QUADRICEPS STRENGTH IN WOMEN WITH A PREVIOUS HIP FRACTURE: RELATIONSHIPS TO PHYSICAL ABILITY AND BONE MASS

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Associations between physical ability, level of current physical activity and bone mass were examined in 47 elderly women (mean age 80 years) who had suffered from a hip fracture 3–36 months (mean 17 months) previously. Measures of physical ability included isokinetic quadriceps strength of both the non-fractured and fractured leg, and walking and stair climbing speed. An estimate of current physical activity was made using the Northwick Park activity index questionnaire specifically designed for hip fracture patients. Bone mineral density of the spine and hip (Ward's triangle, femoral neck and trochanter) was assessed by dual energy X-ray absorptiometry. Relationships between the measured parameters were analysed using multiple regression analyses, taking into account the confounding effects of age, height, weight and months since fracture. Quadriceps strength of the fractured leg was on average 18% lower than that of the contralateral leg ($p < 0.001$). Quadriceps strength of the fractured leg proved to be the most robust predictor of walking speed ($R_{partial} = 0.69$, $p < 0.0001$), stair climbing speed ($R_{partial} = 0.46$, $p < 0.001$) and the activity index ($R_{partial} = 0.56$, $p < 0.0001$). Bone mineral density was independently predicted only by body weight ($R_{partial}$ range: 0.45–0.72, $p < 0.001$), not by any of the parameters of physical ability or by the Northwick Park activity index. In conclusion, quadriceps strength is markedly affected in women with a previous hip fracture and is associated with walking ability and level of physical activity. This study showed that bone mass is linked to body weight, not to physical ability and activity. Thus, the main benefit of muscle strengthening exercises in these women may be to promote mobility.

Key words: physical activity, bone mineral density, hip fracture, muscle strength.

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INTRODUCTION

The number of hip fractures occurring in the world in 1990 has been estimated at 1.3 million. With the ageing of the population the annual number of hip fractures is expected to increase by more than 250% by the middle of the next century (1).

Disability and dependency are common after hip fracture (2–4). The risk of a new hip fracture is increased six times in women who have already sustained one (5). This tendency to fracture could reflect reduced bone strength or increased risk of falling due to diminished neuromuscular response. In fact, bone mass is lower in hip fracture patients than in age-matched controls (6), and during the first year after the fracture, bone loss is accelerated (7). Lean mass after hip fracture has been shown to decrease by 10% during the first year, suggesting that focus on muscle strengthening exercises may facilitate the rehabilitation process (7). Enhancement of muscle strength and physical activity may also have a positive effect on bone mass. Numerous studies have demonstrated positive associations of bone mass with muscle strength and physical activity in young as well as in elderly healthy subjects (8–13). Such associations, however, have not yet been examined in elderly osteoporotic and/or disabled women.

It is unlikely that present efforts to prevent hip fractures will have a substantial effect in the foreseeable future (14). Therefore, there is a need for a better understanding of the relationship between muscle strength, physical function and bone mass with the goal of improving the outcome of rehabilitation. The purpose of this study was to examine relationships between constitutional parameters, physical ability and current level of physical activity, and bone mineral density (BMD) in women with a previous hip fracture.

METHODS

Subjects

Forty-seven consecutive women with previous hip fractures were examined. The mean age was 80.3 ± 7.0 (±1 SD) years. Only women who were otherwise healthy were included. None were on medication known to influence bone metabolism. Forty-two cases concerned cervical fractures and five trochanteric fractures. The fractures were of fragility type. The measurements were carried out 6–36 months (mean 17 months) after the time of surgery. At the time of examination, all women were able to walk with or without a walking aid.

The study was performed in accordance with the Helsinki Declaration and with approval of the Ethics Committee of Copenhagen County. Written consent was obtained from all the women.

Muscle strength measurements

Quadriceps strength (Nm) of the fractured and non-fractured legs was measured at 30°/second by an isokinetic dynamometer (Cybex 6000, Ronkonkoma, NY, USA) as previously described in detail (15).

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Table I. *Characteristics of the study group*

	Mean ± 1 SD	Range
Age (years)	80.3 ± 7.0	62–96
Height (cm)	156 ± 6	144–176
Weight (kg)	60.0 ± 11.3	42–88
Bone mineral density (g/cm^2)		
Neck	0.55 ± 0.10	0.30–0.76
Trochanter	0.44 ± 0.10	0.21–0.68
Ward's triangle	0.34 ± 0.08	0.19–0.55
Spine	0.81 ± 0.16	0.54–1.16
Walking speed (km/h)	3.3 ± 1.0	0.9–6.2
Stair climbing speed (steps/min)	51 ± 22	12–103
Activity index (%)	43 ± 19	7–86
Quadriceps strength (Nm)		
Non-fractured leg	66 ± 22	31–118
Fractured leg	54 ± 22	18–107

Walking and stair climbing speed

The women were free to use a stick. Assessment of walking speed (km/h) was performed while the women walked a distance of 50 m in a corridor as fast as possible. Stair climbing speed (steps/min) was measured on a staircase with 30 steps. The women were asked to climb up and down as quickly as they could. Time was measured using a stopwatch.

Physical activity

The Northwick Park activity index questionnaire was used to determine the level of physical activity undertaken on a daily basis, with special regard to social circumstances (16). This questionnaire has been developed specifically for patients with previous hip fractures. The questionnaire includes questions regarding employment, shopping, walking aids, walking distance, stair climbing and home help. The index is expressed in percent. A low index indicates functional dependency and a low level of physical activity.

Measurements of BMD

BMD of the femoral neck, the trochanter and Ward's triangle of the non-fractured leg and BMD of the spine (L2–L4) were measured using a Norland XR-26 dual energy X-ray absorptiometer (DXA). Precision errors for BMD measurements at our laboratory are similar to those reported by other investigators and have been presented elsewhere (17).

Statistics

All data were uniformly distributed. Results are given as mean ± 1 standard deviation (SD) and range. The difference in quadriceps strength between the non-fractured and fractured legs was evaluated with a two-tailed Student's *t*-test for paired observations. Pearson's correlation analysis was used to express the strength of the association between two variables. The predictability of a single variable from several variables was assessed by multiple regression analysis (stepwise selection), from which partial correlation coefficients ($R_{partial}$) were derived. The significance level was set at $p < 0.05$ for all tests. Analyses were performed using the software programme SPSS Statistics V. 4.01 (SPSS International BV, Chicago, IL, USA).

RESULTS

Subject characteristics are presented in Table I. Quadriceps strength was on average 18% lower in the fractured leg than in the contralateral leg ($p < 0.0001$).

Several significant linear inter-correlations were found between the measures of physical ability, the Northwick Park activity index, BMD, age, weight, height and months since fracture (data not shown). Consequently, multiple regression analyses were used to examine the predictability of one variable from several variables. Table II shows the results of multiple regression analyses with the Northwick Park activity index, walking speed or stair climbing speed as the dependent variable and age, height, weight, months since fracture and quadriceps strength of both legs as the independent variables. Quadriceps strength of the fractured leg was the most important determinant of walking speed, stair climbing speed and the Northwick Park activity index. Quadriceps strength of the non-fractured leg did not independently predict any of these three parameters. However, when excluding quadriceps strength of the fractured leg from the analyses, quadriceps strength of the non-fractured leg predicted the activity index ($R_{partial} = 0.45$, $p < 0.001$), walking speed ($R_{partial} = 0.52$, $p < 0.001$) and stair climbing speed ($R_{partial} = 0.29$, $p < 0.05$) independently of age, height, weight and months since fracture.

The Northwick Park activity index was independently correlated with months since fracture ($p < 0.001$). Walking speed and stair climbing speed were positively correlated with body height ($p < 0.05$) and negatively correlated with body weight ($p < 0.05$) (Table II). In multiple regression analyses adjusting for age, height, weight and months since fracture, the Northwick Park activity index was positively associated with walking speed ($R_{partial} = 0.64$, $p < 0.0001$) and with stair climbing speed ($R_{partial} = 0.71$, $p < 0.0001$).

Table III shows the results of multiple regression analyses with BMD as the dependent variable and age, height, weight, months since fracture, the activity index and quadriceps strength as independent variables. Body weight was the only independent predictor of BMD at any measurement site ($R_{partial}$ range:

Table II. *Partial correlation coefficients derived from multiple regression analyses with the Northwick Park activity index, walking speed or stair climbing speed as the dependent variable and age, height, weight, months since fracture and quadriceps strength as the independent variables in 47 women with previous hip fractures*

					Quadriceps strength	
	Age	Height	Weight	Months since fracture	Non-fractured leg	Fractured leg
Activity index	−0.17	0.17	−0.04	**−0.48****	0.02	**0.56****
Walking speed	−0.24	**0.30***	**−0.41****	0.10	−0.10	**0.69****
Stair climbing speed	0.00	**0.40****	**−0.31***	0.14	−0.17	**0.46****

**** $p < 0.0001$, *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Table III. *Partial correlation coefficients derived from multiple regression analyses with bone mineral density (BMD) of the femoral neck, trochanter, Ward's triangle or spine as the dependent variable and age, height, weight, months since fracture, the Northwick Park activity index and quadriceps strength as the independent variables in 47 women with previous hip fractures*

						Quadriceps strength	
	Age	Height	Weight	Months since fracture	Activity index	Non-fractured leg	Fractured leg
BMD							
Neck	−0.23	0.20	**0.65******	−0.23	0.08	0.19	−0.02
Trochanter	−0.16	0.19	**0.72******	−0.26	−0.01	−0.11	0.06
Ward's triangle	−0.23	0.12	**0.45*****	−0.08	−0.04	0.24	0.08
Spine	0.00	0.09	**0.47*****	−0.12	0.11	0.08	0.17

**** $p < 0.0001$, *** $p < 0.001$.

0.45–0.72, $p < 0.001$). No correlations were found between BMD and walking speed or stair climbing speed (data not shown).

DISCUSSION

Studies of elderly, generally healthy subjects without fractures have reported relationships between muscle strength and functional status (18), chair rising ability (19), and walking and stair climbing speed (19–21). Furthermore, an association between muscle strength and the risk of recurrent falls (22, 23) and fractures (10, 24, 25) has been demonstrated. Although hip fracture patients with mental disorders and coexisting medical conditions known to influence bone mass or muscle function were not included in this study, the mean activity index was only 43%, indicating a low level of physical activity (16). Quadriceps strength was markedly reduced (18%) in the fractured leg compared to the non-fractured one. It this context, it should be taken into consideration that quadriceps strength of the *non-fractured* leg in women with previous hip fractures may be reduced by 25% compared to that in healthy age-matched controls (26). In the present study of women with previous hip fractures, we showed that quadriceps strength of the fractured leg was positively and independently associated with walking and stair climbing speed and with the current level of physical activity. Moreover, the level of physical activity was dependent on walking and stair climbing ability. Although the degrees of explanation (R^2) were only moderate (for example, $0.69^2 = 48\%$ of the variability in walking speed was independently explained by quadriceps strength (Table I)), the findings illustrate the need for improved rehabilitation of muscle function after hip fracture.

Body weight seemed to be an independent contributor to problems related to walking and stair climbing. This is also the case for women suffering from osteoarthritis of the knees (27). Body height, which may associate with the distance covered in a step, was positively related to walking and stair climbing speed.

Several studies of young and elderly women with no physical handicaps have demonstrated independent relationships between BMD and muscle strength (8, 11, 28, 29). Only one previous study has focused on hip fracture patients. Wand et al. (16) examined 12 hip fracture patients rehabilitated 6–33 months previously. The patients had a mean activity index (Northwick Park) of 40% similar to the one found here (43%). A significant inverse relationship between hydroxyproline excretion and the activity index was reported. Based on this finding an association between bone mass and physical activity was suggested for hip fracture patients. However, in the present somewhat larger study, independent associations of BMD at the Ward's triangle, trochanter, femoral neck and spine with the activity index as well as with walking and stair climbing speed were not demonstrated. Consequently, we cannot confirm the suggestion of Wand et al. (16) that physical activity may have a positive effect on bone mass in women with previous hip fractures. Using multiple regression analysis, we found that body weight was the most important determinant of BMD in these women. Reduced muscle strength and a low level of physical activity in women with previous hip fractures possibly make the effect of body weight on bone mass more important. Body weight may mediate effects on bone mass through increased weight-loading on the skeleton. Fatty tissue, a major contributor to body weight, may also mediate positive effects on bone mass via conversion of adrenal steroid precursors to estrogens (30).

A reference population of healthy age-matched women was not available. Bone mass, however, has been shown to be lower in patients with a recent hip fracture than in age-matched controls (6). Furthermore, there is an increased rate of bone loss following the fracture (7). Accordingly, the BMD values found by us were considerably lower than those demonstrated in women who had sustained a hip fracture a few days previously (6). We did not find associations between BMD and months since fracture. The reason may be that total BMD, not the change in BMD, was measured. Moreover, BMD decreases mainly during the first year following the fracture (7), indicating that a linear correlation between bone loss and time since fracture may not be present.

Notwithstanding the limitations of the cross-sectional study design, we conclude that quadriceps strength in women with previous hip fractures is markedly reduced and is associated with walking ability and level of physical activity. Bone mass is linked most closely to body weight, not to age, disease duration, quadriceps strength or current level of physical activity. Thus, the main benefit of muscle strengthening exercises in these women may be to promote mobility, not to reduce bone loss.

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