Factors in secondary prevention subsequent to distal radius fracture

Focus on physical function, co-morbidity, bone mineral density and health-related quality of life

Helena Nordvall
You do not really understand something unless you can explain it to your grandmother

Albert Einstein

Mummun muistoa kunnioittaen
ABSTRACT

In Sweden approximately 25000 distal radius fractures occur annually, which is 37% of all fractures related to osteoporosis. In this thesis, risk factors for osteoporosis, bone mineral density (BMD) and health-related quality of life (the SF-36) were compared in patients who suffered a distal radius fracture after low energy trauma with a control group matched on the basis of age, gender, and municipality of residence. The aim was also to analyse, among these patients, whether a risk factor questionnaire, tests on dynamic and static balance and a one-leg rise test could identify those, who have osteopenia or osteoporosis, and run a risk of new falls. Moreover, in a three-year follow-up, mortality, the need for in- and outpatient care, and health-related quality of life after radius fracture were investigated and compared between the patients and matched controls. Finally, the effect of a preventive intervention program including patient education and self-training was evaluated. Falls were reported in a risk factor questionnaire and in a fall diary.

The patients aged 45-64 years showed lower, although not statistically significant, BMD, compared with the controls of the same age, but there was no difference concerning their history of falls. In contrast, the patients aged 64 years or older had a history of falling more often than the corresponding controls, but no difference in BMD was found. For all other risk factors, except falls, no differences were found between the patients and the controls. The results of the one-leg rise test were associated with those of dynamic and static balance, but none of the functional tests were associated with the number of falls. Decreased height and cigarette smoking were the only risk factors, which predicted osteopenia and osteoporosis.

Five patients, although none of the controls, died during the study time. The patients needed statistically significantly more episodes as inpatients than the controls. The patients also had lower SF-36, Role Physical scores, than the controls at three months. This difference disappeared by the time of the follow-up.

Both the patients, who participated in a four-week intervention program, “the osteoporosis school” followed by a one-year home-based exercise program, and the controls showed statistically significantly improved dynamic and static balance, ability to walk backwards and to stand on one leg with eyes open and closed at the end of the study. However, no significant differences were found between the patients and the controls in any of the tests, in BMD or in the number of the falls.

The thesis shows that, except for the falls in patients aged over 64 years, there were no significant differences between patients and controls with respect to BMD and other risk factors related to osteoporosis. Consequently, in patients aged 45-64 years and older, the underlying cause of a distal radius fracture is more related to falls than to osteoporosis. Furthermore, the thesis shows that the functional tests and the risk factor questionnaire seem to be of limited value for identifying
people with a radius fracture, who are at risk of falling or have osteopenia or osteoporosis. If, in spite of this, functional tests on musculoskeletal function are considered for testing of functional ability in patients with a recent radius fracture, the one leg-rise test may be sufficient. There seems to be an increased mortality and morbidity necessitating inpatient care among patients with a recent radius fracture. The osteoporosis school had no significant effect on BMD, balance, muscle strength or falls in this thesis. Therefore, the lack of proven efficacy of the osteoporosis school for the secondary prevention of distal radius fractures highlights the need for more and long-term randomised controlled follow-up studies in this specific population.

**Keywords:** Distal radius fracture, bone mineral density (BMD), functional tests, mortality, morbidity, the SF-36, fall diary.
SVENSK SAMMANFATTNING

I Sverige får ungefär 25000 personer varje år distal radiusfraktur, vilket är 37% av alla frakturer, som är relaterade till osteoporos. I den här avhandlingen jämfördes patienter med distal radiusfraktur med kontrollpersoner med samma kön, ålder och bostadsort avseende riskfaktorer för osteoporos, benäthet (BMD) och självskattad livskvalitet (SF-36). Syftet var också att, bland patienterna, undersöka om ett frågeformulär för benskörhet, tester för dynamisk och statist balans och uppresningstest, kan identifiera de som har osteopeni eller osteoporos, och löper risk för nya fall. Dödlighet och behov av vård på sjukhus och i öppen vård samt självskattad livskvalitet undersöktes tre år efter radiusfraktur, där jämförelser gjordes mellan patienter och kontrollpersoner. Slutligen utvärderades effekten av ett preventivt träningsprogram, som innehöll undervisning och träning, med uppföljning av fall med frågeformulär och falldagbok.

Patienter i åldern 45-64 år hade inte signifikant lägre BMD än kontrollpersonerna och det fanns inte heller någon skillnad mellan grupperna avseende fall. Däremot föll patienterna i åldern 64 år och äldre signifikant mer än kontrollpersonerna, men det förelåg ingen signifikant skillnad i BMD. Ingen skillnad fanns heller mellan patienter och kontrollpersoner med avseende på andra riskfaktorer för osteoporos. Det fanns ett statistiskt signifikant samband mellan uppresningstestet och dynamisk och statist balans. De funktionella testerna uppvisade inget samband med antalet fall. Minskad kroppslängd och rökning var de enda riskfaktorer som predicerade osteopeni och osteoporos.

Beträffande dödlighet och sjuklighet under uppföljningstiden påvisades att fem patienter dog under studietiden men ingen bland kontrollpersonerna. Antalet sjukhusbesök i sluten- och öppenvård var statistiskt signifikant högre bland patienterna. Patienterna hade lägre skattad livskvalitet än kontrollpersonerna tre månader efter frakturtillfället, men skillnaden försvann till treårsuppföljningen.


Den här avhandlingen visade att förutom förekomst av fall hos patienter äldre än 64 år, fanns inga skillnader mellan patienter med radiusfraktur och kontrollpersoner avseende BMD eller riskfaktorer för osteoporos. Detta talar för att den underliggande orsaken till distal radiusfraktur hos patienter äldre än 64 år är mer relaterad till fall än till osteoporos. Vidare visade avhandlingen att funktionella tester och
screening med riskfaktorformulär, tycks ha begränsat värde för att identifiera personer med benskörhet. När sekundär prevention planeras för patienter med distal radiusfraktur, behöver hänsyn tas till en högre grad av sjuklighet i denna patientgrupp. Osteoporoskolan med hemträningsprogram visade i denna avhandling inte någon signifikant effekt på BMD, balans, muskelstyrka eller fall i ett-års perspektiv. För utvärdering av sekundär prevention behövs långsiktiga randomiserade kontrollerade uppföljningsstudier.

**Nyckelord:** Distal radiusfraktur, bentäthet (BMD), funktionella tester, dödlighet, sjuklighet, SF-36, falldagbok.
# ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
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<tr>
<td>BMD</td>
<td>Bone Mineral Density (g/cm²)</td>
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<td>T-Score</td>
<td>SD from mean in areal BMD of healthy young European women</td>
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<td>Z-score</td>
<td>The number of the standard deviations from the mean for women of the same age</td>
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<td>DXL</td>
<td>Dual-energy X-ray absorptiometry and Laser</td>
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<td>ICD-10</td>
<td>International Classification of Diseases, 10th edition</td>
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<td>SF-36</td>
<td>Short form 36-item health survey</td>
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<td>WHO</td>
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INTRODUCTION

This thesis is based on observations of patients with a distal radius fracture due to low-energy trauma. Radius fracture is defined as a fracture of the radius at the wrist. A low energy trauma is commonly a fall on the same level. There are approximately 25000 radius fractures annually in Sweden, which is 37% of all fractures related to osteoporosis [1]. Kanis et al. [2] estimated the remaining life-time risk of distal radius fracture to 21.5% in women at the age of 45 years in Malmö, Sweden. Osteoporosis causes more than 8.9 million fractures worldwide annually [3], [4], [5], [6]. Sweden and Norway have the highest incidence worldwide of fractures related to osteoporosis and within Sweden the incidence is higher in the northern part of the country [7]. The cost of osteoporosis-related fractures in Sweden is calculated to € 0.5 billion [8].

Distal radius fracture

Historical background

Already in 400BC Hippocrates described injuries of the wrist as inward or outward carpal dislocations [9]. More likely this is the first description of a distal radius fracture in literature. In 1705 Petit suggested that these dislocations could be fractures of the end of the radius, and this was subsequently accepted later on by other researchers [9]. Several researchers have developed the procedures of diagnosis, management and treatment of distal radius fractures (Pouteau 1783, Colles 1814, Goyrand 1832, Barton (1838), Smith (1847), Dupuytren and Morton). Wilhem Conrad Röntgen started a new era in the management of fractures with his discovery of x-rays (1895), and this of course influenced the treatment of radius fractures as well. Plain radiographs are still the most common method to diagnose and classify distal radius fractures.

Classification

Radius fractures can be divided in Colle’s, Smith’s or Barton’s fractures [10]. More detailed classification is to be found in Frykman’s [11], and AO’s [12] classification systems. Most radius fractures require some kind of stabilization for optimum recovery and function [13], [14], [15], [16]. Depending on the type of fracture this may involve a range of procedures from a simple closed reduction and plaster [17] pins, external fixation and soft tissue repair to open reduction, because of severe rotation of the fragments, and internal fixation with plates and screws [18]. This thesis does not deal with acute treatment of radius fractures nor with classification systems of distal radius fractures.
Treatment and rehabilitation

The goal for rehabilitation after distal radius fractures is to achieve complete and rapid recovery of range of motion, strength, and function of the wrist and hand [19] [18, 20-22]. Therefore the rehabilitation has to start already during fracture immobilization. The physiotherapist instructs the patient how to reduce oedema and maintain range of motion for the shoulder, elbow, fingers, and thumb, mobilizes soft tissues, monitors circulation and sensibility and gives advice in order to reduce pain. In patients with plaster fixation, early active motion of the wrist can be started after removal of the plaster.

Distal radius fracture after a low-energy trauma

A distal radius fracture is a predictor for a new fracture [23], [4], and is considered a strong indicator for osteoporosis [3].

The mean age for the patients with a distal radius fracture in Sweden was 63 years in 1994 [24], and 67 years in 2004 [25]. For patients with a hip fracture the mean age was 83 years [26]. Consequently, there is often an interval of several years between a radius fracture and a subsequent hip fracture. This period is potentially important for secondary prevention. Several researchers have stressed the importance of detecting individuals with low BMD and a tendency to fall, in order to consider treatment or other measures to prevent new fractures [27-29] [30]. However, a single BMD measurement alone cannot specifically detect those, who will actually sustain a fracture [31], but has to be combined with clinical risk factors [32].

About 30% of people aged 65 or older living in their homes fall each year. The risk for falling increases with age [33], [34]. Falls are involved in the majority of the fractures related to osteoporosis [35]; 93% of distal radius fractures are caused by falls [36], [37], often a fall on the same level in forward or backward direction [38] [39]. Falling is the strongest single risk factor for fractures in elderly people [40], [41], [42]. Järvinen et al. [43] and Poole [44] recently considered that risk of falling is “completely overlooked in many important publications on preventing fractures”. The authors want to shift the focus in fracture prevention from osteoporosis to falls. For patients with a recent radius fracture, however, the focus for secondary prevention in order to prevent new falls and fractures; prevention of falls or treatment of osteoporosis, needs more studies.
Introduction

Distal radius fracture related to risk factors for osteoporosis or falls

In this thesis the definition of a fall according to the Kellog International Work Group on the Prevention of Falls by the Elderly was used: “A fall is an event which results in a person coming to rest inadvertently on the ground or other lower level and as a consequence of a violent blow; loss of consciousness or sudden onset of paralysis, as in a stroke or epileptic seizure” [45].

At present there are 400 different risk factors for falling, which have been mentioned in the literature [46], [47], [6].

Besides falls, other risk factors for a distal radius fracture are said to be heredity [48], low calcium intake [49], low arm strength, poor vision [50], walking quickly [51] or often [50], and walking on slippery and uneven ground such as snow and ice [52]. By contrast lower-than-average risk for radius fractures was found for people with impaired walking ability due to overweight [50], [49], and for those seldom walking outdoors [53]. For some of these risk factors, the grade of the impact has been questioned, for example no associations were found with calcium intake [51], [54], body-weight [55], [54], or visual problems [55]. Kelsey et al. [Kelsey, 2005 #97] stated that for reducing the risk for distal radius fracture people should “preserve bone mass, slow down, and do not fall”!

Functional tests of balance and leg strength for patients with a distal radius fracture

For daily living and all ordinary tasks such as walking, standing, dressing, eating and so on, one needs both balance, muscle strength and many combinations of different neuromuscular skills. There are many functional tests to evaluate these skills. For balance, the one-leg stance is often used [56], [57], [58], [59]. Other tests of balance are, for ex. the functional reach test [60] and the timed “Up & Go”-test [61]. The one-leg raise test is also used to estimate muscle strength of the legs [62]. Bohannon [58] described tests and normative values for comfortable and maximum walking speed in the elderly. Tests which combine several tasks have also been suggested [63], [61]. Poor results in these tests indicate and predict a risk for falls [64], [65], [66]. All these tests have been used to predict risk for falling in older and often frail people. Nordell et al. [67], [68] recommended the use of the one-leg stance and walking speed tests for the patients with a recent distal radius fracture. Prevention strategies need to be based on knowledge about the most important risk factors, and these risk factors should be possible to evaluate in clinical tests or questionnaires.
Introduction

Distal radius fracture, co-morbidity and mortality

Co-morbidity and mortality after a hip fracture are known to be increased [69], [7]. The most common serial fracture sequence is a hip fracture followed by a new hip fracture [70]. Not surprisingly, an increased morbidity has been reported for this group of patients [71], [72]. The second most common sequence of osteoporosis related fractures is a distal radius fracture followed by a hip fracture [70]. Already in 1982 Owen et al. [73] found a 50% increase in the relative risk for sustaining a hip fracture in patients with a distal radius fracture. Furthermore, an earlier fracture in conjunction with smoking was a risk factor for new fractures [73], [74]. Rozental et al. [75] studied survival in elderly patients after distal radius fracture and found that it was shorter than expected compared to the individuals in the standard population, and that men were twice as likely to die as women and also did so almost twice as quickly. Mortality and co-morbidity is, however, much less investigated for patients with a radius fracture compared to patients with a hip fracture, but is as important for the planning of secondary prevention strategies.

Distal radius fracture and health-related quality of life questionnaires

Health-related quality-of-life is one of the different aspects for describing clinical outcomes after a distal radius fracture [76]. Amadio et al. [77] presented the opinion that questionnaires of health-related quality of life can complete other clinical measurements such as functional tests and measurement of BMD. There are several questionnaires for investigation of health-related quality of life. One of these is The Medical Outcomes Study 36-Item Short Form (SF-36) [78] or its 12-Item Short Form version (SF-12) [79]. Other commonly used questionnaires are The Nottingham Health Profile (NHP), the Sickness Impact Profile (SIP) and EQ-5D (EuroQol) [80]. Depending on the purpose of the health-related quality of life investigation, any of these questionnaires can be used.

The SF-36 has been used in several studies for investigating health-related quality of life in patients with a distal radius fracture [25, 76, 81] [82]. The physical domains of health and bodily pain of SF-36 are most conceptually relevant for the patients with a distal radius fracture. Endres et al.[82] found that the radius fracture influenced the SF-36 profile soon after the fracture, but this was normalized by the time of the follow-up. Although radius fractures are sometimes associated with complications and poor function (such as instability of the wrist [83] and pain [84], this did not influence the SF-36 profile. Nordell et al. [68] showed lower
health-related quality of life scores than expected in patients with a distal radius fracture, compared to Swedish normative data. These researchers recommend that women with low SF-36 score should be referred for health review in order to prevent further falls and increased functional impairment.

**Secondary prevention strategies and their effect on BMD, falls, balance and muscle strength of lower limbs**

Many studies have been made to find out the most suitable preventive program for the elderly who are frail and also for the patients with a distal radius fracture. Grahn-Kronhed et al. [85] showed that a program with weight-bearing exercises during one year, resulted in a significant increase in BMD. Conversely, Korpelainen et al. [86], found that impact exercises during 30-months had no effect on BMD. In a prospective randomised study Preisinger [87] showed that four years of regular and in the beginning supervised training resulted in an unchanged BMD, while BMD in the controls decreased. There is also evidence that regular Thai Chi Chuan-training during one year can delay osteoporosis in weight bearing bones in post menopausal women [88] [89]. A summary of studies on the effect of physical exercise, on BMD in people with or without distal radius fracture, 40 years of age or over is shown in Table 1.
Introduction
Howe et al. [100] found in a systematic review of studies on exercise interventions, that training involving multiple types of exercise, such as muscle strengthening, co-ordination and functional exercises had the greatest impact on indirect measures of balance, and that there was limited evidence that the effect of the exercises was long-lasting.

In the elderly 15% of falls can be prevented with an individual exercise and intervention program [41], [101, 102] [98, 99]. Preventing falls among the elderly reduces the number of fractures, sometimes by over 50% [103], [104], [105], [106], [86], [107], [98]. Lord [108] reported that exercise was shown to improve muscle strength and balance in healthy elderly people and Carter [109] reported the same in women with osteoporosis. Baum et al. {Baum, 2003 #303] showed that frail elderly (aged 75 to 99 years) were able to participate and benefit from a supervised strength-training program with low-cost equipment during one year. Other studies suggest that exercise programs may improve balance and mobility [110] [99], trunk extension strength [111] and reduce the risk of falls [112] [90] [113]. Consequently, there is relatively firm evidence that prevention can reduce falls and injuries in elderly people [114], [115], [116], [117] [98, 102]. The working group of the Swedish Council on Technology Assessment in Health Care [28] reported that individual training of muscle strength and balance was proven to decrease the risk of falls.

For reduction of situational risk factors for falls, and preventing falls, a single intervention strategy with an individualized training program with exercises on balance and strength was recommended [115]. In order to individualize the program, focusing on functional deficits is reasonable, but if so, relevant tests on different abilities are urgently needed. Even if scientific data, to some extent support training in order to improve strength, mobility and balance, there is a lack of knowledge about type and mix of exercises, frequency and duration. Furthermore almost none of the studies in the literature address independently living people of 65-70 years of age, i.e. the common age at the radius fracture.

The best clinical practice, consistent with current evidence and expert consensus, could be to identify people who have had a radius fracture, measure their BMD and inform them of the future fall and fracture risk [118], [119] [6], but there is lack of evidence about the effectiveness of such an intervention.

Rationale of the thesis

Osteoporotic fractures are a major cause of morbidity of the population and associated with high costs for society. Osteoporosis is a “silent” disease, while a low-energy fracture is the clinical manifestation of osteoporosis. A distal radius fracture is the most common low-energy fracture and often the first sign indicating osteoporosis and a predictor for new fractures.
Among patients with a radius fracture, those with an impending risk for new falls and fractures, may also be carries of a higher co-morbidity and mortality, just like patients with a hip fracture. A radius fracture due to low energy trauma, should call for action, but on the other hand the obvious threat for the typical patient may be experienced as low. This may result in a low grade of motivation for training and other actions of prevention. Furthermore, the long-term effectiveness of this type of prevention has been questioned.

The best practice could be to identify people 45 years of age or older with a radius fracture, to measure their BMD, and to identify those at risk of becoming frequent fallers, and to start a preventive program. Today most patients who sustain a distal radius fracture are not offered measures to prevent future fractures, such as evaluation or treatment for osteoporosis. In other words this is given a low priority by the health-care system. A possible explanation is that such a program has to be made more individually focused, based on the individual unique risk factors to improve effectiveness and to increase motivation to participate. Before this can be done we need more knowledge about different risk factors at the stage in a “serial fracture course” when the radius fracture appears, and how to identify those at risk from clinical data and simple tests and examinations. Obviously many patients with a radius fracture will never have a second fracture and consequently do well without any preventive programs. Also, before we undertake long-term studies on the effect of prevention programs, we need to test in a smaller scale, the effect in the short term on functional tests, falls etc. to get a picture of the patients’ willingness to participate.

In Norrbotten county, at Sunderby hospital there are about 250 patients treated for a distal radius fracture annually. In this thesis a multifactorial intervention program was launched among these patients in 2004-2005 in a preventive program.
AIMS OF THE THESIS

The general aim was to investigate how to identify those patients with a recent radius fracture who have osteopenia or osteoporosis and are at risk for new falls. The aim was also to study mortality and co-morbidity and health-related quality of life after a radius fracture, and to evaluate the effect of a preventive program including patient education and one-year home-based training.

Specific aims

To compare the risk factors for osteoporosis and health-related quality of life in patients with a distal radius fracture after a low-energy trauma, with a control group matched on the basis of age, gender and municipality of residence (Paper I).

To analyse whether functional tests could identify those, who are at risk of falling, and whether generally accepted risk factors for osteoporosis can identify people with osteopenia and osteoporosis within a group of patients with a distal radius fracture (Paper II).

To investigate mortality, co-morbidity and health-related quality of life issues associated with distal radius fractures by comparing patients with control subjects matched for age, gender, and municipality of residence (Paper III).

To evaluate the effect on BMD, dynamic and static balance, muscle strength of the lower limbs and falls by offering a four-week intervention program, the osteoporosis school, followed by a one-year home-based exercise program to patients with a radius fracture, in comparison with a non-exercise control group (Paper IV).
METHODS

Study population

All subjects, both the patients, treated for a distal radius fracture at the Department of Orthopaedics at Sunderby hospital, Luleå, and their age, gender and municipality of residence matched controls live or lived in Norrbotten in the northern part of Sweden. Sunderby hospital is primarily responsible for fracture care for 100,000 inhabitants. The studies included women born in 1958 or earlier (i.e., 45 years or older on December 31, 2003) and men born in 1938 or earlier (i.e., 65 years of age or older on December 31, 2003). All subjects were living in their own homes. The patients had a fall due to a low-energy trauma resulting in a distal radius fracture.

A total of 307 patients and 154 controls were invited to participate in the studies. Two controls for each patient (Paper I), were randomly selected within the matching criteria, from the Register of Population of Norrbotten County using the random generator in SPSS 10.1 software. If both controls agreed to participate, the one whose date of birth was closest to that of the patient was chosen. The exclusion criteria for all studies were impairment of mental or physical health which prevented the subjects from providing correct information or completing the questionnaires at home (for example dementia). The base data for each patient were collected from the orthopaedic medical records at Sunderby hospital. The patients with osteopenia or osteoporosis according to the BMD measurement were referred to the primary care service. The first patient of the thesis was investigated in December 2003 and the last in December 2005.

There are two samples in the thesis, the first one consists of 98 patients and 98 controls and the second of 141 patients (Figure 1).
Figure 1. The flow-chart of the subjects in the thesis.

Methods

An analysis of non-participants was performed to see whether they differed from the participants according to age, baseline characteristics and their reported motive not to participate in the studies. In Papers I and II, 68 patients both women and men, who declined to participate in the studies were 6-8 years older compared to those who accepted. This difference between the participants and non-participants was, however, not statistically significant. In Paper III, 24 of 98 patients were excluded because they were enrolled in an intervention, called the osteoporosis school. These 24 did not differ from the 117 patients, who were invited from the beginning. In Paper III at the three-year follow-up four patients had died and 14 declined to participate at the follow-up. There were no statistically significant differences in the baseline characteristics between these participants and the non-participants.
Data collection methods

Data collection methods included measurements of BMD, two questionnaires, one of risk factors for osteoporosis and one of health-related quality of life, (SF-36, short form). The methods also included functional tests: walking 30 metres, as fast as possible, with a 180° turn halfway, walking backwards 20 steps; standing on one leg with open or closed eyes and finally, a one-leg rise test for leg strength. The data about falls was collected retrospectively from the risk factor questionnaire for osteoporosis and prospectively through a fall diary. Mortality was collected from The Swedish Cause of Death Registry from December 2003 to February 2007 and verified with the medical records. For assessment of morbidity, defined as a need for in- and or outpatient care, we retrospectively collected all inpatient and outpatient data that identified visits to the health care system (except visits to a general practice) from the medical records at Sunderby Hospital and the Medical Care Register. In Paper III and IV all the different methods were collected at the beginning and the end of the study period. The use of the different methods is shown in Table 2.

Table 2. The use of the different methods in the thesis, Papers I-IV.

<table>
<thead>
<tr>
<th>Methods</th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
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<td>Risk factor questionnaire</td>
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<td>SF-36 questionnaire</td>
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<td>Fall diary</td>
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<td>An intervention; the osteoporosis school</td>
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Bone mineral density (BMD)-measurement (Papers I and IV)

For the measurement of BMD, a dual X-ray and laser technology, the DXL Calscan© device was used (Demetech AB; Stockholm, Sweden; Figure 1). The left heel bone (calcaneus) was measured. The result is given in g/cm² and is then converted into T- and Z-scores [120], [121], [122], [123]. The T-score is based on the standard deviation (SD) from the mean in areal BMD of healthy, young European women of the same age. The Z-scores are related to the mean areal BMD in the reference
population at the same age as the patient. In this thesis the Z-scores are only reported in Paper I. Osteoporosis according to the WHO criteria [27] is a state of low bone mass, with micro-architectural deterioration of the bone tissue, leading to increased bone fragility and increased risk of fractures. Normal BMD: T-score > –1 SD. Osteopenia: T-score between –1 and –2.5 SD. Osteoporosis: T-score < –2.5 SD. Manifest osteoporosis: Fracture and T-score < –2.5 SD [28].

Risk factor questionnaire for osteoporosis (Papers I and II)

Risk factors for osteoporosis were evaluated using the questionnaire established by the Swedish Medical Products Agency [124] (Appendix, Paper I). It includes eleven “yes” or “no” questions. The subjects completed the questionnaire at home without any help from the investigator. The questionnaire includes loss of body height and weight compared to similar criteria at 25 years of age, earlier forearm or vertebral fractures, a question whether the subject has fallen more than once during the past year, smoking habits and medical treatment for certain diseases e.g. marked impairment of kidney function. A question about family history, defined as whether the patient’s mother or father had had a hip fracture was also included. Finally, we added an extra question about Calcium, D-vitamin and bisphosphonate intake.

Health-related quality of life questionnaire, the SF-36, (Papers I and III)

We used the Health Survey Questionnaire, Short Form (SF-36) [78] to investigate health-related quality of life. This questionnaire uses 36 questions to assess the physical, mental and social quality-of-life as a direct function of health problems. The goal is to estimate the different aspects of physical and mental health. The questionnaire contains eight areas of health, which are presumed to be universal and represent basic human functions and well-being. The functions assessed are: PF; Physical Functioning, RP; Role-Physical, RE = Role-Emotional, SF; Social Functioning and BP; Bodily Pain. The scales of well-being are: MH; Mental Health, VT; Vitality and GH; General Health. These subscales are scored out of a maximal score of 100. Based on these subscales PCS; Physical Health and MCS; Mental Health are assessed. The questionnaires were filled in at home without any help from the investigator.
Methods

Functional tests (Papers II and IV)

The tests were selected due to their applicability to the elderly, and because they were easy to perform without any special equipment. The tests were:

- walking with a turn (first 15 metres forward, then a turn 180°, and 15 meters back) [57]
- walking backwards 20 steps (the patient was instructed to place one foot behind the other) [96]
- standing on one leg with eyes open [57], [58]
- standing on one leg with eyes closed [57], [58]
- one-leg rise [62]

Both walking with a turn and walking backwards are considered to mirror dynamic balance [57], [96]. The test standing on one-leg with eyes open [125] and eyes closed [59], are considered to mirror static balance [57], [58]. The one-leg rise test Ekdahl et al. [62] estimates the strength of the lower extremities.

Before carrying out the tests, they were demonstrated to the patient by an investigator, and after that the patient tried it once. All the tests were performed indoors. The floor was of non-slip material, and an investigator walked behind the patient to prevent falls. Another investigator registered the result with a chronometer as the shortest time for the walking tests, and the longest time in seconds, (cut off 30 seconds) for the tests standing on one leg. In both walking tests the subjects were requested to walk safely but as quickly as possible, and to stand as long as possible in the stance test. All patients who started a walking test, completed it. No one stopped before the test was completed.

For the one-leg rise test the only necessary equipment was a 45 cm high chair. The patient sits on the chair and is asked to rise on one leg at a time with the arms crossed over the chest. The test was done with the right knee extended on the first attempt, and the left on the second attempt. The investigator assessed the performance on a three-point scale (0-2), 2 = normal function, no time-delay, 1 = slight / moderate impairment and 0 = severe impairment/ unable to carry it out.

Fall diary (Papers II and IV)

One hundred and seventeen patients completed a fall diary from May 2005 to December 2005 (Paper II) and from October 2006 to May 2007 (Paper IV). The subjects were asked to register all falls during eight months, both indoors and outdoors, as well as all fractures and other injuries, which occurred in conjunction with a fall. A written reminder was sent after three months and once again two - three months before the end of the registration period. After eight months the patients sent their fall diaries to the investigator.
Mortality and co-morbidity (Paper III)

Mortality was registered through The Cause of Death Registry. Available data was cross-checked by the medical records at Sunderby hospital. The diagnosis (ICD-10 code), which was registered as the main causes of death, was noted. For assessment of morbidity, we collected all visits to the health care system (except general practice), both as outpatient and inpatient care, from the computerized medical records at Sunderby Hospital. The causes of the consultations were classified according to the International Classification of Diseases, ICD-10.

Four-week educational and exercise program, the osteoporosis school (Paper IV)

A four-week intervention program, called the osteoporosis school modified with kind permission from Röjhammar [126] was used in Paper IV. This school was followed by a self-administrated exercise program during 12 months based on the osteoporosis school. The osteoporosis school included both theoretic education, on topics such as; osteoporosis as a disease, risk factors for osteoporosis, treatment of osteoporosis, fall prevention, and practical exercises to improve balance and leg strength, aiming to prevent future fractures and falls. All patients had four lessons. Each lesson had a theoretical and a practical part and lasted for three hours. During the last hour of each lesson the participants were instructed in a program for self-training at home (Appendix). The exercises were aimed at strengthening of the thighs, the back muscles, and to improve balance and co-ordination. A team consisting of a physician, a nurse and a physiotherapist participated in the osteoporosis school. The physiotherapist planned the lessons in cooperation with the other members of the team.

Statistics

All the statistical analyses in the thesis were performed using SPSS statistical software versions from 10.1-14.1 for Windows. The value of acceptance for statistical significance was set at p<0.05. Mean and SD were calculated for all baseline characteristics, and independent samples t-test was used to compare the differences between two groups. The Paired samples test was used to analyse differences within the groups. The items in the Swedish version of the SF-36 Health Survey were calculated according to SF-scoring instructions. The Fisher’s exact test, Chi ²-test and odd ratios (OR; 95% confidence interval, CI) were used to compare the groups according to three BMD-classifications, morbidity and risk factors for osteoporosis (yes/no-questions). An age-adjusted logistic regression was used to explore the risk factors regarding patients.
with and without osteopenia / osteoporosis and functional tests regarding to fallers/non-fallers. An overview of statistics used in Papers I-IV is shown in Table 3.

Table 3. Overview of statistical tests in Papers I-IV, statistical program SPSS 10.1-14.2 was used.

<table>
<thead>
<tr>
<th>Statistical Test</th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent samples t-test</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Fisher’s exact test</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chi² test</td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Wilcoxon</td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Log regression* ANOVA**</td>
<td></td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Paired samples t-test</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Univariate logistic regression and multivariate regression** with a forward stepwise selection.

Ethics

The subjects gave their informed consent. The Research Ethics Committee of Umeå University approved all the studies, §120/04, diary number 04-135M.
Results

RESULTS

Bone mineral density (BMD), tendency to fall and distal radius fracture (Paper I)

The mean T-score was –2.1 (SD 1.0) for the patients and –1.9 (SD 1.1) for the controls, (p=0.29). The T-scores indicated normal BMD in 28 (20%), osteopenia in 78 (55%), and osteoporosis in 35 (25%) patients in the female group. Three of the men had normal BMD and three had osteopenia. The patients >64 years compared to their controls had no difference in T-score. By contrast, patients 45-64 years old showed a tendency to lower T-score (p=0.09) (Table 4).

<table>
<thead>
<tr>
<th>Age Group (years)</th>
<th>Patients n</th>
<th>T-score mean</th>
<th>SD</th>
<th>Controls n</th>
<th>T-score mean</th>
<th>SD</th>
<th>Mean difference in T-score</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>45-64</td>
<td>39</td>
<td>-1.77</td>
<td>0.80</td>
<td>37</td>
<td>-1.44</td>
<td>0.87</td>
<td>-0.33</td>
<td>0.09</td>
</tr>
<tr>
<td>≥65</td>
<td>45</td>
<td>-2.35</td>
<td>1.14</td>
<td>43</td>
<td>-2.30</td>
<td>1.18</td>
<td>-0.04</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Although the patients >64 years had a history of falling significantly more often than their controls (p=0.01), no such difference was found in the 45-64-year age group (Table 5). Neither were there any significant differences between the patients and the controls according to the following risk factors: previous fracture, loss body height, cigarette smoking, nor heredity indicated by parent with a hip fracture.
Table 5. The breakdown of the rate of the patients (n 87) and the controls (n 82) that had more than 1 fall during the previous year. The subjects were divided into groups according to age.

<table>
<thead>
<tr>
<th>Age group</th>
<th>Patients rate</th>
<th>Controls rate</th>
<th>Total rate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>45-64</td>
<td>Fall 10 0.3</td>
<td>7 0.2</td>
<td>17 0.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No fall 29 0.7</td>
<td>30 0.8</td>
<td>59 0.8</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total 39 0.7</td>
<td>37</td>
<td>76</td>
<td>0.6</td>
</tr>
<tr>
<td>≥65</td>
<td>Fall 21 0.4</td>
<td>8 0.2</td>
<td>29 0.3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No fall 27 0.6</td>
<td>37 0.8</td>
<td>64 0.7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total 48 0.6</td>
<td>45</td>
<td>93</td>
<td>0.008</td>
</tr>
</tbody>
</table>

Fisher’s exact test.

Health-related quality of life (SF-36) and distal radius fracture

There were statistically significant differences between the patients and the controls according to Role-Physical (RP) (p<0.001), BP (p=0.002) and Physical Component Summary (PCS) (p=0.003) (Figure 2) at baseline (Paper I). Among the subjects with normal BMD the patients had lower values for RP than the controls (p=0.02). In the group with osteopenia, the patients had lower values for RP and BP (p<0.001 and p=0.005). No significant differences were found in the group with osteoporosis (Paper I).

Figure 2. The mean scores according to the SF-36 for the patients (88) and the controls (84) are shown (Paper I). All the items in the questionnaire are expressed: PF (Physical Function), RP (Role-Physical), BP (Bodily Pain), GH (General Health), VT (Vitality), SF (Social Function), RE (Role-Emotional) and MH (Mental Health), each with a score between 0-100. The sum indexes of related sub-scores PCS (Physical Health) and MCS (Mental Health) are also shown.
After three years (Paper III), a statistically significant improvement was found in the patients’ RP (Role-Physical)-score (mean 27.2 compared to 62.5; p>0.001). Moreover, there was a slight, but not a statistically significant improvement in the patients’ Role-Emotional score (RE) (mean 76.4 compared to 60.7; p=0.111). No differences remained at the follow-up, neither between the patients and the controls, nor compared to the normative values for the general Swedish female population above the age of 45 years [127] (Figure 3).

**Figure 3.** The mean scores according to the SF-36 for the patients (n=56) and the controls (n=49), three years after the fracture (Paper III), and the norms for the general female Swedish population above the age of 45 years [127]. All the items in the SF-36 are shown: PF (Physical Function), RP (Role-Physical), BP (Bodily Pain), GH (General Health), VT (Vitality), SF (Social Function), RE (Role-Emotional), and MH (Mental Health), and PCS = Physical Component Summary and MCS = Mental Component Summary with scores between 0-100. The norms could only be given in the eight subscales, not in PCS or in MCS.

**Prediction of low BMD and falls (Paper II)**

The results of the one-leg rise test were significantly (p<0.001) associated with those of dynamic balance (OR 6.9; CI95% 2.57-18.30), and those of static balance (OR 0.24 CI 95% 0.11-0.53; p<0.001). The patients with normal BMD performed significantly better both in functional tests of dynamic and static balance than those with osteopenia or osteoporosis (p=0.05). Forty of 117 patients reported prospectively one or more falls. One of these 40 fell five times, two four times, 12 three times, six fell twice and 19 fell once. No association was found between the results in the functional tests and the occurrence of falls according to
the fall diary. No statistically significant difference was found between the fallers and the non-fallers in performing the functional tests (Table 6). There was no significant difference in BMD between the fallers (T-score -1.84) and non-fallers (T-score -1.98) according to the fall diary (p=0.418).

Table 6. The age-adjusted, multiple logistic regression analysis (Odds Ratios; OR, with 95% Confidence Intervals, CI), of the results in the functional tests for the fallers (n=40) and the non-fallers (n=77, OR=1).

<table>
<thead>
<tr>
<th>Test</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking 30 m, turn</td>
<td>1.0</td>
<td>0.3-3.5</td>
<td>0.944</td>
</tr>
<tr>
<td>Walking 20 steps backwards</td>
<td>1.4</td>
<td>0.5-4.3</td>
<td>0.548</td>
</tr>
<tr>
<td>Standing, eyes open</td>
<td>0.8</td>
<td>0.3-2.3</td>
<td>0.677</td>
</tr>
<tr>
<td>Standing, eyes closed</td>
<td>0.4</td>
<td>0.2-1.2</td>
<td>0.113</td>
</tr>
<tr>
<td>One-leg rise</td>
<td>1.6</td>
<td>0.6-4.1</td>
<td>0.371</td>
</tr>
</tbody>
</table>

In the analysis the patients were divided depending on their result in relation to the median value for the whole group (less than or equal to the median, or greater than median). In the one-leg test, the patients were divided into those who managed the test and those who were unable to or had problems.

Among the risk factors for osteoporosis in the risk factor questionnaire, only decreased height (p<0.05), and cigarette smoking (p<0.005) and age (p<0.05) had some significant and independent value in predicting osteopenia and osteoporosis (Table 7). The risk factors, in this model, were estimated to explain a low BMD to an extent of 27% (Negelkerke R²).

Table 7. Logistic regression and Odds Ratios, OR, with stepwise regression for all 14 independent risk factors for osteoporosis with 95% Confidence Intervals, CI. After the co-variation analysis between these 14 variables, the outcome regarding the significant risk factors; “body height decreased by >3 cm of your height at the age of 25 years” and; “smoking or have smoked for a period of >10 years”, related to the patients in age group ≥65.

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>OR</th>
<th>95% CI</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1 Decreased body height &gt; 3 cm</td>
<td>5.7</td>
<td>1.3-25.3</td>
<td>0.023</td>
</tr>
<tr>
<td>Step 2 Decreased body height &gt; 3 cm, Smoking &gt; 10 years</td>
<td>7.7</td>
<td>1.7-35.3</td>
<td>0.009</td>
</tr>
<tr>
<td>Step 3 Age group ≥65 years</td>
<td>2.8</td>
<td>1.1-7.4</td>
<td>0.040</td>
</tr>
<tr>
<td>Decreased body height &gt; 3 cm</td>
<td>5.9</td>
<td>1.2-27.7</td>
<td>0.026</td>
</tr>
<tr>
<td>Smoking &gt; 10 years</td>
<td>4.5</td>
<td>1.6-12.6</td>
<td>0.004</td>
</tr>
</tbody>
</table>
Mortality, co-morbidity and a need for in- and outpatient care associated with a distal radius fracture (Paper III)

Four patients died, but none of the controls, during the study period. One patient suffered a new distal radius fracture, but besides this no other new fractures were reported. The total number of registered ICD-codes as out- and inpatient care were 268 for the patients (19/73) and 83 (12/73) for the controls, respectively. There was no significant difference (p=0.224) in the total need for health care visits (among the patients for other reasons than the radius fracture) between the patients compared to the controls. However, the patients needed more inpatient care than the controls. This difference was statistically significant (p=0.038) (Table 8).

<table>
<thead>
<tr>
<th>Care</th>
<th>Group</th>
<th>n</th>
<th>Mean</th>
<th>SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outpatient</td>
<td>Patients</td>
<td>72</td>
<td>2.2</td>
<td>5.8</td>
<td>0.277</td>
</tr>
<tr>
<td></td>
<td>Controls</td>
<td>73</td>
<td>1.3</td>
<td>4.1</td>
<td></td>
</tr>
<tr>
<td>Inpatient</td>
<td>Patients</td>
<td>65</td>
<td>0.9</td>
<td>2.5</td>
<td>0.038</td>
</tr>
<tr>
<td></td>
<td>Controls</td>
<td>67</td>
<td>0.2</td>
<td>0.9</td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>Patients</td>
<td>73</td>
<td>3.4</td>
<td>7.64</td>
<td>0.168</td>
</tr>
<tr>
<td></td>
<td>Controls</td>
<td>73</td>
<td>1.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8. The mean number of visits in out- and inpatient care for the patients and the controls December 2003 to February 2007. The p-value reflects the level of significance of the difference between the patients and the controls.

Independent samples t-test for equality of means.

There was a three times increased need for the health care of the patients, compared with the controls, in the ICD-10 groups for malignant tumours, respiratory- and cardio-vascular diseases and new injuries. Out of the 73 patients initially, 37 (51%) had daily medication for osteoporosis three years later.

Secondary prevention – the effect of an intervention, the osteoporosis school, in patients after distal radius fracture (Paper IV)

One of the exercisers reported a new distal radius fracture during the study time. The results in the functional tests of dynamic and static balance before and after intervention are shown in Table 9. No statistically significant differences were found between the exercisers and non-exercisers. Both the exercisers and non-exercisers performed
Results

significantly better in the balance tests at the time for the follow-up compared to the performance at baseline; the exercisers in two of four tests and the non-exercisers in three of the tests (Table 9).

Table 9. Mean values in seconds (SD) between and within the exercisers and the non-exercisers in dynamic and static balance before and after intervention.

<table>
<thead>
<tr>
<th>Tests</th>
<th>Exercisers (n=41)</th>
<th>Non-exercisers (n=172)</th>
<th>Mean Difference</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dynamic balance:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking with turn</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>17.8 (5.3)</td>
<td>18.6 (7.0)</td>
<td>-0.8</td>
<td>0.515^1</td>
</tr>
<tr>
<td>After</td>
<td>17.4 (4.0)</td>
<td>17.0 (3.6)</td>
<td>+0.3</td>
<td>0.622^1</td>
</tr>
<tr>
<td>p=0.58^2</td>
<td>p=0.004^2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking backwards</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>11.9 (2.3)</td>
<td>11.5 (3.0)</td>
<td>+0.4</td>
<td>0.506^1</td>
</tr>
<tr>
<td>After</td>
<td>10.3 (1.7)</td>
<td>10.0 (1.6)</td>
<td>+0.3</td>
<td>0.294^1</td>
</tr>
<tr>
<td>p=0.000^2</td>
<td>p=0.000^2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Static balance:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing, eyes open</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>19.4 (11.1)</td>
<td>19.3 (11.1)</td>
<td>+0.1</td>
<td>0.969^1</td>
</tr>
<tr>
<td>After</td>
<td>25.4 (8.4)</td>
<td>23.0 (9.1)</td>
<td>+2.5</td>
<td>0.104^1</td>
</tr>
<tr>
<td>p=0.000^2</td>
<td>p=0.000^2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standing, eyes closed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>5.1 (5.5)</td>
<td>6.0 (7.2)</td>
<td>-1.0</td>
<td>0.428^1</td>
</tr>
<tr>
<td>After</td>
<td>5.7 (5.5)</td>
<td>6.1 (6.2)</td>
<td>-0.4</td>
<td>0.707^1</td>
</tr>
<tr>
<td>p=0.37^2</td>
<td>p=0.89^2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Independent samples t-test for equality of means^1. Paired samples test, Paired differences^2. For compensating for mass-significance, the p-value was set to p<0.01 in this analysis.

Statistically, significant more persons in the exercise group (30/41) managed the one-leg rise test before intervention compared to non-exercisers (86/167), (p=0.026). After intervention no significant difference was found between the exercise and non-exercise groups in this test (p=0.459).

BMD and falls (Paper (IV))

Before intervention the exercises had the mean T-score −1.86 (SD 0.9) and after intervention −1.95 (SD 0.8). The corresponding results for the non-exercises were −2.00 (SD 1.1), and −2.06 (SD 1.9). There were no statistically significant differences between the exercisers and the non-
Results

exercisers, neither at baseline (p=0.40) nor at the follow-up (p=0.69; Independent samples t-test). Neither was there any improvement in T-score in any of the groups. There were no statistically significant differences in the number of falls between the exercisers and the non-exercisers (Table 10).

Table 10. The number of those (percentages) who reported one or more falls during eight months after the osteoporosis school.

<table>
<thead>
<tr>
<th>Report 1 or &gt; fall(s)</th>
<th>Exercisers n (%)</th>
<th>Non-exercisers n (%)</th>
<th>Total</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>12 (29.3)</td>
<td>37 (21.5)</td>
<td>49 (23.0)</td>
<td>0.29*</td>
</tr>
<tr>
<td>No</td>
<td>24 (58.5)</td>
<td>68 (39.5)</td>
<td>92 (43.2)</td>
<td></td>
</tr>
<tr>
<td>Report missing</td>
<td>5 (12.2)</td>
<td>67 (39.0)</td>
<td>72 (33.8)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>41 (100)</td>
<td>172 (100)</td>
<td>213 (100)</td>
<td></td>
</tr>
</tbody>
</table>

*Chi²-test.
DISCUSSION

Main Findings

The main finding of Paper I was that the patients with a distal radius fracture often have osteoporosis or osteopenia, but not more often than their age, gender and municipality of residence matched controls. The exceptions were women 45-64 years of age who had a lower, but not statistically significant T-score (p=0.09). Patients 65 years and older fell more often than their controls. No difference in history of falls was found among patients 45-64 years.

The main finding of Paper II was that none of the functional tests: walking forwards or backwards, one-leg stance or one-leg rise could identify persons with a distal radius fracture who were at risk of falling. Neither was the risk factor questionnaire of more than limited value in detecting those with a radius fracture with osteopenia or osteoporosis. However, if functional tests, in spite of this, are considered, the one leg-rise test may be sufficient for this task. This is due to the fact that those who managed the one-leg rise test also managed significantly better in other functional tests.

In Paper III mortality was 4% among patients, no deaths occurred among the controls. Significantly more patients than controls needed inpatient care at a hospital. No difference in need for outpatient care was noted. The panorama of the diseases was also different among the patients. This difference was statistically significant (p=0.04). A significant difference was found in the SF-36, RP (Role Physical) between the first and second examination (p<0.01). The significantly lower sub-scores of the SF-36, noted in Paper I, did not remain 18 months after the fracture.

The main finding of Paper IV was that the osteoporosis school seemed to have a limited effect for secondary prevention of falls.

Risk factors for low BMD

This thesis failed to show any differences between patients with a distal radius fracture and controls with respect to BMD. There was, however, a tendency towards a lower BMD among the patients of 45-64 years old. This was also indicated by Earnshaw et al. [3]. It could also be shown in this thesis, that decreased body height, cigarette smoking and being over 65 years were risk factors for low BMD. Other authors [39], [128] are in agreement with these findings. However, it is important to remember that a low BMD is not the essential risk factor for a distal radius fracture, whereas falling was in people over 64 years of age, studied in this thesis. Knowing these four risk factors, decreased body height, cigarette smoking, falling and being over 65 years, may new
possibilities be provided for giving guidance in a clinical practice; i.e. through measuring the patients height and BMD, focusing on fall prevention and life style factors, such as to stop cigarette smoking.

Falls

The strongest single risk factor for fracture is accidental falls independent of and additive to, the risk attributable to age and osteoporosis [129], [40], [41]. This has been overlooked in many studies on fracture prevention [44]. Also frailty, in this thesis, indicated by increased morbidity and mortality, is related to an increased risk of falling [130].

This thesis showed that patients older than 64 years had a history of falling more often than their controls. This was not true for the patients of 45-64 years old. This tendency for falling and new fractures was also found by Nordell et al. [67] in their group of patients with a distal radius fracture at the same age. Eriksson et al. [131] showed that elderly patients with dementia living in residential care facilities fell twice as often as those without dementia, and that 5% of 197 falls resulted in 11 new fractures. On the contrary, Jensen et al. [132] found no association in subjects also living in residential care facilities between improved mobility and reduced risk of falling. In elderly in residential care with higher or lower levels of cognition Jensen et al. found that those with higher Mini-Mental State Examination (MMSE) results had fewer falls after multifactorial intervention than those with lower MMSE [133].

In this thesis no association was found between the results in the functional tests and the occurrence of falls according to the fall diary. There was no significant difference between the fallers and the non-fallers in results of the functional tests (p>0.5). Neither was there any significant association between the report of falls retrospectively in the risk factor questionnaire and prospectively in the fall diary. This is contrary to Gerdhem et al. [134] who found a recalled fall to be the most important predictor of future falls in women aged 75 years. One possible explanation for our finding is that the period for surveying falls was short, 12 months before and eight months after the testing, considering that most patients did not fall at all or only once. This thesis also included less patients compared to Gerdhem et al. [134] who had 964 elderly women. However, the cohort of the thesis is almost a one-year group of radius fracture patients at a Swedish hospital serving 100 000 inhabitants. In other groups of older and frailer patients, the Timed “Up & Go Test” (TUG) [135], [66], and the Mobility Interaction Fall (MIF) [136], [137] has shown a significant association with falls. Moreover, there are also other tests obtaining more specific information, especially those studying balance, i.e. Turn 180 [138], the Timed “Up & Go” (TUG) [61], one-leg stand (OLS) [64], Functional Reach (FR) [60], Tinetti balance (TB) [139], Berg balance scale [63] and a Modified Figure Eight test (MFE) [140]. These tests were more complicated and more time consuming and
required equipment to perform, and were therefore not chosen in this thesis.

Eriksson et al. [131], found that the common risk factors for falling explain only a small portion of the variation in falls in subjects with dementia, and a smaller proportion than in those without dementia. This is similar to our findings that all risk factors in the risk factor questionnaire of the Swedish Medical Product Agency, was estimated to explain the occurrence of osteopenia and osteoporosis to an extent of 27% in this thesis.

**Health-related quality of life, the SF-36**

In the thesis the physical domains of health and bodily pain of the SF-36 were most conceptually relevant to the patients with a distal radius fracture. This is in accordance with the results shown by Amadio et al. [77], Lydic et al. [141] also confirmed that SF-36 is a valuable tool among osteoporosis-targeted questionnaires because of its attempts to evaluate the total impact of the disease on quality of life within subjects at a single point a time.

In this thesis the patients with normal BMD had lower values of Role-Physical compared to the controls, and the patients with osteopenia had also significantly lower values for Role-Physical and Bodily-Pain than the controls. Among the subjects with osteoporosis no significant differences were found. A significant difference was found between the patients’ Role-Physical-scores initially and three years later. Moreover, there was a slight, although not a significant difference, in the patients’ Role-Emotional-score initially compared to three years later. After three years there were no differences between the patients and the controls in the SF-36.

MacDermit et al. [76] showed that the standardized response mean for the SF-36 sex months after a distal radius fracture was similar to those obtained sex months after hip arthroplasty [142], but higher than that obtained for workers treated for variety of musculoskeletal conditions [143, 144]. Hallberg et al [25] showed that vertebral, and hip fractures have a considerably greater and more prolonged impact on health-related quality of life compared to radius and humerus fractures. Moreover, Hallberg et al. and Peterson et al. [145] showed, that for patients with a hip fracture, the majority of the recovery measures by Physical-Role subscales of the SF-36, had taken place during the first one to one-and-a-half-year after the fracture. Hiligsmann et al. [146] made the systematic review of the literature, and found that the distal radius fractures have no more effect on health-related quality of life one year after the fracture. Not many studies compare the health-related quality of life, like the SF-36 in patients with a distal radius fracture with subjects of similar age, longitudinally after the fracture. It is more common that the studies evaluate outcomes after treatment of distal radius fractures by the use of physical measures, such as physical capability, range of motion and
Discussion

grip strength [147]. With the development of a number of scoring scales that focus on general health, quality of life [148] or wrist pain [76], it has been possible to evaluate the impact of injury and treatment from the patient’s perspective. With the SF-36 or other scales rating health-related quality of life, a picture of the impact of a radius fracture in a wider meaning is obtained [81].

Functional tests

In this thesis there was a lack of association between the results in the functional tests and falls, both before the tests (risk factor questionnaire) and after the tests (fall diary). There was one exception, however; in patients aged 65 years and over, a significant association between the static balance test and falls according to the fall diary, was found. Considering the lack of association, further studies are needed. To the best of our knowledge this is the first study of functional tests to predict fall risk in patients with a radius fracture. Gerdhem et al. [134] also found functional tests to be of little value in predicting falls in 964 75-year old women randomly selected from a general Swedish population.

In this thesis, a statistically significant association was found between the results of the one-leg rise test and the walk and balance tests (p<0.01). The one-leg-rise test estimates leg strength, which has been shown to be important for safe walking [149], [150]. Liu-Ambrose et al. [94] found that older women with osteoporosis had increased postural sway and weaker quadriceps strength than their healthy controls.

Methods to assess balance can be categorized into three groups: self-reported, laboratory, and performance measures such as functional tests. Functional tests in this thesis, walking, dynamic and static balance and leg strength, are more reliable and have more internal and external validity than self-reports. They can help contravene memory errors from aging, and reduce the effect of cognition and hearing impairment on a subject’s ability to perceive or answer a questionnaire. Furthermore, unlike laboratory tests (e.g., dynamic posturography) functional tests do not require any specialized and costly equipment and can easily be administered to elderly people. Because of this they were appraised to be useful in this thesis.

Mortality and co-morbidity

In this thesis, five patients with a distal radius fracture died during the study period, four of them were from the cohort with 98 patients in the studies I and III. They died during the first 27 months after the fracture. Another patient, from the cohort with 190 patients (Paper II), died as well. No deaths occurred among the controls.

Co-morbidity, in this thesis, seemed to be increased among the patients (Paper III), and this difference was significant for more serious
morbidity, requesting institutional care. Some researchers consider a distal radius fracture a predictor for a new fracture and an indicator for osteoporosis [4], [3]. Johnell et al [7] reported significantly increased mortality and morbidity during the first year after a hip fracture. The corresponding data for patients with radius fracture was conflicting; Rozental et al. [75] found a co-morbidity related increase in mortality compared to the general population, but others have found no difference or even a lower than expected mortality rate [151], [152], [82], [153]. Our data support those of Rozental et al. [75] and add some evidence, as they are based on a case-control study.

The results in this thesis indicate an increased morbidity in patients with a recent radius fracture requiring institutional care. Deaths were also more common among the patients with radius fracture. This impairment of general health might be a contributor to the increased presence of osteopenia and osteoporosis and the increased tendency to fall [67], which has been demonstrated in this group of patients.

Even if radius fractures sometimes are associated with complications and poor functions, such as instability of the wrist [76], [83], and pain [84], this seem to be a relatively minor problem, at least in some patients as compared to the problem of a tendency towards bad general health [154]. At least, this illustrates the need for a more holistic perspective in the management of patients with a radius fracture, and that a higher morbidity necessitating in-patient care has to be taken into consideration when secondary prevention programs for these patients are designed and implemented. Therefore, as Melton III [155] wrote “eligibility criteria should be expanded and fracture endpoints generalized to acknowledge the entire burden of osteoporotic fractures”.

In addition, a program aiming at secondary prevention necessarily involves all aspects of health, which can influence the risk for new falls and the progress of osteoporosis. Therefore, knowledge about mortality, morbidity and health-related quality of life will influence the content of the program.

### Intervention – the osteoporosis school

The multifaceted intervention program, the osteoporosis school, applied in this thesis may not have had the expected effect. Contrary to the results presented here, Grahn-Kronhed et al. [85] showed that a program with weight-bearing exercises for patients with a distal radius fracture during one year showed a significant increase in BMD for the exercisers. Korpelainen et al. [86] on the other hand found that a 30-month intervention with impact exercise, i.e. jumping, climbing stairs and leg strength training with 30-month intervention had no effect on BMD, while Kaptoge et al. [156] found that measuring of bending resistance of the hip - meaning mechanical strength loading of the hip - is more strongly related to reported physical activity than BMD. In order to increase the effect on BMD and prevent new fractures in general among
patients with distal radius fracture, there is evidence that combined weight-bearing training leads to delaying the progression of the bone fragility [157] [113].

Howe et al. [100] found in a systematic review of exercise interventions' effect on balance, that training involving different types of exercise, such as muscle strengthening, co-ordination and functional exercises had the greatest impact on indirect measures of balance. This review also showed that there was limited evidence that the effect of the exercises was long-lasting. In addition, when prescribing an exercise program, through evaluation of the subjects' dynamic and static balance and the strength of their legs is important, to ensure that the content of the exercise program corresponds to the functional deficits. This will allow effective and efficient improvement of function, better balance and leg strengths, to be obtained.

The intervention with training at home was a program with 11 exercises for one-year without any follow-ups (Appendix, Paper IV). The exercises had several advantages: they can be implemented at home because they do not involve the use of expensive equipments, the level of intensity is low and the exercise instructions are easy to understand and could easily be trained during the four lessons in a clinic. The thesis showed that both the exercisers and the non-exercisers improved their dynamic balance (walking backwards) significantly after intervention. That may imply that all subjects paid attention to their balance and improved their ability for controlling postural sway [158]. This is in agreement with Cahn et al. [89] who showed that a one-year exercise intervention with Tai Chi Chuan was beneficial by delaying bone loss, and possibly a better neuromuscular function, as shown by Qin [159], in elderly women.

Other researches have reported that exercise resulted in better muscle strength and balance in healthy older people [108] and in women with osteoporosis [109]. Also Baum et al. [160] showed that the frail elderly (aged 75 to 99 years) were able to participate and benefit from a supervised strength-training program with low-cost equipment during one year. Furthermore, these researchers suggested that more studies are needed to determine the ideal frequency and duration of the strength-training. Maybe, in the present thesis, with more supervised training, and several follow-ups the results of the osteoporosis school may have shown more significant results.

Methodological considerations

Subjects and setting

The thesis is a total investigation of all patients during a three year period in a middle-sized hospital serving 100,000 people in northern Sweden. There were two samples of patients with a distal radius fracture
in this thesis, one consisting of 117 patients and their age- and municipality-based controls and another of 190 patients. The patient population in terms of numbers can, thus, be considered as a representative sample for patients with a radius fracture in northern Sweden. The samples can also be considered representative for radius fracture populations in general, in countries with similar socio-demographic circumstances. The patients were compared to matched controls according to age, gender and municipality of residence. To ensure sufficient numbers of controls, two for each patient, were selected from the population register. If both controls agreed to participate, the one whose date of birth was closest to that of the patient was chosen as a control subject. The supernumerary controls were assessed with the BMD-measurement, but they did not participate in the studies.

In the intervention study patients declined to participate as exercisers in the training intervention. There seems to be a general problem to motivate people to participate in interventions, where the benefits are possibly seen ten or more years ahead [85]. The patients were possibly not enough aware of or informed, that a radius fracture may be the first sign of osteoporosis with risk for future falls, new injuries or diseases. Similar difficulties to motivate people are confirmed by Rolandsson [161] and Ruge et al. [162], when they tried to recruit high-risk individuals to a diabetes prevention program.

Outcome measures

BMD-measurements allow estimation of whether BMD or bone mineral mass are within a normal range and quantification of the degree of any abnormality. In this thesis according to the WHO criteria for the diagnosis of normal BMD, osteopenia and osteoporosis the heel-DXL© (Dual-energy X-ray absorptiometry and Laser) was used to measure BMD. This method is confirmed by several researchers [123], [122]. The researchers have compared -DXL with axial BMD measurements [163], [164], [165], [166]. They showed that heel-measurements could discriminate those with low BMD from those with normal BMD. Consequently, the DXL-technology is considered to have high precision and to enable reliable diagnosis even at the onset or at early stages of bone fragility. Regarding to the DXL-measurement at the heel, it has a concordance to axial densitometry measurements on hip, spine and the whole body of more than 95% [167], and to the WHO thresholds for osteoporosis and osteopenia [123].

In this thesis a questionnaire, established by the Swedish Medical Products Agency concerning risk factors for osteoporosis, was used, (Appendix, Paper I). This questionnaire is a self-test of bone fragility and has 11 questions, one of which concern falls and asks how many times a person fell during the last year. One may wonder how well the subjects remembered their falls, i.e. how high the recall bias was. This
The questionnaire is not tested for reliability- or validity, but was recommended by the Swedish Medical Products Agency at the time when the study was initiated. More specific information, i.e. direction, location, outdoor- or indoor falls should have been of interest, but were not asked for in this questionnaire.

The subjects were also asked to fill out a fall diary during one year. This method was easy to use and gave information about the number of falls. Two written reminders were made to the patients not to forget to fill in the diary. In spite of this, several subjects failed to hand in the questionnaires, and only 117 of 136 were available for the analysis. The missing answers were mostly due to the loss of interest and the lack of time.

Evaluation of self-rated quality of life has become an important and valid component of outcome evaluation in patients with a distal radius fracture. When the SF-36 questionnaire is combined with functional test scores or tests, a more comprehensive evaluation of outcome is possible.

The functional tests used in this thesis were documented to mirror walking ability [57], [168], [169], balance [96], [58] and leg-muscle strength [62]. These tests were chosen due to their reliability and validity for this thesis. The tests did not need any equipments or any time in laboratories, and could be performed during the same visit as the BMD was measured. There are other tests than those in this thesis which could have been used to get a more specific information, e.g. to study balance, i.e. Turn 180 [138], the Timed “Up & Go” (TUG) [61], one-leg stand (OLS) [64], Functional Reach (FR) [60], Tinetti balance (TB) [139], and Berg balance scale [63] for evaluating elderly people and a Modified Figure Eight test (MFE) [140]. These tests were more suited for patients with greater impairments than the radius fracture group in this thesis.

In this thesis co-morbidity in terms of need for health care; in- and outpatient care at a hospital was compared between the patients and matched controls. This method was described as a simple count measurement by Farley et al. [170]. To ensure the quality of data, only visits at the hospital through computerized medical records were included. This is in accordance with several other authors [171] [172] [173] [174]. We know that some minor morbidity was missed due to this; however, it is unlikely that any differences between patients and controls exist in this respect. This method was easy to use because the visits were recorded and classified according to the International Classification of Diseases, ISD-10. Alternatively co-morbidity can be described as an index [175]. Unlike a simple count, an index usually weighs the extent of a disease and its influence on health. De Groot [175] described 13 different methods defining co-morbidity as the sum of clinical conditions, the sum of all disease severities, or on the basis of the most serve co-morbid diseases. Black et al. [176] used a Fracture Index, which assesses the 5-year risk of osteoporotic fractures in the elderly people. Farley et al. [170], however, found that simple count measurements were “better predictors of future expenditures than the co-morbidity indices”. In accordance with
Discussion

Farley et al. (2006) we relied on a count of diagnosis clusters as a good method to measure morbidity in patients with a distal radius fracture.

**Intervention – the osteoporosis school**

One of the aims in the osteoporosis school was to teach the patients the program for self-training, which was used for a one year of home-based exercise training (Appendix). High compliance with this kind of exercises is only possible if the exercisers are motivated for the training and have been thoroughly instructed. Smith et al. [177] showed that elderly patients, over 65 years of age, do not remember physiotherapy exercises after a one session. The osteoporosis school had four sessions of exercise and our patients were younger with a mean age of 64 years and thus it is not likely that they did not understand how the exercises should be performed. However, one or two or monthly, supervised follow-ups during the home-based training-year, could have increased the compliance and the effect of these exercises. Furthermore, the majority of those, who were invited to participate in the osteoporosis school declined to participate. This phenomenon that patients decline to participate in as exercisers in training interventions seems to be a general problem [85]. The challenge to motivate patients for exercise interventions needs more attention.

The every day exercise program had 11 exercises. The exercises had several advantages: they could be implemented at home because they did not involve the use of equipment, the level of intensity was low and the exercise instructions were easy to understand and practice during four lessons in the clinic. However, one may speculate if the non-exercisers trained too, because the thesis revealed that both the exercisers and the non-exercisers improved their static and dynamic balance significantly over the period of the study. That may imply that all subjects paid attention to their balance and improved their ability for controlling postural sway [158]. Moreover, according to the effect of the exercises, Howe et al. [100] found that there was limited evidence that the effect was long-lasting. In this thesis the exercisers were trained during one year, which may be not be sufficient, at least in respect to the possibility to achieve an effect on BMD.

**Clinical implications**

In clinical practice, there is a need to identify patients with radius fractures at risk for future fractures and increased co-morbidity. There is a debate on BMD-screening of patients with no symptoms of disease at the time of the fracture. However, with BMD-measurement patients with osteopenia or osteoporosis can be detected and targeted for treatment and prevention. The risk factor questionnaire used in this thesis is not effective for screening among patients with radius fracture in order to
achieve a defined referral to BMD measurement, and to avoid that in those, who are unlikely to have osteoporosis. This supports the opinion of Wigderowitz et al. [178] and Johnell et al. [179] that all patients more than 50 years of age presenting a fragility fracture, should be evaluated for osteoporosis by measurement of BMD. The risk factor questionnaire is however, useful as a part of secondary prevention of new fractures for screening risk factors, such as smoking, medical treatments, that increase the risk of fractures, such as corticosteroids or levothyroxines. For a quick estimation of physical function, the one leg rise test might be sufficient.

Furthermore, preventing new falls and fractures as well as comorbidity, need to be taken into account in secondary prevention in this patient group. Especially the risk for new falls, known to be related to frailty, has to be paid attention to [130]. Up till now implementing BMD-measurements and treatment of osteoporosis, have been the main focus for the secondary prevention in patients with a distal radius fracture [180]. In accordance with Järvinen et al. [43] who recently called for a shift in focus in fracture prevention from treatment of osteoporosis to prevention of falls; this thesis also points to the importance of mapping concurrent disease and frailty. This seems to be true for patients with hip fracture, but also for patients with a recent radius fracture.
CONCLUSIONS

The thesis demonstrates the following:

- There were no significant differences between patients and controls with respect to BMD, and the majority of the risk factors related to osteoporosis.

- The patients, 65 years and over, more often had a history of falling than their controls.

- The functional tests and the questionnaire with generally accepted risk factors for osteoporosis seemed to be of limited value to identify those with a radius fracture who are at risk of falling or having osteoporosis.

- For quick estimation of function in patients with a recent radius fracture, the one leg-rise test may be sufficient.

- Mortality and co-morbidity was higher among the patients compared to the controls.

- Health-related quality of life (Role Physical score) was significantly lower at three months in patients compared to controls, but this difference disappeared after three years.

- The osteoporosis school had no effect on BMD, dynamic or static balance, neither on muscle strength of the lower limbs or falls.
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52
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53
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