies suggest overweight and obesity in childhood and adolescence reduces bone mineral content below that predicted based on weight and this is associated with an increased incidence of childhood fractures (Whiting, 2002) and hip fractures as adolescents (Maffeis and Tato, 2001). Heavier individuals may also be expected to have low levels of sex hormone-binding globulin, a finding among women with recent hip fractures (Skalba et al., 2001), and a high rate of comorbid conditions that are known risk factors for falling, such as hypertension, arthritis, diabetes and medical

Table 2
Selected studies investigating the role of body mass in mediating hip fractures

Authors	Study design	Conclusion
Bean et al. (1995)	Prospective study of 50 consecutive women with fractured hips and 50 age-matched healthy women with no hip fractures	After exclusion of heavily dependent patients, hip fracture was not associated with reduced body mass or fat
Bernstein et al. (1999)	Retrospective analysis of body mass indices of 330 women who sustained hip or wrist fractures categorized by age and race	For whites and blacks, those with hip fractures were lighter on average than those who fractured their wrists; normal body mass was protective against hip fractures, but not wrist fractures
Ensrud et al. (1997)	Prospective study of 8011 women followed for incident hip fracture	During an average of 5.2 years, 235 (2.9%) experienced hip fracture. Women with smaller body size had a higher risk of subsequent hip fracture compared with those of larger body size. This effect remained after adjusting for height, smoking status, physical activity, health status, estrogen and diuretic use. After further adjustment for femoral neck bone mineral density, the effect of weight was negligible among thin women
Farahmand et al. (2000)	Population-based case–control study of 1327 postmenopausal women 50–81 years	Weight loss was associated with increased hip fracture risk; weight loss vs. weight change demarcates different patterns of hip fracture risk
Grisso et al. (1994)	Case–control study of 114 black women with first hip fracture	Women in the lowest quintile for body-mass index had a markedly increased risk of hip fracture compared to women in the highest quintile
Langlois et al. (1998)	Prospective study of 2413 community-dwelling white men aged 67 years or older	Weight loss is a marker of frailty that may increase the risk of hip fracture in older men
Langlois et al. (2001)	Prospective study of 2180 community-dwelling white women aged 50–74 years	Weight loss of 10% or more from maximum weight among both middle-aged and older women is an important indicator of hip fracture risk
Margolis et al. (2000)	Prospective cohort study of 8059 nonblack women 65 years and older over 6.4 years	Women in the lowest quartile of weight had relative risks of 2.0 for hip fracture
Mussolino et al. (1998)	Prospective population-based follow-up study for maximum of 22 years of 2879 white men	Weight loss is a risk factor for hip fracture in men
Tromp et al. (2000)	Prospective study of 348 health women, aged 70 years and above	Body mass index was found to be a predictor of hip fracture

conditions associated with osteoporosis, such as cancer (Folsom et al., 2000; Marks and Allegrante, 2002; Nicodemus and Folsom, 2001).

1.2.4. Decreased muscular strength

Hayes et al. argue that in the presence of muscle weakness, both the characteristics of the fall, and to a lesser degree, body habitues, which can both influence the risk of incurring a hip fracture, may be detrimentally altered, with a consequent increase in trauma intensity, regardless of bone strength. Having weak muscles may also decrease the force required to fracture a hip (Bean et al., 1995). Muscle weakness, which is usually associated with a decreased muscle mass could also impact adversely upon total body mass, which is found to have independent relationship to the risk of hip fracture (Farmer et al., 1989). Farmer et al. who found the risk of hip fracture was negatively associated with a low arm muscle area, suggested having a low arm muscle mass might slow normal reflexive protection mechanisms, such as extension of the forearm, thereby reducing the effectiveness of inherent protective strategies against bone fractures when falling. Similarly, Cummings and Nevitt (1989) have argued that the effectiveness of protective responses which depends on arm strength, and declines with age, along with hip strength, might heighten the risk of fracturing a hip when falling.

Muscle weakness also hastens bone demineralization (Birge, 1993), and this, along with poor protective responses heightens the risk of incurring a hip fracture during a fall (Luukinen et al., 1997). Also, in the presence of any reduced muscle mass at the hip joint, there may be insufficient soft tissue protection of the hip bone and, thus, a reduced ability to prevent the occurrence of a hip fracture in response to a fall injury.

An increased risk of falling, which can lead to a hip fracture, has also been noted in association with hip weakness (Robbins et al., 1989), poor grip strength (Cooper et al., 1988), neuromuscular impairment (Slemenda, 1997), poor ankle strength (Lord et al., 1994; Whipple et al., 1987), low body and knee extensor strength (Lord et al., 1994; Roy, 1993; Sherrington and Lord, 1998), and the inability to rise from a chair without using one's arms (Cummings et al., 1995). There may also be a greater proclivity to incur a hip fracture if the knee extensors are weak because this could greatly increase the velocity of falling (Luukinen et al., 1997) and/or reduce gait speed, which potentiates sideways or backward falls, and impact on or near the hip (Smeesters et al., 2001). The status of the neuromuscular system at the ipsilateral hip and knee just prior to fracture, may also play a dominant role in gait speed and hip fracture risk (Dargent-Molina et al., 1999), the distribution and absorption of stresses on the femur, and the localization of a fracture (Christodoulou and Dretakis, 1984; Dretakis and Christadoulou, 1983).

Phillips et al. (1998) recently undertook to determine: the extent of muscle weakness in older female hip fracture patients compared with healthy older and young women; the extent to which this weakness is caused by a decline of the force produced per unit area of muscle rather than by a decline in muscle bulk; and the mechanism of this proposed decline in force per unit area. The findings suggested that people who sustain hip fractures have poorer isometric force generating capacity due to defective muscle cross-bridge force generating mechanisms than age-matched controls. It may be possible, however, to screen for this intrinsic deficiency, and to improve this capacity by early intervention.

Table 3
Possible contributory factors to muscle weakness, and primary and secondary hip fractures

Age-related structural changes of muscles
A reduced muscle mass
Excessive muscle catabolism
Micronutrient deficiencies, e.g. Vitamin D, calcium
Neuromuscular disorders, e.g. Parkinson's disease, stroke
Impaired muscle metabolism
Inactivity
Pain
Decreases in insulin-like growth factor I
Changes of the muscle cross-bridge contractile mechanisms
Impaired proprioception
Poor endurance capacity
Malnutrition
Muscle damage
Joint damage and joint effusion
Nerve damage
Frailty and poor health status
Medications such as steroids

1.2.5. Inactivity

Cooper et al. have argued that inactivity, which can lead to muscle weakness and atrophy, is associated with an increased risk of hip fracture in elderly people, as have Coupland et al. (1993), Farmer et al. (1989), Lyritis (1996) and Wickham et al. (1989a) (see Tables 3 and 4). In both males and females, Cooper et al. found physical activity as measured by four out of five activity indices to double the risk of fracturing a hip. Reported levels of physical activity were also correlated with grip strength, which was inversely related to the risk of incurring a fracture.

Similarly, as was observed by Cummings et al. (1995) with respect to walking, Coupland et al. found subjects who did not weight-bear regularly, or perform muscle loading activities such as climbing stairs, and productive activities such as gardening, were all more than twice as likely to sustain a hip fracture, when compared with subjects at the higher end of the activity spectrum. These increases in risk remained after adjusting for body mass index, smoking, alcohol consumption, and dependence in daily activities.

Farmer et al. suggested the following explanations to account for their observations that those who exercise frequently are at lower risk for hip fracture. First, they suggested that athletes have wider bones and more cortical bone in exercised limbs, a view supported by Coupland et al. Second, they suggested those who exercise are more coordinated and less likely to fall. Third, they are less likely to fall, than those who do not exercise, because they are healthier. Finally, they point out that muscle provides a major source of estrone in postmenopausal women, which could delay bone resorption. All of their suggestions seem plausible and are substantiated by empirical studies. Their arguments, plus the findings of Huang et al. (1996), that reduced arm muscle areas were significantly and inversely related to subsequent hip fracture risk in persons with poor nutritional status, along with findings that men and women with fresh hip fractures display significant reductions in the size of

Table 4
Evidence that physical activity participation reduces hip fracture risk

Authors	Study design	Finding
Cooper et al. (1988)	Case–control study of 300 elderly men and women with hip fracture and 600 controls matched for age and sex	Daily activity, including standing and walking protected against hip fracture
Coupland et al. (1993)	Population based, case–control study of 197 patients older than 50 years with hip fracture and 382 controls matched by age and sex	Customary physical inactivity is an independent determinant of hip fracture in the elderly
Grisso et al. (1997)	Case–control study of 34 hospitals and 356 men with first hip fracture and 402 control men matched for age and geographic location	Physical activity was markedly protective
Hoidrup et al. (2001)	Prospective study of leisure-time physical activity levels and changes in relation to risk of hip fracture among 1211 men and women with first hip fractures	Moderate levels of physical activity appear to protect against later hip fracture; declining physical activity over time is an important risk factor for hip fracture
Joakimsen et al. (1997)	Meta-analysis of studies on the association between physical activity and hip fractures	The association is present for physical activity from childhood to adult age, and is consistent across populations; daily chores, such as stair climbing and walking, plus leisure activities protect against hip fracture
Kanis et al. (1999)	Case–control study of 730 European men with hip fracture and 1132 age-stratified controls were followed prospectively	Decreased physical activity and exposure to sunlight accounted for the highest attributable risks among a number of different risk factors
Lau et al. (1988)	Case–control study of 400 Chinese men and women with hip fractures and 800 controls	Daily walking outdoors, upstairs, uphill, or with a load protected against fracture, as did higher levels of reported activity in middle life, independent of smoking or alcohol consumption
Nieves et al. (1992)	Case–control study of 161 white women with hip fracture and 168 cases matched by age, hospital and frequency of utilization services	Recreational activities in adolescence and early adulthood afford protection against hip fracture; greater protection seemed afforded by the frequency of participation
Suriyawongpaisal et al. (2001)	Case–control study of 187 Thai men over 51 years of age with hip fracture and 177 age-matched community controls	Physical activity was independently associated with reduced risk of hip fracture after controlling for confounding factors
Wickham et al. (1989a)	Fifteen years follow-up study of 1688 community-dwelling subjects	The adjusted odds ratio for physical activity showed this protected against hip fracture
Wickham et al. (1989b)	National survey of 983 people	Those who had fallen one or more times had reduced grip strength and were less mobile than those who had not fallen

their vastus laterals muscle fast twitch fibers than expected (Aniansson et al., 1984), strongly emphasize the unique role muscle may play in either mediating or preventing fractures at the hip, as emphasized by Coupland et al.

Low physical activity along with a Vitamin D deficiency that may reflect inadequate outdoor activity, may also cause severe type II muscle fiber atrophy, and such changes may weaken the support of the hip joint and lead to falls that result in hip fractures (Sato et al., 2002). Low physical activity levels, particularly load-bearing activities may, thus, have a strong bearing on the increases in hip fracture rates reported by developing countries, as well as first-world countries (Slemenda, 1997).

1.2.6. Impaired cognition

In addition to the aforementioned factors, depression, Alzheimer's disease, dementia and/or the presence of cognitive impairment may heighten the risk of falling and fracturing a hip (Birge, 1993; Boonen et al., 1999; Buchner and Larson, 1987; Guo et al., 1998). In particular, since cognitively impaired individuals may not be able to move independently, or may be unmotivated to move, their impaired mobility may become a significant risk fracture for hip fracture (Greenspan et al., 1998). Similarly, a prevailing cognitive impairment may reduce the effectiveness of postoperative rehabilitation strategies, as well as cognitive strategies designed to hasten functional recovery after hip fracture surgery (Magaziner et al., 1990; Mossey et al., 1989). Poor baseline mental status following hip fracture surgery is also a strong predictor of mortality and institutionalization. This latter association, however, is due partly to the hazards prevailing in those environments (Clemenson et al., 1996), and is not deemed as important as other predictors of hip fractures such as lower-extremity joint pain and muscle weakness (Nevitt et al., 1989). Further, although the risk of falling after a hip fracture may arguably be linked to a hazardous environment (Clemenson et al., 1996), the slowing of central integration processes associated with impaired mental functioning has been postulated to be the stronger predictor of hip fractures. This seems to result from inappropriately delayed or weakened muscular responses which predispose the individual with mental deterioration to falls and failure to break these falls with the timely extension of their forearm (Birge, 1993) normally evoked to counter any balance loss. The individual with mental deterioration who trips and fails to break their fall with a timely extension of their forearm is consequently deemed more likely to land with full force on the hip with an increased risk of hip fracture (Birge, 1993), especially if already osteoporotic with reduced arm muscle mass and strength, due to poor nutritional status (Huang et al., 1996).

1.2.7. Impaired perception

In addition to cognitive factors and those related to falls, disturbances of the mechanisms of balance can also predispose the elderly to hip fracture (Boonen et al., 1993; Falsh et al., 1993; Sherrington and Lord, 1998). Disturbances of balance, may in turn, be related to age-associated declines in perception with respect to vision, vestibular function, proprioception and/or transient circulatory insufficiencies (Baker, 1985; Grisso et al., 1991a; Meunier, 1997; Nevitt et al., 1989) and impaired sensory integration or motor functioning (King and Tinetti, 1995; Slemenda, 1997). Loss of vibration sense, reduced pain perception at the knee, and having absent Achilles and quadriceps reflexes may influence hip fracture risk during falls as well (Luukinen et al., 1997).

1.2.8. Impaired vision

Impaired vision may be an independent risk factor for hip fracture (Boonen et al., 1999; Grisso et al., 1991a; Luukinen et al., 1997). Evidence for this has been provided by Ivers et al. (2000) in a case–control study of 911 cases and 910 controls aged 60 years or older. The population attributable risk of hip fracture due to poor visual acuity or stereopsis, vision wherein two separate images from two eyes are successfully combined into one image in the brain, was 40%. Pfister et al. (1999) also noted impaired vision as significantly prevalent among women ages 50 and older with fractures of the proximal femur. Impaired vision has also been associated with hip fractures occurring in the hospital (Lichtenstein et al., 1994) and among the Framingham Study Cohort, the fracture rates in those with moderately impaired vision to poor vision were higher than in those whose vision was good (Felson et al., 1989). Further, those with moderately impaired vision in one eye and good vision in the other had higher risk of fracture than those with a similar degree of binocular impairment.

1.2.9. Environmental circumstances

Norton et al. (1997) investigated the circumstances of falls resulting in hip fractures among older adults in New Zealand and explored whether the circumstances differed by gender, age, or residential status. Information collected for 911 patients aged 60–104 years (mean age 82 years) who had been hospitalized with a hip fracture between 8 July 1991 and 7 February 1994 showed 96% of the fractures were associated with a fall, and 16% were associated with an acute medical or physical condition. Although 85% of the fractures involving a fall occurred at home, only about 25% of these were associated with an environmental hazard, leaving the authors to conclude that intrinsic factors such as balance play a greater role than extrinsic factors, regardless of age or residential status in causing falls that cause hip fractures. Further, while environmental factors may be one of several factors that contribute to falls (King and Tinetti, 1996), a recent study by Allander et al. (1998), which found the correlation between the number of risk factors of the faller and the environment to be 0.07, suggested environmental hazards are of minimal importance in mediating hip fractures.

1.2.10. Drugs

Although Rashic and Logan (1986), who examined the role of drugs in hip fractures found that with the exception of antibiotics, fracture risk was lower in those taking drugs, drugs reported to be related to falls include: cimetidine, psychotropic anxiolytic/hypnotic drugs, barbiturates (which may decrease bone quality), opioid analgesics, and antihypertensives (Baker, 1985; Boonen et al., 1993; Grisso et al., 1991b, 1997; Guo et al., 1998), long-acting benzodiazepines, anticonvulsants (which can accelerate bone demineralization and cause osteoporosis) and caffeine (Cummings et al., 1995; Schwab et al., 2000). Tranquilizers, sedatives and exposure to any of the three classes of antidepressants is associated with a significant increase in the risk of falling and sustaining a hip fracture (Liu et al., 1998; Meunier, 1997; Ray et al., 1987). In particular, along with impaired perception, long-acting sedatives and alcohol that can slow reaction time might partly explain the increased risk of hip fractures associated with the use of sedatives and regular intake of alcohol (Boonen et al., 1999; Cummings and Nevitt, 1989; Grisso et al., 1994; Jacqmin-Gadda et al., 1998; Lau et al., 2001). Alternately, alcohol abuse may increase corticosteroid secretion and negative bone balance (Rees et al., 1977), and decreased balance, impaired gait, and risk-taking behaviors (Hemenway et al., 1988). Tricyclic antidepressants may increase the risk for hip fracture due to their detrimental cardiovascular side effects, and/or their side effects of sedation and confusion (Pacher and Ungvari, 2001). Use of corticosteroids is also a documented risk factor for hip fracture (Lauritzen, 1997), and may reflect the detrimental effect of corticosteroids on bone mineral density, as may levothyroxine when used by males (Sheppard et al., 2002). Smoking cigarettes or a pipe, and the consumption of tea, and fluorine concentrations over 0.11 mg/l (Jacqmin-Gadda et al., 1998) also increases the risk of hip fracture (Grisso et al., 1997; Kanis et al., 1999).

1.2.11. Chronic illnesses

Certain chronic illnesses, in particular, arthritis and Parkinson's disease, substantially increase the risk of falling, and hence, of incurring a hip fracture (Boonen et al., 1993; Grisso et al., 1991a; Johnell et al., 1992b). This may be due to pain, impaired joint motion, sensory changes or reduced muscle strength around the affected lower-extremity joints. Problems in postural control are associated with Parkinson's disease (Nevitt et al., 1989). In addition, arrhythmias, postural hypertension, and peripheral neuropathies may increase the risk of falls and hip fractures (Meunier, 1997), as may the presence of lower limb dysfunction, Alzheimer's type dementia (Buchner and Larson, 1987) and other neurological conditions, such as stroke with hemiplegia that cause poor gait patterns and reduced bone density on the affected side (Christodoulou and Dretakis, 1984; Grisso et al., 1991a). Diabetes mellitus (Schwartz et al., 2001), hyperthyroidism (Boonen et al., 1999; Cummings et al., 1995), medical conditions associated with osteoporosis (Poor et al., 1995b), other forms of disability associated with an increased risk of falling (Poor et al., 1995b), use of walking aids (Grisso et al., 1994), as well as prolonged immobilization (Lauritzen, 1997), may also lead to an increased risk of hip fracture.

In summary, as indicated in a variety of experimental and epidemiological studies, a variety of age-related and other factors may affect the two ultimate determinants of hip fracture, femoral bone strength and propensity to trauma. In particular, the decline in muscle function that occurs with aging will affect both determinants of hip fractures and, hence, the incidence and impact of falls (Boonen et al., 1996). Muscle strength and size and its influence on reaction time, balance, proprioception, fracture site and bone mass may also underlie sub-group differences in hip fracture incidence and functional outcomes. The relationship between these factors and the cycle of disability associated with hip fractures is shown in Figs. 2 and 3.

1.3. Management

In terms of the nature of hip fracture injuries, five categories have commonly been described: (1) nondisplaced or minimally displaced femoral neck fractures; (2) displaced femoral neck fractures; (3) stable intertrochanteric fractures; (4) unstable intertrochanteric fractures; and (5) subtrochanteric fractures. Femoral neck fractures are considered intracapsular fractures, and intertrochanteric and subtrochanteric fractures are extracapsular fractures.

In terms of management, for most hip fracture patients, surgical management is considered the optimal and most cost-effective approach for treating nondisplaced, minimally displaced, and displaced intracapsular fractures and all extracapsular fractures (Lyons,

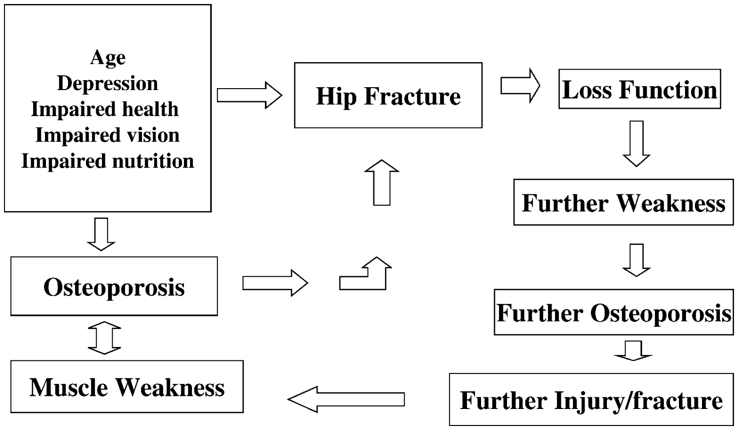

Fig. 3. Hypothetical model outlining role of muscle weakness in hip fracture disability.

1997). However, nondisplaced intracapsular fractures can be treated with bedrest and a 6–8 weeks' delay of weight bearing in the "younger" elderly (<70 years). In addition, if the patient is <50 years of age, and the fracture is nondisplaced, attempts should be made to treat the fracture by means of open reduction, internal fixation and stabilization.

Although surgery is not advisable for bed-ridden patients or those with very osteoporotic bones and extensively comminuted fractures (Lichtblau, 2000), nondisplaced or minimally displaced femoral neck fractures can be treated with cannulated screws with largely excellent result (Hudson et al., 1998). In the physiologically elderly medically stable patient, the most common treatment used for displaced neck fractures is a monopolar or bipolar hemiarthroplasty procedure, where the femoral head is replaced by an artificial head affixed into the femoral bone, without replacing the socket. While there is considerable ongoing debate concerning the relative merits of internal fixation versus arthroplasty in the treatment of femoral neck fractures (Schmidt and Swiontkowski, 2002), literature derived outcome studies show that elderly patients with displaced femoral neck fractures achieve best functional results after reduction and internal fixation (Iorio et al., 2001). However, a recent study by Rogmark et al. (2002) reported a lower rate of failure and better functional outcomes after arthroplasty for displaced fractures of the femoral neck when compared to internal fixation. Hemiarthroplasty was also found superior to screws in treating displaced femoral neck fractures in patients over 75 years of age (Puolakka et al., 2001). Other findings suggest, that as compared to hemiarthroplasty, early reduction and internal fixation in type II or III fractures of the femoral head permits bony union and better function in younger patients with good ambulatory capacity (Heikkinen et al., 2002). Total joint arthroplasty seems to be indicated in type IV comminuted fractures (Yoon et al., 2001), and in old patients with normal mental function and high functional demands (Johansson et al., 2000). However, the relative benefits of unipolar and bipolar hemiarthroplasty, as well the relative benefits of total hip arthroplasty for treating femoral neck fractures, continues to be poorly understood (Schmidt and Swiontkowski, 2002), although the more mobile bipolar prosthetic devices seem to yield better function during the early postoperative recovery period than the nonmoving monopolar prosthesis (Hudson et al., 1998). Ong et al. (2002) found no advantage to the use of bipolar endoprostheses in the management of displaced femoral neck fractures in the elderly, however, even though this form of treatment has been advocated by Miettinen and Kettunen (1999) for treating active elderly patients.

For hip fractures in the intertrochanteric region, the most common operative procedure is open reduction and internal fixation (Lichtblau, 2000) (see Fig. 4). For example,

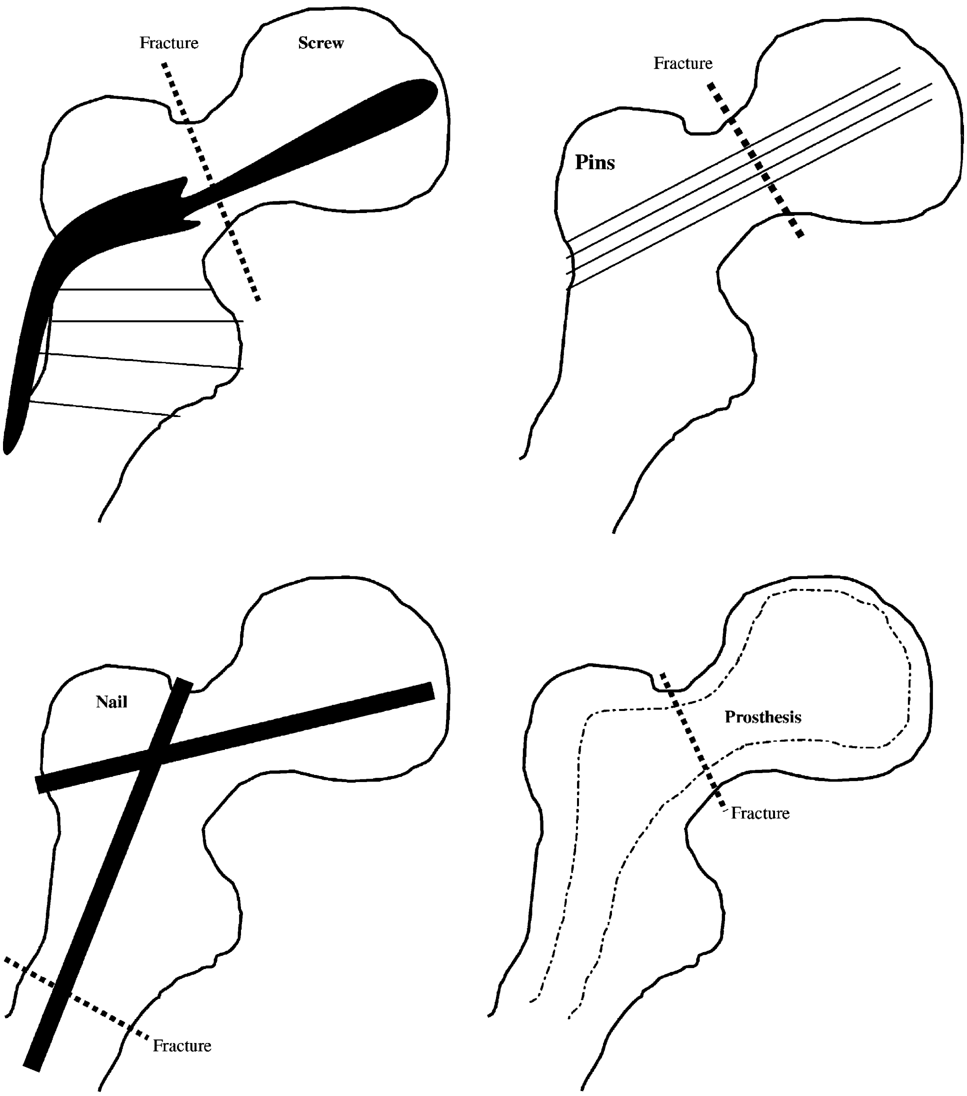

Fig. 4. Graphic representation of selected modes of hip fracture surgery including a metal compression screw, metal pins, a metal nail, which may be inserted across the fracture or down into the femur to hold fragments of bone together, and a prosthesis to replace the head of the femur.

extracapsular pertrochanteric hip fractures are usually repaired using a dynamic hip screw or a variant of sliding nail fixation (Lyons, 1997), such as a percutaneous compression screw and plate (Kosygan et al., 2002; Stavrou et al., 1997), which is applied to the lateral side of the proximal femur to join the femoral shaft and neck, without replacing any bone. Subasi et al. (2001) who evaluated the results of treatment for intertrochanteric fractures of the femur by external fixation in 33 patients, average age 65.9 years, with either stable type I or unstable type I hip fractures, found this method yielded complete healing of the fracture site in all patients, along with easy implant removal. Trochanteric fractures may also be treated successfully with a proximal femoral nail (Domingo et al., 2001), and on occasion by hemiarthroplasty, rather than osteosynthesis or internal fixation of the fracture by means of a mechanical device, such as a pin, screw, or plate (Vahl et al., 1994). Currently, unstable intertrochanteric fractures are most commonly treated with intramedullary-neck screw devices. These instruments yield high rates of union with less cutout and neck collapse (Banan et al., 2002).

Subtrochanteric fractures of the femur can also be treated surgically using an extramedullary or an intramedullary device, with or without adjunctive reduction techniques (Herscovici et al., 2000). Antegrade or proximal-to-distal nailing, remains the treatment of choice for the vast majority of subtrochanteric femur fractures, although distal-to-proximal retrograde femoral nailing may be an effective option for some patients with associated femoral neck fractures (DiCicco et al., 2000).

Methods of intracapsular fracture repair vary geographically and according to surgeon preference. Prospective, randomized, controlled studies are needed, however, to compare repair methods, including internal fixation versus hemiarthroplasty for intracapsular fractures and the use of cementless versus cemented hemiarthroplasties for treating acute femoral neck fractures, as this impacts on functional and social recovery, and mortality. Total hip arthroplasty for the treatment of displaced femoral neck fractures, where both the ball and socket of the femur are replaced, has shown promising results, however, when compared to hemiarthroplasty procedures (Arnold et al., 1974; Jonsson et al., 1996; Rodriguez-Merchan, 2002) or internal fixation with two parallel and percutaneously inserted screws (Johansson et al., 2000). There may be a problem of an increased rate of dislocation or complications (Lee et al., 1998), however, especially in patients with mental dysfunction, and several authors have strongly recommended avoiding total hip replacement in active elderly patients without pre-existing acetabular disease (Rodriguez-Merchan, 2002).

The timing of surgery remains controversial though, and evidence that a delay in operating leads to increased morbidity is inconclusive. In general, early surgery is indicated in pre-morbidly fit and medically stable patients, whereas surgery should be delayed briefly if correctable comorbidities are present, such as severe anemia, pneumonia, and highly impaired coagulation (Lichtblau, 2000). Complications after hip fracture surgery remain avascular necrosis of the femoral head, nonunion, infection, peri-implant femoral fractures, prosthetic dislocations, acetabular protrusion and implant loosening.

1.4. Outcomes

A fairly high proportion of hip fracture patients, approximately 20%, particularly men (Davidson et al., 2001; Myers et al., 1991) and those older than 75 years, die within the first

3–6 months of their injury. This risk of mortality is increased for those with the diagnosis of septicemia and pneumonia/influenza. Patients with various disorders of the digestive system also are at greater risk (Myers et al., 1991). The relative odds of dying also doubles in the presence of cardiac, cerebrovascular disease or neoplastic disease (Cooper, 1997; Myers et al., 1991; Stavrou et al., 1997), poorly controlled systemic disease (particularly if multiple comorbidities are present); and cognitive disorders. Patients undergoing surgical intervention before stabilization of the fracture, particularly in patients with multiple comorbidities, are at even greater risk. Failure to implement prophylaxis against deep vein thrombosis also increases postoperative mortality. Magaziner et al. (1997) reported a mortality differential between a large group of individuals with hip fractures in Baltimore, Maryland and a control nonfracture group to the extent of an excess of nine deaths per 100 women, 5 years post-fracture. Their results suggest an immediate increase in mortality following a hip fracture in medically ill and functionally impaired patients, in contrast, for patients in relatively good health at the time of the fracture there is a decrease in mortality, which is gradual over time.

In their study of men with hip fractures hospitalized in Rochester, Minnesota, Poor et al. (1995a) found advanced age and postoperative deterioration of mental status significantly increased the risk of early death following hip fracture, reported at 16% after 30 days. Comorbidities, on the other hand, had a suggestive but not statistically significant influence on mortality. More than half of the 131 patients who contracted an initial hip fracture due to moderate trauma during 1978–1989 were discharged to nursing homes. Seventy nine percent of the patients who survived 1 year resided in nursing homes or intermediate care facilities or were attended by home care. Only 41% of survivors recovered their prefracture level of functioning and nearly 60% limped and required a cane or walker. The study clearly demonstrated the strong negative impact of hip fractures on the short-term outcomes following hip fracture, especially among men.

A prospective case–control study in the Mediterranean region by Lyritis (1996) showed that after discharge of the fractured elderly from the hospital, mortality increased dramatically and 28% of patients died during the first year, most deaths occurring within the first 3 months. During the second year, functional capacity deteriorated in 44% of the 62 cases and in 16% of the 91 controls. At 2 years, the mortality rate was 35% in cases and 18% in controls.

Data by Wolinsky et al. (1997) similarly show that having suffered a fracture can increase the likelihood of dying by 83% and the likelihood of having any subsequent hospital episodes by 231%. Thereafter, any subsequent incident increases future incident episodes by 9.4%, the total number of hospital days by 21.3% and the total charges by 16.3%. For persons re-interviewed in 1990 having suffered a hip fracture in 1984, these investigators found the number of basic difficulties of daily living increased by one percent, the number of lower body limitations increased by 0.93% and the number of upper body limitations increased by 0.26%. These findings along with evidence by Karlsson et al. (1996) of a seven percent decrease in bone mineral density in the fractured hip during the first year after a fracture, along with a five percent loss of lean body mass, and fat gain of 11% suggests that postoperative failures or secondary fractures are likely to occur readily, particularly if no preventive remediation is forthcoming.

Myers et al. (1996b) who examined the relationships among prefracture status, development of complications, mobility outcomes at discharge, and disposition at discharge found prefracture status had a significant effect on these variables. Marottoli et al. (1992) found, however, that the vast majority of hip fracture survivors experienced a substantial decline in function, but they could not identify remediable factors that may have been contributing to this decline. Similarly, Dolk (1989) reported a decline in walking capacity post-hip fracture for most patients and only about half of 282 consecutive patients with femoral neck or trochanteric fractures followed up for 2 years postoperatively became independent walkers. This is important because patients who remain functionally dependent and need professional help after discharge are found to experience much higher rates of falling during the month after discharge, than those who achieve independence (Mahoney et al., 1994).

However, one underlying reason for the observations of Dolk, Maratolli et al., Mahoney et al. and Myers et al. could have been the poor balance capacity exhibited by their post-operative hip fracture patients. In addition to prolonged bedrest that can lead to a loss of muscle strength and increased postural sway (Mahoney et al., 1994), when Jarnlo (1991) tested standing balance on a computerized platform, middle-aged patients with a previous hip fracture showed larger postural sway areas, indicating a lower balance capacity, plus a lower walking speed than healthy controls. It was not possible, however, to estimate whether the findings were causal.

Hatta et al. (1992) also provide an alternate explanation. They found the response to hip fractures in the elderly to be divided into two types based on their brain function as assessed using electroencephalogram (EEG) records. In all cases, the 23 hip fracture cases studied had independent prefracture ambulation status. EEG findings were graded as normal, abnormal (minor degree, moderate-to-severe degree) and states of ambulation after hip fracture were graded good or poor. Good ambulation was defined as total independence and poor ambulation was defined as dependent on assistance or bedridden. In 11 cases of good ambulation, nine had an EEG that was normal or abnormal to a minor degree during pre- and post-surgical periods. In 12 cases of poor ambulation, seven had an EEG that was normal or abnormal to a minor degree in the pre-surgical period, but in the post-surgical period, only two were in the same grade and five showed moderate-to-severe abnormal EEG findings. Out of 12, 5 cases of poor ambulation demonstrated moderate-to-severe EEG abnormality in pre- and post-surgical periods. The study suggested two different outcome responses to hip fractures in the elderly based on brain function. One group could maintain good brain function after hip fracture surgery, while the other showed moderate-to-severe abnormalities in brain function and this group lost their ambulatory ability.

As indicated by an abnormal carnitine distribution or defects in the respiratory chain, elderly patients with hip fracture also display muscle metabolic alterations that may contribute to neuromuscular impairment (Gonzalez-Crespo et al., 1999). In addition, magnetic resonance imaging of the hip in patients with a clinically suspected impacted fracture of the femoral neck examined within 24 h of admittance to hospital showed one patient who had sustained a nondisplaced acetabular fracture with increased joint fluid also had muscle contusions (Stiris and Lilleas, 1997). The presence of increased joint fluid, along with muscle contusions consequent to sustaining a hip fracture may be underreported or remain undetected due to plain film radiographic usage and may too explain, in part, the delayed or limited recovery of selected cases. Reflecting the muscular trauma that may occur in fall-induced fracture cases, are the following pathologic changes observed among 42 elderly women with respect to middle gluteal muscles: degenerating and regenerating fibers; fiber necrosis; and inflammatory reaction (Sato et al., 2002).

Regardless of cause, however, a recent report by Cooper (1997) strongly emphasizes that 1 year after fracturing a hip, 40% of patients are still unable to walk independently, 60% have difficulty with at least one essential activity of daily living, and 80% are restricted in other activities, such as driving and grocery shopping. Moreover, 27% of patients will have entered a nursing home for the first time (Kirke et al., 2002). These data are slightly different from those of Zuckerman (1995) who found that only 41% of 137 patients maintained their prefracture ambulatory status at 1 year, while 40% became more dependent on assistive devices. In addition it was observed that 12% of previous community ambulators became household ambulators, and eight percent became nonfunctional ambulators. In another study (Hannan et al., 2001), the in-hospital mortality rate among 571 adults older than 50 years with hip fracture was 1.6%, at 6 months it was 13.5%, and another 12.8% needed total assistance to ambulate. More recently, elderly patients with hip fracture studied at 12 months showed fewer resided at home and most had declined functionally when compared to their prefracture status (Kaehrle et al., 2001) (see Table 5).

There can, thus, be no lack of consensus on the gravity of any of the above events. The very detrimental impact of sustaining one or more hip fractures, which is portrayed in Table 6, cannot be underestimated and stresses the urgent need for a careful examination of all factors that might foster improved recovery and survival rates for the hip fracture patient, while limiting the incidence and risk of secondary complications. Although only pre-morbid physical and mental factors may predict declines in physical function after hip fracture (Marottoli et al., 1992), a clear description of factors that impact upon physical function cannot be obtained from prefracture status reports unless these data have been collected a priori for some reason.

1.5. Factors predicting functional recovery/mortality

According to Lyons (1997), factors facilitating recovery of a patients prefracture ambulatory ability include: a younger age, being male, the absence of dementia, the absence of a postoperative confusional state, and the use of a walking aid before the fracture, which may denote independent ambulation and/or unimpaired psychological status. Other documented factors influencing functional recovery after hip fracture are: prefracture health, mental and functional status including muscle power of the good limb (Chow et al., 1992; Kaehrle et al., 2001), type of surgery, fracture type, surgical complications, in-hospital self-efficacy beliefs, depressive symptoms, numbers of medications (Ruiz, 1992), hip pain (Cree et al., 2001; Feldt and Oh, 2000; Lee, 1998), poor self-rated health (Cree et al., 2001) and the presence of comorbidities (Cree et al., 2001; Koval et al., 1995; Marottoli et al., 1992; Parker and Palmer, 1995), urinary incontinence (Myers et al., 1996b) and chronic diseases (Visser et al., 2000), especially cardiovascular and respiratory diseases (Stavrou et al., 1997). Mortality is said on the other hand to be directly related to: the number of postoperative medical conditions of the patient, the duration of the period of posttraumatic stabilization of physiological imbalances prior to hip fracture surgery (Stavrou et al., 1997), self-rated health (Barangan, 1990), the occurrence of postoperative complications (Aharonoff et al., 1997) and increased dependence (Jensen et al., 1979).

Although Bonar et al. (1990) and Guccione et al. (1996) reported that the likelihood of a patient's returning home after hip fracture was influenced by the intensity of nursing care

Table 5
Summary of studies describing poor outcomes after hip fracture, regardless of contemporary management and rehabilitation strategies

Authors	Population	Outcomes
Aharonoff et al. (1997)	Six hundred and twelve elderly who sustained a nonpathologic hip fracture were followed	Four percent died during hospitalization, 12.7% died within 1 year of fracture, the factors predictive of mortality were age >85 years, pre-injury dependency in basic activities of daily living, a history of malignancy other than skin cancer, and the development of one or more in-hospital complications
Bonar et al. (1990)	One hundred and fifty-one community-dwelling elders discharged to community after hip fracture were studied	Sixty-four were discharged home within 6 months, 33% became permanent nursing home residents, factors contributing to favorable outcomes included younger age, family involvement, and a greater number of physical therapy hours
Davidson et al. (2001)	Three hundred and thirty-one hip fracture cases were followed for approximately 1 year	Twelve months mortality was 26%; follow-up of 231 surviving patients 12–24 months later showed 27% still had pain and 60% had worsened mobility they attributed to the fracture
Giaquinto et al. (2000)	The impairment and disability of 58 patients, mean age 86.7 years referred for rehabilitation after hip fracture surgery was assessed	Twelve patients died after complications of previous risk factors, on average survivors showed functional gains from admission to discharge on the Functional Index Measure but most required supervision at discharge
Jalovaara and Virkkunen (1991)	One hundred and eighty-five patients mean age 80 years treated by cementless hemiarthroplasty for acute femoral fracture were studied prospectively for 6 years	There were 22 early complications, and 6 late complications; mortality after 3 months was 12% above controls, 19% at 12 months and 21% at 18 months; the average loss of life in the fracture group compared to the control group was 425 days; at 6 years, half of the patients and most of the controls were able to move about independently
Jette et al. (1987)	Fifty patients with intertrochanteric, and 25 patients with subcapital hip fractures, 67% female, mean age 78 years	Twenty-nine percent died in first year after fracture, only 33 and 21% regained prefracture function in five basic and six instrumental activities of daily living; 26% regained their prefracture level of social/role functioning
Koike et al. (1999)	A retrospective study of 114 patients with hip fracture	The mortality rate after 1 year was 18%, which was 2.5 times larger than the general population; it was related to age, ECG abnormality, and postoperative complications

Table 5 (*Continued*)

Authors	Population	Outcomes
Kirke et al. (2002)	Undertook a 2-year follow-up of 106 older Irish women with hip fracture histories and 89 without hip fracture	Mortality at 1 year was 16%, and 23.6% at 2 years; this occurred even though males or subjects with moderate or severe mental impairment were not included in the study. Hip fracture had a marked negative effect on functional independence
Maggio et al. (2001)	Case–control study of 42 hip fracture cases among patients in nursing homes	The percentage of residents ambulating autonomously fell from 95 to 32% among those with fractures, although their prefracture mobility status was better than those who never fractured their hips
Marottoli et al. (1994)	One hundred and twenty patients with hip fractures were studied prospectively	Eighteen percent died within 6 months, 35% were institutionalized within 6 months, the primary predictor of these outcomes was mental status
Stavrou et al. (1997)	Two hundred and two patients with femoral neck or trochanteric fracture, ages 52–95 years, all treated surgically	Eighteen percent died during first year; mortality was greater in patients with cardiorespiratory diseases, and if operation was delayed 3 days, or if hemiarthroplasty was performed
Parker and Palmer (1995)	Six hundred and forty-three patients admitted from home with a hip fracture were studied	Mortality at 1 year was 22%; 14% were in long-term residential care; and the remaining 65% were living at home, the most useful predictor of outcome was prefracture mobility
Van Balen et al. (2001)	Prospective study of 102 elderly hip fracture patients mean age 83 years	Mortality at 4 months was 20%, 57% of survivors went back to original accommodations, 43% reached same level of walking ability, 17% achieved same prefracture abilities to carry out activities of daily living, quality of life at 4 months was worse than reference population
Wolinsky et al. (1997)	Three hundred and sixty-eight persons with hip fracture were studied and outcomes were compared to persons with no fracture history	Hip fracture increased the likelihood of mortality in the first 6 months postfracture significantly; it also increased the likelihood of subsequent hospitalization, and number of days in hospital

and therapy provided, many determinants of outcome appear independent of the level of care given. Instead, most predictive for returning home appear to be: prefracture status, particularly ambulatory or mobility status (Koval et al., 1995; Parker and Palmer, 1995; Zuckerman, 1995), and psychosocial factors including level of social support and not living alone, positive emotional status, and self-confidence (Barangan, 1990). Specifically, Ceder et al. (1980) who conducted a statistical investigation into the rehabilitation outcome of 103

Table 6
Components of a comprehensive intervention model designed to improve hip fracture surgery outcomes

Hospital-based strategies
Identification of prevailing problems including risk factors for falls
Identification of potential problems including risk factors for falls
Identification of patient's concerns
Identification of patient's unique:
Social situation
Economic situation
Mental status
Neurological status
Health status
Educational level/intellectual capacity
Additional skills
Determine the intervention goals, in light of the patients situation, goals and needs
Use theories, as indicated, to translate the above elements into a goal-oriented program
For care beyond the hospital
Reanalyze the above criteria periodically for purposes of adjusting goals and program plan
Refine, redesign, and reconceptualize prevailing program plan as required
Implement modified program and reanalyze accordingly to evaluate outcome

elderly hip fracture patients, found that the ability to walk 2 weeks postoperatively, living with someone, and general medical condition were most important for predicting return home. After 1 year, younger age and ability to visit someone before the fracture had the greatest prognostic significance for returning and remaining at home.

While restrictions in function that arise from pain, anxiety, and a fear of falling (Mahoney et al., 1994), plus low self-efficacy expectations (Allegrante et al., 1991), and a lack of social support (Lee, 1998) may limit or negate gains made through rehabilitation (Petrella et al., 2000; Ruiz, 1992), functional variables have been found to explain more of the variance in hip fracture outcomes than psychosocial variables (Roberto, 1992). Of these functional variables, failure to recover prefracture ambulatory ability may be most important for predicting return home. In this respect, recovery patterns examined by Koval et al. show post-hip fracture patients who were more limited in their prefracture ambulatory ability were more likely to regain their prefracture status than those patients who were more independent in their prefracture ambulation. Furthermore, community ambulators who used a cane or a walker before the fracture were less likely to remain community ambulators. While this may be counter-intuitive, Koval et al. suggest this may be related to the fact that a drop in ambulatory ability in these patients would produce a greater relative loss of ambulatory ability than those who already had poor ambulatory status at baseline.

Also supporting the significance of physical function in predicting recovery postfracture, are the findings of Fox et al. (1998) in their examination of the predictive value of a balance and gait test on subsequent mortality, morbidity, and healthcare utilization among hip fracture patients 65 years or older. These investigators found that after adjusting for age, gender, race, and comorbidity, the patient's balance and summary mobility scores were the most powerful predictors of mortality. They also found poor balance, but not poor gait, was associated with an increase in hospitalizations up to 24 months postfracture. Further, both poor balance and poor gait were associated with an increased odds of being placed in a nursing home. Since increased postural sway, which denotes poor balance has been found correlated with strength (Schenkman et al., 1996), as has mobility (Rantanen et al., 1994), their findings may indicate the importance of muscle strength as shown by Barnes and Dunovan (1987), Walheim et al. (1990) and Visser et al. (2000) as an independent indicator of subsequent mobility recovery and independence, mortality and healthcare utilization of the postfracture hip patient. As well, it may show the need for aggressive physical therapy in this respect as advocated by Koval et al. (1997).

2. Rehabilitation

While Koval et al. (1997) stress that aggressive physical therapy after hip fracture is essential to optimizing the patient's short and long-term functional recovery, Zuckerman et al. (1993) and Lyons (1997) state that to maximize rehabilitation potential, a concentrated multidisciplinary effort using skilled medical, nursing, and paramedical care appears to be essential. In both cases, however, prospective controlled studies are required to demonstrate the long-term effectiveness of using an intense multidisciplinary effort in mediating optimal functional recovery and the likelihood of the hip fracture patient returning home after a hip fracture. As well, Lyons argue that in today's cost-cutting environment, caution must be taken to prevent short-term cost-saving measures from compromising long-term outcome for elderly hip fracture patients. This would include a failure to correctly ascertain the patient's pre-injury function, their prevailing neuromuscular status, particularly with respect to strength of those muscles believed to determine postoperative functional ability such as the knee extensors as demonstrated by Lamb et al. (1995) and possibly the stability of the fracture device used. For patients with unstable hip fractures, Walheim et al. (1990) further advocate rehabilitation continue for more than 3 months after surgery.

Important short-term nursing and physical interventions designed to promote functional outcomes of the elderly hip fracture patient include the prevention of: (1) dehydration and electrolyte imbalance; (2) thromboembolism; (3) pneumonia; (4) decubitus ulcers; (5) voiding dysfunction; and (6) confusion and depression. Long-term rehabilitation on the other hand, should aim to restore individuals to their former or to an optimal functional and environmental status, and to maintain or maximize remaining their functions. For the hip fracture patient, this includes maintenance of the individual's usual activities of daily living and their restoration to an acceptable quality of life (Barangan, 1990).

Discharge planning for elderly hip fracture patients involves the assessment of the patient's assets and limitations during hospitalization, planning for continuity of their health care after discharge, and obtaining services that enhance their strength recovery, both physical and emotional. Based on the identified risk factors for hip fracture, appropriate education of the patient and other care givers including their families (Kaehrle et al., 2001), plus an environmental assessment and an appropriate alteration of the discharge destination should be forthcoming. To review exercise programs, prevent contractures and optimize functional independence, Barangan (1990) advocates arrangements be made on an ongoing basis for long-term physical therapy visits. Our own experiences (Allegrante et al., 2001; Marks and

Allegrante, 2001), those of Giaquinto et al. (2000) and the finding that training improvements were lost a fter stopping training post-hip fracture surgery (Hauer et al., 2002) suggest the need for a highly comprehensive intervention model for both in-hospital and follow-up care (see Table 6).

3. Prevention

Over 10 years ago, Cummings and Nevitt (1989) outlined a number of strategies they advocated would greatly improve our understanding of the physical factors that underlie hip fractures. In particular, they argued for the importance of the status of the neuromuscular system in mediating hip fractures. In our view, while many factors may be involved in the pathogenesis of hip fractures, muscle weakness, is one amenable to intervention, and could result in the improvement of several risk factors for hip fracture such as: (1) decreased bone mineral content and bone loss; (2) decreased walking speed; (3) decreased effectiveness of protective reflexes; (4) decreased soft tissue cushioning; (5) decreased mobility; and (6) the increased proclivity to falls and falling. The availability of comprehensive screening for hip fracture risk factors, including muscle strength and responsiveness, and a focus on reducing the adverse effects of muscle weakness is indicated, therefore, for preventing a high proportion of hip fracture injuries. In addition, the maintenance of an optimal strength capacity across the lifespan, and intensive exercise may be helpful in preventing unwarranted disability post-hip fracture injury, and/or in substantially reducing the incidence and disability attributable to second hip fractures or secondary injuries. Adults with excessively low or high body mass indices, those who have recently incurred weight losses greater than 10%, those with comorbid conditions or cognitive impairments, those who have limited access to nutrients and physical activity, those with impaired vision, those using steroids, benzodiazepines or other psychotropic agents, and those who are taller than the norm should be especially targeted.

Other strategies that cannot be overlooked are the role of calcium and Vitamin D supplements, Biphosphonates, PTH, treating visual dysfunction, avoiding alcohol, certain drugs and caffeine, hormone replacement therapy, multidimensional falls injury prevention programs and hip protectors and safety floors that can dampen or attenuate fall impact.

4. Conclusion

Although many potential risk factors for hip fractures have been identified as contributing to the rising incidence of hip fractures world-wide, it can be hypothesized that a high percentage of hip fracture injuries among the elderly are attributable to a combination of neuromuscular mechanisms and their interaction with bone mass, and fall mechanisms as outlined in Fig. 2. Since muscle function and structure and its influence on bone quality and integrity and postural responses may be amenable to intervention, regardless of age, it is likely that many hip fracture injuries could be prevented. Further, it appears that significant improvements in rehabilitation outcomes could be forthcoming if potential hip fracture surgery patients exhibited optimal strength and mobility at time of surgery. To further prevent hip fracture disability and enhance functional outcomes after hip fracture, high intensity strengthening exercises and others that promote early mobilization after surgery, along with prolonged follow-up strategies designed to foster functional independence, and reduce drug dependence are strongly indicated. In concordance with Young et al. (2001), we suggest that to specifically reduce hip fracture morbidity and mortality rates, future public health interventions should focus on encouraging physical activity participation and exercises that promote muscle strength among all community-dwelling younger and older adults, regardless of health status. High-risk adults in the community should be targeted, in particular.

In closing, and in recognition of the growing epidemic of hip fractures, we believe and would like to echo the words of Baker (1985) who stated:

> "There is no major health problem where the potential for improvement exceeds that of the hip fracture ..." Indeed, it was Baker's hope [and the fervent hope of the current authors] that this potential will soon be realized so that ... "our generation and those that follow will not be subject to the same likelihood of morbidity, disability and tragic changes in lifestyle that today characterize falls in the elderly that lead to hip fracture."

Acknowledgements

The authors would like to thank The Arthritis Foundation, New York Chapter, and The Cornell Aging Center, New York, for financial support.

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