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**Community-based osteoporosis prevention: Physical
activity in relation to bone density, fall prevention,
and the effect of training programmes**

The Vadstena Osteoporosis Prevention Project

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Cover design:

Vadstena a small town situated between the Östergötland plain and Lake Vättern
– the skyline including the town hall, the castle, and the abbey –
shown against a background of trabecular bone.

Nothing is great or little otherwise than by comparison.
Jonathan Swift. Gulliver's Travels. 1726. Part II, Chapter 1.

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ABSTRACT

This thesis is based on studies of the ten-year community-based intervention programme entitled, the Vadstena Osteoporosis Prevention Project (VOPP). The specific aims of the research were to describe the effects of physical activity and training programmes on bone mass and balance performance in adults, to determine whether a fall risk prevention programme could motivate personal actions among the elderly, to ascertain whether the intervention programme could reduce the incidence of forearm and hip fractures.

Two studies addressed training programmes for middle-aged and old people. First, VOPP participants who were aged 40–70 years and had low forearm bone mineral density (BMD) values were invited to take part in a one-year weight-bearing training study. Thirty of those individuals were included in the investigation. Additional bone mass measurements were performed at the hip and the lumbar spine, and balance and aerobic capacity were also tested. The training programme was performed twice a week (I). In the second study, healthy persons aged 70–75 years were invited to participate in a balance-training study. Fifteen persons joined an exercise group, and another fifteen were controls. The training programme comprised specific balance exercises and was carried out twice a week for nine weeks (II). The association between forearm BMD values and several lifestyle factors was explored in random samples of the population aged 20–72 years ($n=880$) in a cross-sectional study (III). Another study explored the association between calcaneal stiffness, forearm BMD, and lifestyle factors amongst participants aged 20–79 years ($n=956$) at the final registration of the VOPP (V). Effects of the VOPP interventions directed at environmental risk factors for falls and the promotion of physical activity were examined in people aged ≥ 65 years (IV). The incidence of forearm and hip fractures was studied amongst middle-aged and elderly individuals in the intervention and the control communities during the study period 1987–2001 (VI).

The exercise group ($n=15$) in the weight-bearing training study showed increases in BMD at the greater trochanter ($p<0.01$), one-leg stance balance with the eyes closed and co-ordination tests ($p<0.05$), and aerobic capacity ($p<0.05$). No significant difference was found when the groups were compared concerning changes in the different tests during the intervention period (I). In the balance-training study, the exercise group showed post-training improvement in the following tests: standing on the right leg with eyes closed ($p<0.01$), standing on the right leg ($p<0.01$) and on the left leg ($p<0.05$) while turning the head, and walking 30 metres ($p<0.01$). There were significant differences between the groups in these tests when changes were compared at the post-intervention test (II). Age ($p<0.0001$) and body mass index ($p\leq 0.0001$) were associated with forearm BMD in both sexes. Reported moderate physical activity levels in men were positively associated with forearm BMD ($p<0.05$) (III). In both sexes, reported moderate ($p<0.05$) and high (women $p<0.05$ and men $p<0.001$) physical activity levels were positively associated with calcaneal stiffness. The correlation coefficient between forearm BMD and calcaneal stiffness was 0.58 in women and 0.34 in men (V). Persons aged ≥ 65 years at the follow-up in 1994 reported more use of shoe/cane spikes and moderate physical activity levels compared to controls (IV). There was no change in the general incidence of forearm and hip fractures between the communities for the study period. However, there was a tendency towards decreasing incidence of forearm and trochanteric hip fracture in both sexes during the late intervention period in the intervention community (VI).

A community-based intervention programme aimed at reducing the incidence of osteoporotic fractures must be regarded as a long-term project and should preferably be monitored over an extended post-intervention period.

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LIST OF PAPERS

This thesis is based on the following papers, which are referred to in the text by their Roman numerals:

Paper I. Grahn Kronhed AC, Möller M. Effects of physical exercise on bone mass, balance skill and aerobic capacity in women and men with low bone mineral density, after one year of training – a prospective study. *Scand J Med Sci Sports* 1998; 8: 290-8.

Paper II. Grahn Kronhed AC, Möller C, Olsson B, Möller M. The effect of short-term balance training on community-dwelling older adults. *JAPA* 2001; 9: 19-31.

Paper III. Grahn Kronhed AC, Angbratt M, Blomberg C, Toss G, Waller J, Möller M. Association between physical activity and forearm bone mineral density in 20-72-year-olds. *Adv Physiother* 2002; 4(2): 87-96.

Paper IV. Grahn Kronhed AC, Blomberg C, Löfman O, Timpka T, Möller M. Evaluation of a community-based fall risk intervention programme for the elderly – a quasi-experimental study of behavioural modifications. Submitted.

Paper V. Grahn Kronhed AC, Knutsson I, Löfman O, Timpka T, Toss G, Möller M. Is calcaneal stiffness more sensitive to physical activity than forearm bone mineral density? A population-based study of persons aged 20–79 years. Submitted.

Paper VI. Grahn Kronhed AC, Blomberg C, Karlsson N, Löfman O, Timpka T, Möller M. Impact of a community-based osteoporosis intervention programme on fracture incidence – a follow-up study amongst middle-aged and elderly. In manuscript.

ACRONYMS AND DEFINITIONS

ADL	activities of daily living
ANOVA	analysis of variance
BMD	bone mineral density
BMI	body mass index, calculated as weight/(height squared)
bone mass	the amount of bone tissue in a bone or skeleton, preferably determined as volume minus the marrow cavity (the mass indicator does not account for bone architecture)
C group	control group
CI	confidence interval
CV	coefficient of variation
diffTUG	difference Timed Up&Go
DI sample	dual intervention sample, included persons who participated in the VOPP at least two times
DXA	dual-energy X-ray absorptiometry
dysequilibrium	a feeling of unsteadiness when standing or walking
E group	exercise group
IVEG	intervention of elderly in Gothenburg
osteopenia	low bone mass, defined as a BMD-value between 1 and 2.5 standard deviations below the mean in young women (<i>T</i> -score)
osteoporosis	is defined as a BMD-value more than 2.5 standard deviations below the mean in young women (<i>T</i> -score)
PHCC	primary health care centre
QUS	quantitative ultrasound
SD	standard deviation
SI sample	single intervention sample, included persons who participated only once in the VOPP
SPA	single photon absorptiometry
<i>T</i> -score	defines the BMD results in relation to the mean BMD-value in young healthy women
TUG	Timed Up&Go
VAS	visual analogue scale
Vertigo	an illusory feeling of movement, usually rotatory but may also be linear
VOPP	the Vadstena Osteoporosis Prevention Project
<i>Z</i> -score	defines the bone mineral density results adjusted for age

INTRODUCTION

PUBLIC HEALTH PROGRAMMES AND VISIONS

PUBLIC HEALTH PROGRAMMES

Public health programmes are collective actions taken to improve the health of entire populations, whereas clinical medicine deals with the problems of individuals. Public health research is multidisciplinary in that the biological, social, and behavioural sciences are applied to study health issues in human populations. Epidemiology is central to public health because it focuses on populations and employs quantitative methods (1, 2). According to the World Health Organisation (WHO) programme called *Health for All, by the Year 2000*, the main determinants of health exist outside the health care sector, and primary health care is the key to achieving the goal – health. The WHO and the World Bank have identified some major challenges in public health research, including the growing epidemics of non-communicable diseases and injuries, as well as assessment of the efficiency of public health programs (1, 3).

The population approach to prevention is supported by several studies (1, 4). The first Swedish community development programme with the objective of preventing unintentional injuries was initiated in the municipality of Falköping in 1978 (2, 5). Later in the 1980s, an accident prevention programme was started in the municipality of Motala that was called the Motala Accident Prevention Study (6). A community-based intervention programme to reduce cardiovascular disease was also started in the district of Norsjö in 1985 (7). During the same period, a county health programme was formulated and implemented in Östergötland County in 1988 (following the principles and guidelines of the WHO programme *Health for All, by the year 2000*), and that work was the incentive to establish a community-based osteoporosis prevention project (8-10).

VISIONS

The policy for *Health for all in the 21st century* was adopted by the world community in 1998. *Health 21*, is the WHO European Region's response to the global *Health for All* policy, in which twenty-one targets are defined. These targets emphasise aspects such as healthy ageing (particularly important are innovative programmes to maintain physical strength, and to correct sight, hearing, and mobility impairments before they lead to dependence in the elderly), reducing non-communicable diseases (primarily musculoskeletal disorders), lowering injuries caused by violence and accidents (in the home and the workplace, and during leisure-time), and also promoting healthier living (11). The regional public health programme for the Östergötland County for the period 2001–2010 is based on the goals of WHO Health 21 and the strategy of the Health Committee of the European Union. The vision is to achieve a “healthy Östergötland County” (12).

OSTEOPOROSIS AND OSTEOPOROTIC FRACTURES – A PUBLIC HEALTH PROBLEM

DEFINITIONS OF OSTEOPOROSIS

Osteoporosis is defined as a disease that is characterised by low bone mass and microarchitectural deterioration of bone tissue, which leads to enhanced bone fragility, resulting in an increased risk of fractures. To facilitate the diagnosis of osteoporosis, in 1994 the WHO established four categories, based on bone mineral density (BMD) in healthy young women. A BMD-value not more than 1 standard deviation below the mean of the healthy

young women is defined as normal. Osteopenia (or low bone mass) is defined as a BMD-value between 1 and 2.5 standard deviations below the mean of the healthy young women. Osteoporosis is defined as a BMD-value of more than 2.5 standard deviations below the mean of the healthy young women, and if one or more fragility fractures are combined with this low BMD-value the condition is defined as established (or severe) osteoporosis (13-15). When standard deviation units are used in relation to the young healthy women, this is referred to as the *T*-score. Bone mineral measurements in relation to the average expected age value can be expressed in age-specific standard deviation units, commonly called the *Z*-score. The WHO definition is quantitative and is based on measurement techniques using ionising radiation at measurement sites such as the lumbar spine, the hip and the distal forearm. The WHO definition is not valid for the calcaneus measurement site and not for the quantitative ultrasound technique at any anatomical site. Another limitation of the WHO criteria is that separate reference ranges have not yet been developed for men (13, 14, 16).

AETIOLOGY

Osteoporosis is a multifactorial disease that is steadily increasing in the general population, and is a major cause of mortality, morbidity and medical expenditures world-wide. This progressive bone loss has been called “the silent epidemic”, because the condition develops over many decades without any obvious signs. The disease can be subdivided into primary and secondary osteoporosis. Primary osteoporosis entails trabecular bone loss due to postmenopausal oestrogen deficiency (postmenopausal osteoporosis), or it can involve trabecular and cortical bone loss related to the ageing process (senile osteoporosis); these two forms of the disease are also called type I, and type II osteoporosis, respectively. Type II osteoporosis is often characterised by a propensity to sustain an osteoporotic hip fracture. Secondary osteoporosis can be caused by several diseases associated with malabsorption or hypogonadism, but may also be induced by glucocorticoids (16-19). Predisposition to osteoporosis can be explained by a low peak bone mass and by factors underlying excessive postmenopausal and ageing-associated bone loss. Peak bone mass represents the attainment of maximal bone mineral density of the skeleton and depends primarily on genetic factors, with heredity being the most important determinant accounting for about 70–80% of the variability. The effect of genetic factors is obvious considering the ethnic differences in peak bone mass; for instance Afro-American women have greater bone mass than Caucasian women. Peak bone mass is also influenced by aspects of lifestyle, such as dietary calcium intake and physical activity (17, 18, 20). In industrialised countries, physical activity is performed by only a small proportion of the population, chiefly in the form of leisure-time activities, and this mounting inactivity is a threat to public health (1, 21).

EPIDEMIOLOGY

Osteoporosis affects one in three postmenopausal women. The majority of hip fractures occur in North America and Europe (22). It has been estimated that the numbers of hip fractures world-wide will increase from 1.7 million reported in 1990 to 6.3 million in 2050, due to the growing population and the increasing life expectancy (23). However, this type of epidemiological projection may be underestimated, if both the age-specific incidence of hip fractures and the size of the elderly population increase more than expected (24). Scandinavian women have the highest incidence of hip fractures in the world (25). In Sweden, there are about 17 000–18 000 hip fractures each year (26, 27). The incidence of hip fractures in Östergötland County, Sweden, increased almost five-fold from 1940 to 1986 mainly due to an age-specific incidence of trochanteric fractures. The increase was most pronounced in people older than 80 years but was also seen in age groups down to 50 years. It was predicted that there would be 70% more hip fractures in Östergötland in the year 2000 than in 1985, if

the age-specific incidence rates were similar to those previously observed. It was also stated that resources should be spent on preventive programmes aimed at known risk factors for osteoporosis (e.g. low physical activity, smoking, low calcium intake, vitamin D deficiency, high alcohol intake, use of corticoids, and an early menopause) in order to stop the increase in incidence rates (28). In a recent study of all hip fractures in Östergötland in 1982–1996, a trend-break in hip fracture incidence was found for women but not for men. Trochanteric fractures in particular continued to rise in men (29). Another investigation focused on hip fractures in 1992–1995 in the south of Sweden, confirmed that the incidence was no longer increasing (30).

The average age of hip fracture patients has increased over the past half century and it is now around 80 years in women in the Western world (22, 31). In Sweden, the average ages of female and male hip fracture patients are 81 and 78 years, respectively, and the average life expectancy is 82.0 years for women and 77.4 years for men (21, 30). The vast majority (about 90%) of hip fractures in women and men aged ≥ 75 years are caused by falling from the same level at which one is standing or positioned (32). The likelihood of falling increases with age and is greater in elderly women than in elderly men. In Caucasian people who were 50 years at baseline, a study has shown that the average lifetime risk of hip fracture was 17.5% for women and 6% for men, and the corresponding lifetime risk for forearm fracture was 16% for women and 2.5% for men (33). At all ages, the incidence of hip fracture is about twice as large in women as in men, and the risk of these fractures increases exponentially after the age of 70 years (18). The cost of hip fractures is comprised of direct costs to the health care and the social welfare system. The total cost of a hip fracture in an average Swedish woman surviving one year after the fracture amounts to SEK 210 000. These costs are direct costs arising in the health care sector and the social welfare system (including costs for care at the orthopaedic department, geriatric care, other acute hospital care, nursing home care, care in a home for the elderly or a group residence, and municipal home help) (24, 26).

THE VADSTENA OSTEOPOROSIS PREVENTION PROJECT (VOPP)

The magnitude of the problem of osteoporosis and associated fragility fractures was presented to politicians in the Östergötland County (population 420 000) in the middle of the 1980s and this paved the way for decisions to initiate activities aimed at preventing osteoporosis. This in turn led to establishment of an Osteoporosis Unit at the University Hospital in the city of Linköping and the initiation of preventive programmes (34). The municipality of Vadstena (population about 7 500 in 1989) was chosen as the site of a local general osteoporosis prevention project, which was to be mediated by the primary health care organisation and to comprise health-promoting activities and education in the community. Several community development programmes in Scandinavia are aimed at the prevention of injuries, but there are apparently no community-based studies dealing with primary prevention of osteoporosis directed at an entire population (2, 6, 35). Vadstena, is a semi-rural municipality situated on Lake Vättern in the western part of the Östergötland County. The project was called the Vadstena Osteoporosis Prevention Project (VOPP) and the programme was implemented in the community in 1989 and was planned for a duration of ten years. A neighbouring control municipality (population about 5 900 in 1989) was chosen as a control area for a scientific evaluation, using a quasi-experimental design (the VOPP study, Appendix A). The local politicians in Vadstena were contacted before the project started and showed great interest and support. The Norsjö project inspired the VOPP to use combined community-based and individual interventions (7). The aims of the VOPP were to map out risk factors, and to

prevent osteoporosis, and to reduce the incidence of fractures among the residents of the community. Aims of the VOPP are presented in Table 1.

Table 1. Aims of the VOPP:

- to stop the increase in incidence of osteoporotic fractures
- to increase the knowledge of osteoporosis and its risk factors among primary health care and social welfare workers
- to increase the level of knowledge about osteoporosis and its risk factors among children and teenagers in Vadstena
- to influence the lifestyle of the inhabitants of Vadstena in regard to calcium intake, smoking, and physical activity
- to earlier diagnose and treat those individuals at risk of developing osteoporosis
- to influence the living conditions and the environment of older people and to lower the risk of falls
- to initiate widespread involvement in preventive work among the inhabitants of Vadstena
- to increase and encourage physical activity in the community, so that more people in Vadstena would participate in regular physical activity.

COMMUNITY-BASED INTERVENTIONS

The VOPP intervention programme was carried out primarily by a registered nurse and a dietician in close co-operation with one of the general practitioners and one of the physiotherapists at the primary health care centre (PHCC) in Vadstena. The population-based part of the VOPP intervention was directed at all community residents, also including children and teenagers. The general intervention programme in the population was based on direct collaboration with school staff, kindergartens, grocery stores, larger companies, catering services, social welfare workers, nursing home staff, municipal home-help service units, retired people's associations, study circles, and sport clubs in order to encourage increased physical activity and higher calcium intake and to advise against smoking (10, 36). The intervention programme focused on primary prevention of osteoporosis by informing and educating the staff of the PHCC and the general public about the importance of lifestyle for the acquisition and maintenance of bone (10, 36, 37). In the intervention community, risk factors and the consequences of osteoporosis were discussed repeatedly at public seminars, in the local press and on local television channels. Lectures about lifestyle behaviour and risk factors for osteoporosis were given to nursing homes personnel, to municipal home-help service units, retired people's associations and the PHCC staff. The public was informed about where to receive walking aids, cane spikes and medical equipment such as grab bars, toilet raisers and shower chairs. These aids were free of charge, i.e. the county council or the municipality subsidised them. Later during the intervention period, external hip protectors that mitigate the consequences of a fall became available, and information about this type of aid was given to the elderly and the staff of the nursing homes (38-40). The sports shop, shoe shops and electrical appliance shop in Vadstena collaborated regarding the marketing of sturdy shoes and shoe spikes, and the importance of good lighting (10, 36). Checklists of environmental hazards regarding osteoporosis and falls were distributed via the pharmacy and the PHCC (Appendix B). The elderly were given advice regarding safety measures such as: do not climb up on chairs/stools to reach objects, pick up objects on the floor and the stairs, remove loose rugs and cords, install several telephones in the home, mop up wet spots on the floor, use non-slip rubber mats, use suitable footwear, use mobility aids when necessary and use shoe/cane spikes during the wintertime!

Decals with a picture of a slipping woman including the following text, "Going for a walk? Put your spikes on!" were strategically placed in shop-windows, in most blocks of flats and also at the PHCC in the wintertime (Figure 1).



Figure 1. Decal with the picture of a slipping woman and the text: “Going for a walk? Put your spikes on!”

Exhibitions concerning the prevention of osteoporosis and falls were periodically displayed at the PHCC, the municipal library, the tourist information office, the schools and various companies. The VOPP sponsored a fitness run called The Vadstena Castle Fitness Run that was held every September. The project also sponsored a local cabaret to disseminate information to a part of the public that would otherwise have been difficult to reach. Information from the pharmacy about the purchase of calcium tablets was included in the data collection for the intervention period. The name of the project and the logotype with the silhouette of the town was used in letters, exhibitions, and on posters to obtain feeling of “joint ownership” of the VOPP among the population (8, 10, 36). The estimated cost of running the VOPP was 1 054 730 SEK in 1989–1993 (10). The cost was approximately 2 238 400 SEK in 1994–2001. These figures do not include financial support for the project management or the various training studies. The VOPP and the training studies were financially supported by the Östergötland County Council.

INDIVIDUAL INTERVENTIONS

Balance-training groups and “walking groups” were introduced soon after initiation of the project and weight-bearing training groups were established early during the intervention period. Moreover, in a general baseline survey in 1989 a random sample of 15% of the women and men in each age decade between 20 and 79 years (born in 1910–1969) in the intervention community (n=860) was selected from the Population Registry and invited to participate in individual interventions (Appendix A). Each sample was followed up, and new samples in the intervention community were also invited to participate two and a half years (1992), five years (1994) and ten years (1999) after the first registration. The bone mass measurements and the questionnaire were repeated at the three follow-ups. All participants in the individual interventions were asked to answer a questionnaire comprising 62 questions that dealt with lifestyle and health factors (e.g. level of physical activity and intake of calcium, heredity, diseases, and medication), and another 27 questions that concerned knowledge of osteoporosis (10, 37). The participants who were aged 20–69 years at baseline were also offered a bone densitometry measurement of the distal forearm obtained by single

photon absorptiometry (SPA) technique using a Möllsgaard-ND-1100 instrument equipped with an iodine 125-source (41, 42). The non-dominant forearm was measured, but if the subject had a previous history of fracture at this site the contralateral arm was chosen. The mean value of six scans proximal to the point where the interosseous space between radius and ulna reached 8 mm was calculated (43). Correction was made for subcutaneous fat (42). Long-term precision in vivo was 1% [coefficient of variation (CV)]. The definition of low bone mass was a densitometric value for the forearm of more than 1 standard deviation (SD) below a sex- and age-adjusted reference value (Z-score) (14). At the final registration in 1999, the participants were also offered a measurement of the heel bone by quantitative ultrasound (QUS) performed using the Achilles Express equipment (27, 44). The QUS measures trabecular bone of the calcaneus with little interference of overlying soft-tissue. Accuracy is high and precision errors of $< 2.5\%$ (45). Two experienced medical laboratory technologists at the primary health care laboratory performed all the BMD measurements (Figure 2).

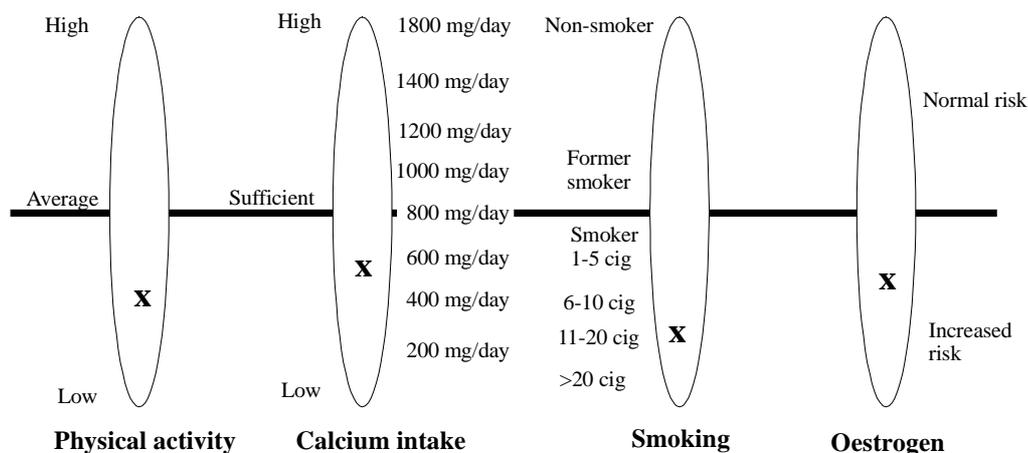


Figure 2. Bone mass measurement of the distal forearm.

All participants also received individual information about their bone mass and about their lifestyle after each registration. Special advice was given to participants with risk behaviour and low forearm BMD and/or calcaneal stiffness (Figure 3).

Facts of osteoporosis

Osteoporosis is a condition of disturbed balance between destruction and formation of bone. Physical activity leads to increasing formation of bone regardless of your age. The mineral, calcium, is an important constituent of our food. An adequate quantity (800mg/day) is a prerequisite of normal bone formation. Smoking is destructive for the skeleton - we know that bone fractures are twice as common among smokers than non-smokers. Oestrogen from the ovaries strengthens the bone. At early menopause or absence of menstruation for a long time, oestrogen replacement therapy may be required. Below is your osteoporosis risk chart.



The information given to a fictitious woman:

“Considering that you have a low level of physical activity and that you smoke we would recommend you to contact the Primary Health Care Centre to get information about appropriate physical exercise and a stop-smoking group. Your calcium intake is below the recommendation. We enclose a sheet of information about how to increase your calcium intake. It is possible that you would benefit from oestrogen replacement therapy. Please consult your gynaecologist or call the Primary Health Care Centre to discuss this issue.”

Figure 3. Health risk profile of a fictitious woman with an unfavourable lifestyle.

AIMS OF THE STUDIES

The general aim of the present thesis is to:

- explore the effects of a community-based osteoporosis prevention programme including fall prophylaxis, physical activity and training programmes for balance and bone mass, and the associations with incidence rates of forearm and hip fractures in adults.

The specific aims of the thesis are to:

- describe the effects of the one-year VOPP weight-bearing training programme, which included exercises for bone mass and balance performance in participants aged 40–70 years
- describe the nine-week VOPP balance-training programme, which included specific balance exercises designed for the healthy elderly aged 70–75 years
- assess the amount of physical activity measured by self-reported questionnaires in random samples of the population aged 20–72 years included in the VOPP
- study the association between forearm BMD and physical activity levels in random samples of the population included in the VOPP
- explore whether the community-based osteoporosis intervention and fall risk prevention programme could encourage personal actions against environmental risk factors for falling and improve physical activity patterns among persons aged 65 years and over included in the VOPP
- explore whether there were differences in effect between the VOPP population-based intervention alone and such intervention supplemented with an individually designed lifestyle intervention among persons aged ≥ 65 years
- explore whether calcaneal stiffness was more sensitive to physical activity levels than forearm bone mineral density in a random sample of the population included in the VOPP
- examine the association between forearm bone mineral density (BMD), calcaneal stiffness, and physical activity levels in a random sample of the population aged 20–79 years
- explore whether the ten-year community-based intervention programme could reduce the incidence of forearm and hip fractures among middle-aged and elderly people.

MATERIALS AND METHODS

The studies included in the present thesis are related to interventions performed in the VOPP. The materials and methods used in the different studies are summarised in this section and more detailed information is presented in the respective paper. The following interventions were studied:

- a one-year weight-bearing training study was designed and carried out for randomised persons aged 40–70 years who were included in the intervention community and participated in bone mass measurement of the distal forearm
- a balance-training study was designed for elderly persons aged 70–75 years for nine weeks
- the general VOPP intervention, consisting of individual and community-based components.

In specific the thesis is based on six studies.

STUDY DESIGNS AND ANALYSES

Study I. *Effects of physical exercise on bone mass*

A quasi-experimental design was used in a one-year intervention study. Bone mass at the hip and the lumbar spine, balance performance and also aerobic capacity were tested before and after the training period in the exercise and the control group.

Study II. *The effect of short-term balance training*

An experimental design was used in a nine-week intervention study with a randomised exercise group and a gender-matched control group. Balance tests were performed before and after the training period in the exercise and the control group.

Study III. *Association between physical activity and forearm BMD*

A descriptive design with cross-sectional surveys was used for the study. Forearm BMD-values were measured and related to age, BMI, physical activity levels and several other lifestyle factors in participants in the intervention samples.

Study IV. *Evaluation of a community-based fall risk intervention programme*

A quasi-experimental design was used in the study and measurements were made at baseline (prior to intervention) and at follow-ups after 2.5 and 5 years in the intervention and the control samples.

Study V. *Is calcaneal stiffness more sensitive to physical activity than forearm BMD?*

A descriptive study design with cross-sectional surveys was used. Forearm BMD and calcaneal stiffness were measured and related to age, BMI, physical activity levels, and several other lifestyle factors amongst participants in the intervention samples.

Study VI. *Impact of a community-based osteoporosis intervention programme*

An observational prospective study design was used to survey the occurrence of forearm and hip fractures among middle-aged and elderly persons in the intervention and the control communities during the study period 1987–2001. Repeated registrations of the same fracture type were excluded from the calculations. The mean Östergötland population between 1987–2001 was used as a standard population.

PARTICIPANTS

Study I. Effects of physical exercise on bone mass

Randomised persons aged 40–70 years (n=48) who participated in the VOPP in 1992 and had low forearm BMD-values, that is more than 1 SD below a sex- and age-adjusted reference value (Z-score), were invited to take part in a weight-bearing training study in 1994, as a part of the VOPP intervention. Thirty-four of the individuals accepted participation and nineteen of them (twelve men and seven women) chose to join an exercise group (using sequence-training equipment at the PHCC). Those remaining persons (n=15) were not interested in group training, but they did want to take part in the different tests and they formed the control group. Several of the controls told that they were physically active on their own through walking and gardening.

Study II. The effect of short-term balance training

Healthy residents of Vadstena aged 70–75 years (n=427) in Vadstena community, were invited to a balance-training study performed in 1989 during the initial phase of the VOPP intervention. Fifty-five persons were interested in participating in the study. A telephone interview was conducted to determine whether the preliminary participants suffered from any disease. Exclusion criteria were severe vertigo, epilepsy, Parkinson's disease, severe heart disease, arthritis and regular use of antivertiginous drugs. The names of the candidates remaining after exclusion were written on pieces of paper, and randomisation was done by drawing lots, and then writing the names consecutively on a list. The persons on the list were contacted by telephone and were invited to participate in the study. Fifteen persons (eight women and seven men) were included in the exercise (E) group and another fifteen persons were gender-matched to these participants and formed the control (C) group.

Study III. Association between physical activity and forearm BMD

The study included 880 subjects (458 women and 422 men aged 20–72 years) who underwent SPA measurement of the forearm at any of the VOPP registrations in 1989, 1992 or 1994 and who answered the VOPP questionnaire. Only results of the first examination of each person were used in the present study.

Study IV. Evaluation of a community-based fall risk intervention programme

In a baseline survey random samples of 15% of the women and men in each age decade between 20 and 79 years in the intervention (n=860) and the control (n=650) community were selected from the Population Registry and invited to participate in the VOPP study (Table 2)

Table 2. The entire populations of the intervention and the control community at the turn of the year 1988/1989.

Age-group	Intervention community		Control community	
	Women	Men	Women	Men
0-9	365	417	367	392
10-19	493	513	412	434
20-29	445	454	278	350
30-39	455	480	350	335
40-49	538	526	380	429
50-59	411	361	300	270
60-69	443	436	378	375
70-79	402	327	295	298
80-89	240	121	163	103
90----	39	10	16	12

The people participating in the VOPP who were aged ≥ 65 years and who answered the VOPP questionnaire were included in the study of community-based fall risk intervention. The participants in the intervention community who entered the study at baseline were asked to take part in the VOPP follow-ups in 1992 and 1994. They were called the dual intervention (DI) sample and received both community-based and individual interventions. Additional random samples were invited to participate in the intervention community in 1992 and in 1994. These samples were called the single intervention (SI) sample and had not yet received any individual intervention (i.e. the personal letter which included a health profile and specific advice) (Figure 3). New random samples were invited from the control community in 1992 and in 1994 and these samples were called the control sample (Figure 4).

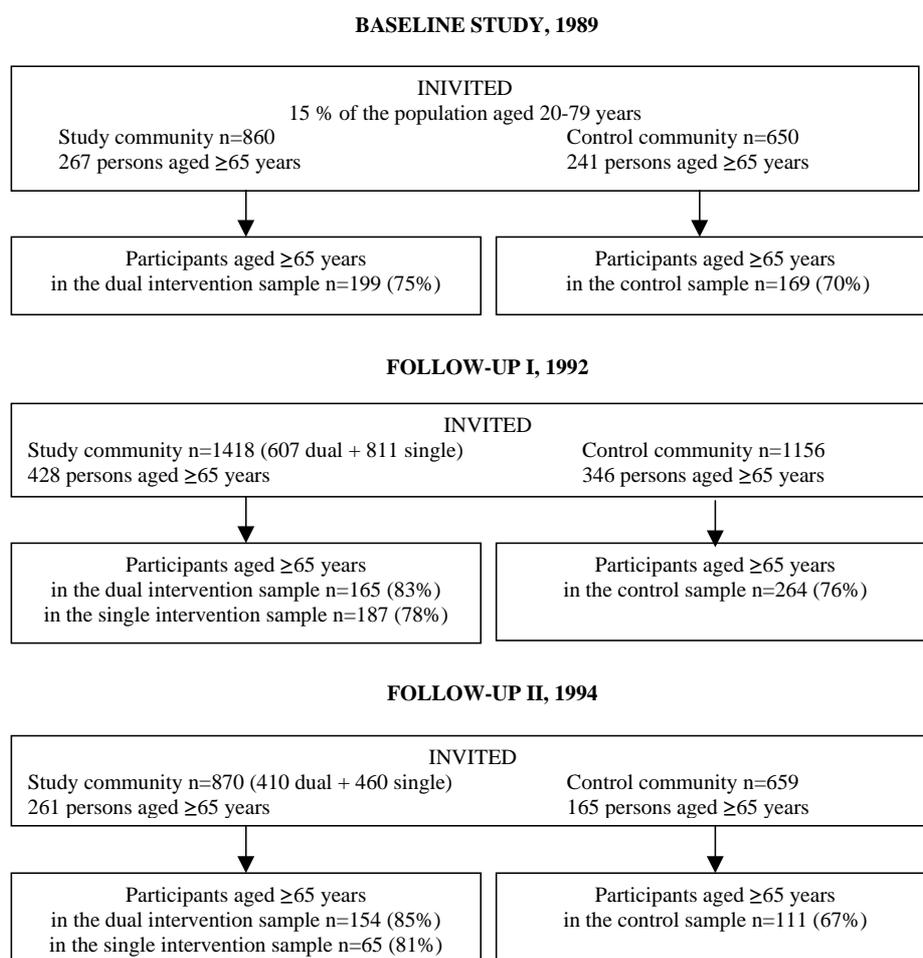


Figure 4. Flow chart of invited persons aged ≥ 65 years and the number and the proportions of those individuals who actually chose to join the intervention and the control samples in 1989, 1992, and 1994.

Study V. *Is calcaneal stiffness more sensitive to physical activity than forearm BMD?.....*

In 1999 at the final registration of the VOPP a new random sample consisting of 60 women and 60 men randomised from each age decade between 20 and 69 years (n=600) was invited to undergo measurements of the forearm by SPA and of the calcaneus by QUS and also to complete the VOPP questionnaire. In addition, there were follow-up samples of participants aged 25–79 years (n=800) who had already been randomly invited to the VOPP study in 1989, 1992 and/or 1994. In all, 956 people (534 women and 422 men) participated in both SPA and QUS measurements and answered the VOPP questionnaire in 1999.

Study VI. *Impact of a community-based osteoporosis intervention programme*

The incidence of forearm and hip fractures was followed in the population in the intervention and in the control communities for the VOPP study period 1987–2001. The years 1987–1991 was called the pre-intervention period; 1992–1996 was called the early intervention period; and 1997–2001 interval was called the late intervention period. Individuals aged ≥ 40 years with forearm fractures, and individuals aged ≥ 50 years with hip fractures (cervical and trochanteric) were included in the study. In 2001, the total population ≥ 40 years comprised 4 240 people in the intervention and 3 045 in the control community.

INTERVENTIONS AND COLLECTION OF DATA

Study I. *Effects of physical exercise on bone mass*

Intervention: The definitive exercise (E) group was divided into two age-specific subgroups: eight persons aged 40–55 years were called the “younger” group while seven persons aged 60–70 years were called the “elderly” group. The training programme was performed to music and carried out for 60 minutes twice a week for one year, with a break for the summer months. The programme included warm-up movements followed by some specific balance exercises and back extension exercises for about 15 minutes. Weight-bearing activity was emphasised by using sequence training equipment such as “leg-press”, “dips” and “pull-down” for loading the arms, “abdominal trainer” and also “back and hip exerciser” (Figure 5). Pulleys, dumbbells, and balance boards were also used during the training sessions. The participants had an individually designed load at each training station, and they were told to increase the load gradually as the training continued. The participants exercised to music in intervals, and changed equipment when the music stopped. The training programme was completed with 10–15 minutes of stretching and relaxation. The participants in the control group were instructed not to change their lifestyle during the intervention period.

Collection of data: All participants answered a questionnaire before the training period. In addition to the SPA-screening, bone mineral density at the hip and at the lumbar spine were assessed by dual-energy X-ray absorptiometry (DXA) (using a Hologic QDR-1000 instrument) performed at the Osteoporosis Unit, Linköping University Hospital before and after the training period. Clinical tests were done regarding mobility of the joints, balance skill and aerobic capacity. Any form of pain was estimated by use of a visual analogue scale (VAS) (46).



Figure 5. Weight-bearing training by using sequence training equipment.

Study II. *The effect of short-term balance training*

Intervention: The training programme was performed to music twice a week for nine weeks. Each session lasted 60 minutes. The programme was designed especially for the study and comprised several exercises covering aspects of daily living. There were jogging/walking activities in different directions and sudden turns on command. The programme also included exercises that entailed throwing/catching/bouncing balls in different directions. Other exercises, which took place in intervals of two minutes at each training station, included use of balance boards, trampolines, a balance ball, and a steeplechase course (Figure 6). The training programme was concluded with 10–15 minutes of relaxation. The participants in the control group were instructed not to change their lifestyle during the intervention period.

Collection of data: All participants answered a questionnaire and underwent clinical balance tests. The clinical balance tests, which were performed before and after the training period, included both static and dynamic tests. Romberg's test, the sharpened Romberg test, and the one-leg stance balance test were performed with the eyes open and with the eyes closed. In addition, rotational stress was added to the one-leg stance test. The dynamic tests were walking as fast as possible for 30 metres (including turning after 15 metres), walking straight forward on a line, and walking backward between two lines. A visual analogue scale (VAS) was used to report any form of vertigo/dizziness; no such symptom was rated as 0 and the worst possible symptom as 100.



Figure 6. Balance training.

Study III. Association between physical activity and forearm BMD

Intervention: The general VOPP intervention, consisting of individual and community-based components for the period 1989-1994 (p. 8-11).

Collection of data: Relationships between forearm BMD, present level of physical activity at work and during leisure-time, and body mass index (BMI) were analysed. Body weight was measured on a digital balance scale, and body height was determined using a stadiometer. BMI was calculated as weight/(height squared) (kg/m^2) (47). The question about physical activity level during daily work was rated on a four-grade scale with respect to skeletal loading (Appendix A) (48). The lowest grade of physical activity during daily work, class 1 was called the “low level”, the combination of classes 2-3 was called the “moderate level” and class 4 was called the “high level”. The question about leisure-time physical activity level was estimated according to a six-grade scale (48-50). With respect to a previous four-grade scale the classes 1-2 were combined to designate a “low level”, classes 3-4 to designate a “moderate level” and classes 5-6 to designate a “high level” (Appendix A). Two experienced medical laboratory technologists at the primary health care laboratory performed all bone mass measurements. Information of the technique used at the bone mass measurements is presented in the section headed Individual Interventions (p. 9).

Study IV. Evaluation of a community-based fall risk intervention programme

Intervention: The general VOPP intervention, consisting of individual and community-based components for the period 1989-1994 (p. 8-11).

Collection of data: The single intervention, the dual intervention, and the control samples were compared concerning their answers of the questions in the VOPP questionnaire in 1989, 1992 and 1994. The questionnaire comprised questions about age, body height, body weight, lifestyle habits, physical activity levels, diseases/medications, and previous fractures. There were six specific questions directed specifically at the elderly aged ≥ 65 years, and these dealt with safety behaviour at home and outdoors (Appendix B). Physical activity levels were estimated according to a six-grade scale, in which the classes were combined to designate a “low level”, a “moderate level”, respectively a “high level” (Appendix A) (48-50).

Study V. Is calcaneal stiffness more sensitive to physical activity than forearm BMD?.....

Intervention: The general VOPP intervention, consisting of individual and community-based components for the period 1989-1999 (p. 8-11).

Collection of data: The associations between calcaneal stiffness, forearm BMD, present level of physical activity at work and during leisure-time, and body mass index (BMI) were analysed. Body weight was measured on a digital balance scale and body height was determined using a calibrated stadiometer. BMI was calculated as weight/(height squared) (kg/m^2) (47). The VOPP questionnaire used on this final registration occasion included the same questions concerning current amount of physical activity at daily work and during leisure-time as on all previous questionnaires (Appendix A) (48-50). The bone mass measurements were performed between August 1999 and January 2000 by two experienced medical laboratory technologists at the primary health care laboratory. The techniques used are described in the section headed Individual Interventions (p. 9).

Study VI. Impact of a community-based osteoporosis intervention programme

Intervention: The general VOPP intervention, consisting of individual and community-based components for the period 1989-1999 (p. 8-11).

Collection of data: Individuals with fractures were identified from files at the Department of Radiology at the local county hospital. Two nurses and an assistant nurse cross-validated the recorded radiological fracture codes against the clinical records. All patients were allocated to

the intervention or control community according to residency registered for the year of fracture. This was done using an overlay technique in a geographic information system (34). Demographic data used for the calculation of age-standardised rates were derived from the continuously updated official population register.

NON-PARTICIPATION AND DROP-OUTS

Study I. *Effects of physical exercise on bone mass*

Four individuals were not invited to join the training study due to following: one was confined to a wheelchair, one worked abroad, one had moved away from Vadstena, and one had recently exercised at the PHCC by using sequence-training equipment. Eight of the invited women (aged 59–70 years) with low forearm BMD values did not want to participate in the study due to a serious illness. Six men (aged 42–70 years) were not interested in participating, because they experienced that they were already physically active or that they lacked the time. Two men and one woman (aged 40–55 years) included in the exercise group withdrew due to lack of time, while one man moved away.

Study II. *The effect of short-term balance training*

We did not invite those persons aged 70–75 years identified by the Population Registry who we knew were dependent on wheelchairs or wheeled walking frames, or those who had a recent severe illness or a recent hospitalisation for a severe disease (n=30). Six of the persons interested in participating were excluded from the randomisation to the training study due to the exclusion criteria. There were no drop-outs during the nine-week intervention period.

Study III. *Association between physical activity and forearm BMD*

About 68% of those invited to undergo bone mass measurements participated. Men rejected participation in bone mass measurements more often than women did, and the proportions were 34% of all women and 40% of all men. The non-participation rate was highest in young persons (aged 20–29 years), where about 51% rejected participation. Some reasons for the drop-outs were that young persons fairly often had their permanent address at their parents' home address even though they had moved elsewhere to study or work. Pregnancy and conscription were other reasons.

Study IV. *Evaluation of a community-based fall risk intervention programme*

A larger proportion of invited elderly persons aged ≥ 65 years participated in the intervention than in the control community, that is they answered the VOPP questionnaire at base-line (1989), at the first (1992) and at the second follow-up (1994). Those persons in the intervention community who claimed that they were not interested in participating were not invited to the VOPP follow-ups. The lists of follow-up participants were checked, and those who were deceased were excluded from further investigation.

Study V. *Is calcaneal stiffness more sensitive to physical activity than forearm BMD?*

About 68% of those invited to undergo bone mass measurements participated. Men rejected participation in bone mass measurements more often than women did. The non-participation rate was highest in young persons (aged 20–29 years), where about 50% rejected participation. Some reasons for the drop-outs were that young persons fairly often had their permanent address at their parents' home address even though they had moved elsewhere to study or work. Pregnancy and conscription were other reasons.

Study VI. *Impact of a community-based osteoporosis intervention programme*

Repeated registrations of the same type of fracture were excluded from the analyses of forearm and hip fractures. Some fractures sustained by the studied individuals might be missing for the pre-intervention period of the VOPP, because there were no routine procedures at the Department of Radiology for those patients who had sustained fractures and died before 1991.

STATISTICAL METHODS

Study I and Study II.

The Wilcoxon signed rank test was used to analyse changes in the different clinical tests in the respectively group during the intervention period. The Mann Whitney U-test was used for comparison between the groups before the intervention period, and for comparison between the groups concerning changes in the clinical tests during the intervention period. A p-value of <0.05 was considered as statistically significant. The statistics were analysed with the StatView software.

Study III and Study V.

Group results were reported as means and 95% confidence intervals. The independent variables were checked for multicollinearity by using a correlation matrix. Multiple regression analysis was used for women and men separately to study several variables of importance to bone mass. A p-value of <0.05 was considered as statistically significant. The statistics were analysed with the StatView software.

Study IV.

Group results were reported as percent and 95% confidence intervals (CI). A Bonferroni correction was made to adjust for multiple comparisons of groups in 1992 and 1994 (51). A p-value of <0.05 was considered as statistically significant. The statistics were analysed with the StatView and the Minitab software.

Study VI.

Cumulative incidences of fractures (expressed as per 1000) were calculated by community and by sex for each study period of five years 1987-2001, and reported as 95% confidence intervals. Data were standardised for age by a method of direct standardisation (52). A two-way analysis of variance (ANOVA) was performed to compare mean ages for fracture types. A p-value of <0.05 was considered as statistically significant. The statistics were analysed with the SPSS software.

RESULTS

Study I. *Effects of physical exercise on bone mass*

The responses of the questionnaire did not differ substantially between the two groups. Four persons in the E-group and three persons in the C-group had had a history of falling during the previous year. Three persons in the E-group and five persons in the C-group had sustained a fracture during adulthood. The average number of times the subjects participated in the training sessions was 45 out of a possible 81 sessions in the “younger” group and 75 out of a possible 99 sessions in the “elderly” group. There was an increase in BMD at the greater trochanter ($p<0.01$) in the exercise group after one year of training. In the C-group, there was an increase in BMD at the lumbar spine ($p<0.05$). There was no change regarding forearm BMD and femoral neck BMD in the groups. After one year of training the participants in the E-group performed better in the one-leg stance balance test with the eyes closed ($p<0.05$), in the co-ordination test called “ski-step”-test ($p<0.05$), and they also showed improved aerobic capacity ($p<0.05$). The effect of the training programme measured as change in BMD, balance performance, and aerobic capacity was not significant when the groups were compared at the post-test. None of the participants sustained a fracture during the one-year training period.

Study II. *The effect of short-term balance training*

Before the intervention period there was a difference between the two groups in two of the balance tests, where lower values were found for standing on the right leg with the eyes open ($p<0.05$) and for walking backward between two lines ($p<0.05$) in the C-group. All participants ($n=30$) performed the Romberg tests perfectly with their eyes open and with their eyes closed. Only three participants were unable to perform the sharpened Romberg test with the eyes open for 30 seconds. The one-leg stance balance test with the eyes open was maintained for an average of 17.2 seconds. The participants managed to stand in the most difficult position, i.e. on one leg with their eyes closed, for about 3-4 seconds. The average participation in the balance training sessions was 16 out of a possible 18 sessions, given an average rate of participation of about 89%. The following balance tests were improved in the E-group after nine weeks of training: standing on the right leg with the eyes closed ($p<0.01$), standing on the right leg while turning the head ($p<0.01$) and on the left leg while turning the head ($p<0.05$), and walking 30 metres ($p<0.01$). There were also significant differences between the groups in the aforementioned tests when comparing changes during the intervention period. No fractures occurred among the participants during the nine-week period.

Study III. *Association between physical activity and forearm BMD*

The number of participants ($n=880$) were relatively equally distributed into the different age classes except in the age category 70–72 years, which included considerably fewer women ($n=6$) and men ($n=11$). Most women (89%) and men (69%) classified their leisure-time physical activity levels as moderate. Younger participants more often reported high leisure-time physical activity levels. The average ages of those women and men reporting high levels were 31 years and 36 years, respectively, while the average ages for low and moderate levels were above the age of 40 years. BMI increased with age in both women and men, except in the oldest women aged 70–72 years. BMI was positively associated with forearm BMD in both sexes, whereas leisure-time physical activity levels were inversely associated with BMI in both women and men i.e. low physical activity levels meant higher BMI-values. Forearm BMD was positively associated with moderate leisure-time physical activity levels in men ($p<0.05$). In women, forearm BMD was not associated with self-reported leisure-time

physical activity levels. There was no association between forearm BMD and estimated physical activity load during daily work for either men or women.

Study IV. Evaluation of a community-based fall risk intervention programme

Characteristics of the participants in the different samples are found in Tables 3a and 3b. There was no change in BMI over time in the respective groups or sexes. More participants in the control than in the intervention samples reported at baseline and at the second follow-up that they lived in a detached or a terraced house. There was no difference between the participants in the intervention and the control samples concerning single living, where about 65% of the participants reported that they lived with a partner. Furthermore, there was no difference between the groups concerning reported fractures during adulthood, where about 32% of the participants reported that they had sustained a fracture (Table 4).

Table 3a. Characteristics of the women in the control, the dual intervention and the single intervention samples aged 65 years or older (≥ 65) regarding age, weight, height and BMI in 1989, 1992 and 1994.

Women (≥ 65)										
		Control sample			Dual intervention sample			Single intervention sample		
	Year	n	Mean	CI	n	Mean	CI	n	Mean	CI
Age	1989	87	71.5	(70.6 - 72.3)	93	72.3	(71.4 - 73.1)			
	1992	132	72.9	(72.1 - 73.6)	78	73.0	(71.9 - 74.1)	92	71.8	(70.8 - 72.7)
	1994	54	70.9	(69.8 - 72.0)	77	73.5	(72.3 - 74.8)	31	72.3	(70.7 - 73.9)
Weight	1989	86	67.9	(65.3 - 70.5)	90	65.9	(63.7 - 68.1)			
	1992	132	68.5	(66.6 - 70.4)	77	67.0	(64.6 - 69.4)	87	68.4	(66.3 - 70.4)
	1994	54	69.3	(66.1 - 72.4)	75	66.8	(64.4 - 69.2)	29	68.1	(64.4 - 71.8)
Height	1989	80	163.7	(162.3 - 165.1)	88	162.5	(161.4 - 163.6)			
	1992	127	162.6	(161.5 - 163.8)	76	162.9	(161.7 - 164.2)	84	163.3	(162.0 - 164.7)
	1994	53	163.4	(161.8 - 165.0)	73	162.5	(161.1 - 163.8)	24	164.0	(162.3 - 165.7)
BMI	1989	79	25.3	(24.3 - 26.3)	86	24.9	(24.1 - 25.7)			
	1992	127	26.0	(25.3 - 26.7)	75	25.3	(24.4 - 26.2)	83	25.6	(24.8 - 26.4)
	1994	53	26.0	(24.8 - 27.1)	73	25.3	(24.4 - 26.1)	24	24.9	(23.5 - 26.4)

BMI (body mass index) calculated as weight in kilograms divided by the square of the height in metres (kg/m^2). Confidence interval (CI) with a 95% confidence level. A Bonferroni correction was made to adjust for multiple comparisons of groups in 1992 and 1994.

Table 3b. Characteristics of the men in the control, the dual intervention and the single intervention samples aged 65 years or older (≥ 65) regarding age, weight, height and BMI in 1989, 1992 and 1994.

		Men (≥ 65)								
		Control sample			Dual intervention sample			Single intervention sample		
	Year	n	Mean	CI	n	Mean	CI	n	Mean	CI
Age	1989	82	72.9	(72.9 - 73.8)	104	72.4	(71.6 - 73.2)	94	71.5	(70.7 - 72.3)
	1992	132	73.4	(72.6 - 74.1)	85	74.3	(73.3 - 75.3)	94	71.5	(70.7 - 72.3)
	1994	57	71.4	(70.4 - 72.5)	77	74.8	(73.6 - 76.0)	33	71.8	(70.2 - 73.5)
Weight	1989	82	80.6	(78.0 - 83.2)	102	77.0	(75.1 - 78.9)	93	78.5	(76.4 - 80.5)
	1992	132	79.8	(77.7 - 81.8)	84	78.8	(76.6 - 81.0)	93	78.5	(76.4 - 80.5)
	1994	54	79.5	(76.6 - 82.3)	77	77.7	(75.2 - 80.3)	32	76.0	(73.2 - 78.8)
Height	1989	78	175	(173.6 - 176.4)	102	174.4	(173.2 - 175.5)	91	175.6	(174.6 - 176.7)
	1992	127	174.7	(173.7 - 175.7)	81	174.6	(173.4 - 175.9)	91	175.6	(174.6 - 176.7)
	1994	52	175.2	(173.2 - 177.2)	76	174.4	(173.2 - 175.6)	32	174.5	(172.4 - 176.6)
BMI	1989	78	26.3	(25.4 - 27.2)	101	25.4	(24.8 - 25.9)	90	25.4	(24.8 - 26.1)
	1992	127	26.0	(25.4 - 26.6)	81	25.6	(25.0 - 26.2)	90	25.4	(24.8 - 26.1)
	1994	52	25.8	(24.9 - 26.7)	76	25.5	(24.8 - 26.2)	32	25.0	(24.1 - 25.9)

BMI (body mass index) calculated as weight in kilograms divided by the square of the height in metres (kg/m^2). Confidence interval (CI) with a 95% confidence level. A Bonferroni correction was made to adjust for multiple comparisons of groups in 1992 and 1994.

Table 4. Differences between the dual intervention (DI), the single intervention (SI) and the control (C) samples of participants aged 65 years or older (≥ 65) in regard to residence, civil status, and previous fracture in 1989, 1992 and 1994.

	Year	C-sample (≥ 65) percent	DI-sample (≥ 65) percent	Difference DI- and C-samples percent	Difference (CI) DI- and C-samples percent	SI-sample (≥ 65) percent	Difference SI- and C-samples percent	Difference (CI) SI- and C-samples percent
I live in a private home	1989	71.7	54.9	-16.8	(-26.6 - -7.0)	47.5	-7.4	(-18.9 - 4.1)
	1992	55.0	49.7	-5.3	(-17.3 - 6.7)	47.5	-7.4	(-18.9 - 4.1)
	1994	74.8	50.3	-24.4	(-38.3 - -10.6)	46.9	-27.9	(-45.8 - -10.0)
I live with a partner	1989	66.1	64.3	-1.8	(-11.6 - 8.0)	63.9	-2.0	(-13.0 - 9.0)
	1992	65.9	64.4	-1.5	(-12.9 - 9.9)	63.9	-2.0	(-13.0 - 9.0)
	1994	64.0	63.4	-0.6	(-14.9 - 13.8)	64.1	0.1	(-17.9 - 18.1)
I have sustained a fracture during adulthood	1989	36.6	28.7	-7.9	(-17.8 - 2.0)	26.8	-7.5	(-18.2 - 3.3)
	1992	34.2	34.0	-0.3	(-11.9 - 11.3)	26.8	-7.5	(-18.2 - 3.3)
	1994	27.9	31.6	3.7	(-10.0 - 17.3)	28.1	0.2	(-16.7 - 17.1)

Confidence interval (CI) with a 95% confidence level. A Bonferroni correction was made to adjust for multiple comparisons of groups in 1992 and 1994. (The difference between the samples is significant when the 95% confidence interval does not include zero).

On the fifth year of the programme participants in the dual intervention sample (36.9%) reported more frequent use of shoe/cane spikes than participants in the control group (19.2%) and the difference between the samples was 17.7%. In 1994, 22.6% of the participants in the dual intervention sample who reported adding non-slip mats in their homes and 15.1% who reported having removed loose rugs in their homes had not reported this at baseline. The reported increase in the use of shoe/cane spikes in the dual intervention sample was observed mainly for the period 1992–1994.

Most participants (about 76.3%) reported a moderate physical activity level. In 1994, the dual intervention sample (87.9%) reported moderate physical activity levels more often than the control sample (67.4%) did. Consequently, the control sample (30.2%) more often reported low physical activity levels in 1994, and the difference between the control and the dual intervention samples was 18.9%. Only a few persons in each sample reported a high physical activity level.

The responses of the dual and the single intervention samples did not differ in any of the questions about safety behaviour and physical activity (Appendix A and B).

Study V. *Is calcaneal stiffness more sensitive to physical activity than forearm BMD?.....*

Age was significantly associated with forearm BMD ($p < 0.001$) and calcaneal stiffness ($p < 0.001$) in both genders. A decrease in forearm BMD and stiffness values was obvious after the age of 60 years in women. In men there was a decrease in forearm BMD after the age of 70 years, whereas stiffness value gradually decreased by age. The forearm BMD means in the eighth age decade was 0.40 g/cm^2 (CI: 0.33 – 0.46) lower than in the third decade in women and 0.28 g/cm^2 (CI: 0.18 – 0.37) lower in men. The differences in calcaneal stiffness means between these age decades were 22.4 (CI: 17.5 – 27.4) in women and 15.8 (CI: 8.0 – 23.5) in men. The correlation coefficient (r) between calcaneal stiffness and forearm BMD was higher in women 0.58 (CI: 0.52 – 0.64) than in men 0.34 (CI: 0.25 – 0.42).

Calcaneal stiffness was positively associated with reported high ($p = 0.025$) and moderate ($p = 0.026$) physical activity levels in women. Calcaneal stiffness was also positively associated with reported high ($p < 0.001$) and moderate physical activity levels ($p = 0.033$) in men. The ratio calcaneal stiffness/forearm BMD was positively associated with high physical activity ($p = 0.0024$) in men. This was not found in women.

Study VI. *Impact of a community osteoporosis intervention programme*

The numbers of observed forearm and hip fractures during the study period 1987–2001 are presented below in table 5.

Table 5. Number of forearm fractures (people aged ≥ 40 years), and trochanteric and cervical fractures (people aged ≥ 50 years) during the study period 1987–2001.

Period	Gender	INTERVENTION COMMUNITY			CONTROL COMMUNITY		
		Forearm	Trochanteric	Cervical	Forearm	Trochanteric	Cervical
1987–1991	Women	89	35	21	43	10	18
	Men	15	10	7	12	7	5
1992–1996	Women	90	24	31	47	18	16
	Men	17	12	13	11	7	10
1997–2001	Women	55	22	33	54	10	17
	Men	7	6	12	11	8	5

Mean age at the time of forearm fracture was 68 (CI: 67 – 69) years, upon cervical hip fracture 80 (CI: 79 – 82) years, and upon trochanteric hip fracture 82 (CI: 81 – 83) years. No significant difference was found between the communities with respect to mean ages at the time of any type of fracture incident. Nevertheless, there was a significant difference between the sexes concerning mean age upon sustaining a forearm fracture, which was 69 years in women and 61 years in men ($p < 0.001$). The median and the mean ages were equal.

No difference was found regarding incidence rates of forearm and hip fractures between the communities. However, in the intervention community forearm fracture incidence in women decreased and there was a tendency of decreasing forearm fracture incidence in men for the late intervention period. This was not found in the control

community. In the intervention community, there was a tendency towards a decrease in the incidence of trochanteric hip fractures in women during the early intervention period and in both sexes during the late intervention period, whereas no such change was found in the control community. There was no similar change found for cervical hip fracture incidence in neither the intervention nor the control community, nor in the genders (Tables 6, 7 and 8).

Table 6. Cumulative incidence per 1 000 of forearm fractures in women and men during five-year intervals for the study period.

Period	Forearm fractures in women				Forearm fractures in men			
	Intervention community		Control community		Intervention community		Control community	
	Cum inc.	CI	Cum inc.	CI	Cum inc.	CI	Cum inc.	CI
1987-91	8.32	(6.59-10.04)	5.54	(3.87-7.21)	1.70	(0.84-2.57)	1.75	(0.74-2.77)
1992-96	7.88	(6.25-9.51)	5.85	(4.18-7.52)	1.95	(1.02-2.88)	1.35	(0.54-2.16)
1997-01	4.62	(3.38-5.86)	6.56	(4.81-8.31)	0.68	(0.17-1.18)	1.49	(0.60-2.38)

Confidence interval (CI) with a 95% confidence level
Cumulative incidence (Cum inc.)

Table 7. Cumulative incidence per 1 000 of cervical and trochanteric hip fractures in women during five-year intervals for the study period.

Period	Cervical hip fractures in women				Trochanteric hip fractures in women			
	Intervention community		Control community		Intervention community		Control community	
	Cum inc.	CI	Cum inc.	CI	Cum inc.	CI	Cum inc.	CI
1987-91	1.92	(1.10-2.75)	2.32	(1.23-3.41)	3.02	(2.02-4.01)	1.37	(0.51-2.22)
1992-96	2.46	(1.59-3.33)	1.93	(0.99-2.87)	1.82	(1.09-2.54)	2.11	(1.14-3.07)
1997-01	2.36	(1.54-3.18)	1.99	(1.05-2.93)	1.50	(0.87-2.13)	1.18	(0.45-1.92)

Confidence interval (CI) with a 95% confidence level
Cumulative incidence (Cum inc.)

Table 8. Cumulative incidence per 1 000 of cervical and trochanteric hip fractures in men during five-year intervals for the study period.

Period	Cervical hip fractures in men				Trochanteric hip fractures in men			
	Intervention community		Control community		Intervention community		Control community	
	Cum inc.	CI	Cum inc.	CI	Cum inc.	CI	Cum inc.	CI
1987-91	0.69	(0.18-1.20)	0.59	(0.08-1.10)	1.04	(0.39-1.69)	0.85	(0.22-1.48)
1992-96	1.22	(0.56-1.88)	1.05	(0.40-1.71)	1.14	(0.50-1.79)	0.80	(0.20-1.41)
1997-01	1.02	(0.44-1.59)	0.51	(0.07-0.96)	0.54	(0.10-0.97)	0.79	(0.24-1.34)

Confidence interval (CI) with a 95% confidence level
Cumulative incidence (Cum inc.)

DISCUSSION

The general aim of the present thesis was to explore the effects of a community-based osteoporosis intervention programme including fall prophylaxis, physical activity and training programmes for balance, bone mass, and fracture outcome in adults. The main findings are that it was possible for adults to benefit from regular training programmes, that old people can be made aware of fall risks, that physical activity levels in both sexes are positively associated with calcaneal stiffness values, and that a community-based osteoporosis intervention programme can reduce the incidence of forearm fractures in women. The effect of community-based interventions on forearm and hip fracture incidence should be followed during an extended post-intervention period.

TRAINING PROGRAMMES FOR BONE MASS AND BALANCE PERFORMANCE (Study I and Study II)

Training studies that are designed to randomise participants to an exercise group or a control group are usually considered to be of greater scientific value than investigations in which the subjects choose groups themselves. In public health science, the strategy of quasi-experimental studies is often to examine the effects of population-based interventions. Both the community-based VOPP investigation and the weight-bearing training study had a quasi-experimental design. The people aged 40–70 years with low forearm BMD values included in the training study had originally been randomised to the individual part of the VOPP. These participants lived in the intervention community and they had previously received individual information about their low BMD values and also detailed advice how to improve bone mass. We did not want to withhold any of them to participate in the weight-bearing training. Thus, they were invited to additional tests of bone mass and balance, and to the group training. Those persons who preferred to exercise together with other people were included in the exercise group, and those who wanted to participate in the different tests but were not interested in training in a group were included in the control group. Although few persons participating in the VOPP bone mass measurements were observed osteopenic (n=52), and the choice of group participation was optional, the final exercise and control groups in the weight-bearing training study comprised equivalent numbers of women and men. A common problem with training studies is that it can be difficult to persuade the participants included in a control group not to change their lifestyle before the study has been evaluated. Some persons included in the control group in the weight-bearing training study told that they had partially increased their amount of physical activity by more walking and playing golf at the one-year follow-up (Study I). In addition, most participants who take part in training studies show learning effect on clinical tests and want to achieve better results at the follow-up (53, 54). There were some persons (irrespective of having been included in the exercise or the control group) participating in the weight-bearing and the balance-training study respectively, who told that they had practised balance tests at home e.g. walking forward or walking backward on a line (Study I and Study II).

Several prospective studies have emphasised that weight-bearing activity protects against hip-fractures. However, the amount, type, intensity, and duration of exercise that are optimal for preserving skeletal health have not yet been decisively determined. The osteogenic effects are site-specific, particularly to the anatomic sites that are loaded, whereas long-term physical activity is suggested to have systemic effects on the skeleton by humoral factors (17, 55-60). As early as the beginning of the 1970s, it was found that athletes had significantly denser bone in the distal end of the femur compared to non-athletes. If the

athletes were grouped according to the load taken on the lower limb, the bone density decreased with decreasing loads (61). Another example of the site-specific osteogenic effect of loading is the positive association between forearm bone diameter and professional tennis playing (62). In the present study, sequence training equipment was used in the weight-bearing training study to involve both the arms and legs for optimal training of the body. The imposed load was intended to alter the daily stress stimulus considerably from its baseline state of equilibrium to effect change in bone mass. It is more effective to provide a higher intensity stimulus than simply to extend the duration of ordinary loading activity to influence bone mass. The warm-up movements for the “younger” group (aged 40–55 years) also included jumps in different directions, as it is adequate to stress the bone in an unusual manner to stimulate the formation of bone (20, 58, 63). Both young and old people may benefit from sequence training, because the load is set individually at each training station. The participants in the weight-bearing training group were told to adjust loads according to personal specifications. However, the participants in the “elderly” group (aged 60–70 years) forgot amazingly often to set their individual load when changing training stations, thus they had to be repeatedly reminded (Study I). Participants in weight-bearing training groups should also be encouraged to progressively increase the load at each training station to augment the stimulation of bone mass (60, 64, 65). These observations clearly indicate that the training in the elderly should be supervised.

The weight-bearing training study was designed for one year. It is advisable to conduct training studies over periods of more than a year due to the slow evolution of skeletal adaptation (17, 20, 63). The osteopenic participants in the training group were offered to continue the weight-bearing training (free of charge) after the evaluation of the study. During the extended training period there were only participants from the “elderly” group (n=5) who continued to regularly exercise twice a week in the training group. Accordingly, the number of participants remaining in the exercise group during the extended training period was too low to allow analysis and comparison of the results (Study I). Other investigators have also observed that compliance with exercise programs often decreases over time (66).

The results of exercise trials aimed at improving bone mass are often unimpressive, with a gain in BMD of only 1–5% (20). BMD-values at the greater trochanter increased by 2.5% in the exercise group for the one-year intervention period. However, there was no such increase in BMD-values at the femoral neck. The proportion of trabecular bone is greater in the trochanter region than in the femoral neck, which instead comprises more cortical bone. In addition, the greater trochanter has attachment sites for several muscle groups, whereas no muscles are attached to the femoral neck (Study I). The trabecular bone has a faster metabolic response than cortical bone and therapeutic effects are usually detected earlier in these regions of trabecular bone (17, 44, 67–69). This fact might also be a reason to the positive association between calcaneal stiffness (which is composed of about 90% trabecular bone) and reported physical activity levels in study V. The progressive, age-related bone loss that occurs in most persons after the age of 50 is another important aspect that should be taken into consideration when evaluating a training programme aimed at affecting bone mass. Generally speaking, for both women and men in their fifties and sixties it seems that age-related bone loss is of the order of 0.5% per year, but that rate accelerates substantially with advancing age (20, 70). In a study conducted in Sweden, it was found that the mean bone loss in women aged 20–79 years was 0.7–1.0% per year for forearm, spine, and femoral neck sites and 0.4% per year for trochanter and total hip regions (41). Hence, no change or a small increase in BMD-values might indicate a positive effect of the training programme in the participants in the weight-bearing training study. Furthermore, at the level of the individual, the gain in bone mass was sometimes considerable higher in some participants after one year of training (Study I). The response of bone to loading is very complex and the effect of training would probably become

more conspicuous, if it was started with very sedentary individuals due to the curvilinear relationship between mechanical loading and skeletal response (20, 63). Twelve participants (six persons in the intervention and six persons in the control group) already walked/jogged at least 30 minutes twice a week at the start of the weight-bearing training study. Bone mass measurements were also performed at the lumbar spine, and the BMD-values at the lumbar spine increased by 1.3% in the control group at the post-intervention test (Study I). This change could be a consequence of progressing degenerative changes and/or vertebral compression concealing a true osteoporosis in the vertebral bodies. Densitometry of the lumbar spine by anterior-posterior projection is therefore not recommended for persons after the age of 60 years. Radiography is a suitable alternative for measuring bone mass in the lumbar spine (71).

The promotion of physical activity and the prevention of falls and subsequent injuries are of utmost importance in the elderly, because old age leads to bone fragility and rather often to dysequilibrium and/or vertigo. Appropriate exercises can contribute to the reduction of typical age-related bone losses and improve balance performance (4, 14, 56, 72, 73). Balance-training programmes are often well tolerated by old people, and it is preferable to choose training programmes of moderate intensity. People aged 70–75 years were invited to take part in the present training study, and the objective was to evaluate the effect of a training programme that included balance exercises developed specifically for the elderly. The age-span was limited and the participants were matched essentially according to sex and not individual factors. The training programme was performed to music in a large gymnasium, and equipment such as balance boards and trampolines were placed close to wall bars or parallel bars to prevent falls. Exercises using balls were included to stimulate the visual and vestibular systems (74-76). Rapid head turning manoeuvres were intended to increase afferent signals from the vestibular organ, which would probably result in better use of the impulses to the brainstem. After the training period the participants in the exercise group performed better in the most difficult balance tests compared to the controls. The improved balance performance was probably the result of better use of afferent impulses, not increases in muscle strength, since the training period was rather short (nine weeks) and was not focused specifically on improving muscle strength (Study II) (77). In a person who has reached the age of 70 years, the function of the vestibular system deteriorates due to a loss of about 40% of the hair and nerve cells. This partial loss can lead to dizziness, which can contribute significantly to poor balance, falls, and fractures in the elderly (76, 78-81). Thus, the improvement of balance performance in the exercise group may be clinically relevant in the attempt to prevent falls amongst the elderly.

A training leader in a gymnastics association for seniors in the intervention community was informed of the importance of including balance exercises in programmes designed for the elderly. The leader invited all participants included in the exercise and the control groups to continue balance training for several years during the intervention period. A gymnasium with sequence training equipment was also expanded at the Vadstena PHCC during the intervention period. In addition, an experienced assistant nurse took a supplementary course and became a gymnastics leader specialised in physical activity. The importance of the positive social effects was obvious among the elderly in the weight-bearing and the balance-training groups: they were markedly considerate and caring towards one another and said that they had made new friends. The weight-bearing training, which was initiated in 1994 has now been going on for more than nine years. The number of persons aged ≥ 65 years participating in this training increased during the VOPP intervention period, and there are still (in 2003) two groups that exercise twice a week (Study I).

BALANCE TESTS FOR OLDER PEOPLE (Study II)

Certain key risk factors for falling can be estimated through relatively simple observations of selected balance and gait manoeuvres or by using questions about previous falls and fractures (Study I, Study II and Study IV). Both static and dynamic balance tests provided valuable information about balance performance among the participants in the VOPP balance-training study, which agrees with the findings of another investigation carried out in Sweden (82). Static and dynamic balance tasks included in the present assessment procedures were chosen to reflect ordinary situations in real life. In the NORA (Nordic Research on Ageing) study it was found that those 75-year-old residents who needed no help in performing ordinary activities had significantly better results in balance tests (83). Lower extremity disabilities, abnormalities of balance and gait are central risk factors for falling and should be assessed by a competent physiotherapist before designing an individually tailored training programme for the patient in the clinic. The static Romberg tests with the feet together and the eyes open and the eyes closed were not difficult enough to challenge the limits of stability either in the healthy persons participating in the present studies or in a study of elderly persons with central vertigo and unsteadiness. The sharpened Romberg test with the eyes open was not either a challenge for the healthy elderly, while it proved to be the most appropriate clinical static balance test in elderly persons with central vertigo (74). Standing on one leg with the eyes open is sensitive to age-related changes in balance and is an appropriate screening test for low functional level and frailty among elderly people in the clinical setting (74, 84, 85). In the present balance-training study the healthy elderly were able to stand on one leg with their eyes open for an average time of 17.1 seconds at the pre-test. Elderly people with central vertigo might manage to stand on one leg with their eyes open for about 10-12 seconds. In general, healthy elderly are usually capable of standing on one leg with their eyes closed for at least a few seconds, whereas this position is too difficult for old people with central vertigo (74). The improved walking speed among the participants included in the exercise group in the balance-training study is in accordance with a training study of 70-year-old women in Sweden (Study II) (84). The walking speed test seems to provide information about health in the elderly. For instance, it has been claimed that slow walking is typical in sedentary older adults and is a reliable predictor of dependence in ADL (activities of daily living) amongst 70-year-olds (86). It has also been suggested that there is a correlation between step length and mobility and physical activity, such that longer steps indicate a more active lifestyle and gait unsteadiness is increased in community-dwelling elderly who fall frequently (87, 88). Consequently, the observation of step frequency and stride-to-stride temporal variations may be of importance when assessing walking performance in presumed fallers.

A screening test “stops walking when talking” was recently developed and used as a predictor of falls among elderly people in residential care. The test might give a hint of certain unsteadiness in the very elderly, as a greater tendency to fall was observed among those who stopped while talking. The inability to carry out two tasks simultaneously might be the reason the person stops walking, as the walking procedure needs much attention. Vestibular asymmetry is another possible reason the walking stops, as this condition might cause the person to experience increased imbalance when the head is turned while talking (81, 89). Yet another plausible explanation is impaired hearing, which may prompt an individual to stop walking in order to obtain additional information through lip reading. The diffTUG (differenceTimed Up&Go) test is another recently developed screening tool for predicting falls in elderly people in residential care. The difference in time between rising from a sitting position with a glass of water (5 cl) in one hand, walking three metres, turning, walking back and sitting down again should not exceed 4.5 seconds (90). These newly developed tests might be used as suitable complementary assessments in the clinic when screening for

abnormalities of balance performance in severely unsteady community-dwelling elderly as well as those residing in nursing homes.

BEHAVIOURAL MODIFICATIONS AND THE PREVENTION OF FALLS (Study IV)

A combination of community-based interventions (population-wide strategy) and individual (high-risk strategy) interventions was used in the VOPP in an attempt to make old people aware of the benefits of a safer home environment. The community-based VOPP intervention alone was not powerful enough to obtain differences between the participants aged ≥ 65 years in the single intervention sample and the control sample in regard to inducing awareness of lifestyle behaviour as a method of preventing falls and fractures. The community-based intervention alone was not either powerful enough to increase the level of knowledge in the community (37). This finding is in accordance with the Minnesota Heart Health Program, which stated that the impact of health programmes might be modest on the entire community, but more apparent on targeted groups (91-93). We found the combined community-based and individual interventions more powerful, since follow-up participants showed greater awareness concerning the use of shoe/cane spikes, and they also reported a higher level of physical activity level at the second follow-up compared to those in the control sample. Those follow-up participants might represent a selective group of people, who were more positive to the intervention message and possibly more interested in the prevention of falls and injuries. The proportion of invited persons aged ≥ 65 years who participated in the intervention samples increased at the follow-ups. This might indicate increased support for the intervention programmes after the initial organising effort. After each VOPP registration, the participants in the intervention samples received a personal letter including a health profile and a note with specific advice about how to decrease eventual risk-behaviour for osteoporosis (Figure 3) (10). Verbal responses made by the participants suggested that this feedback was appreciated (10, 36).

A checklist might help identify those who are at high risk of falls and fractures, and a checklist of environmental hazards and modifications might also be useful when teaching older people to eliminate fall hazards in their home (Appendix B) (Study IV). It is recommended that a careful history is taken of the circumstances surrounding a fall and/or fracture in order to identify those persons at risk for a new fall and fracture (94, 95). The participants in the VOPP study were asked to report and to specify any kind of fracture they had sustained during adulthood, and to recall their age at the time of the fracture. Supplementary questions concerning fall accidents and the circumstances surrounding a fall and eventual fear of falling were addressed to the elderly and added to the VOPP questionnaire in 1999. About one-fourth of these respondents in Vadstena and in the control community reported having a fall during the previous year and about one-third of these respondents were afraid of falling again.

The VOPP emphasised that relatives could provide valuable support by reminding and helping the elderly to make their home environment safer in order to prevent falls. The shops selling shoes, sports equipment, and electrical appliances in Vadstena also collaborated during the intervention period, although, according to the follow-up results this gave no apparent improvement among the elderly in regard to reported adjustment of lighting (10, 36). Reinsch et al. carried out a study of a cognitive-behavioural programme for elderly community residents, and it was discussed whether personal economy or a lack of practical assistance might have been reasons that elderly people do not follow recommendations concerning changes in the home environment to prevent falls (96). Old people might also become used to

the darkness until someone else calls attention to the insufficient lighting. More intervention efforts should probably have been made to inform the public of the importance of good lighting, considering that sight is an important factor in controlling balance and can augment sensory information (Study II and Study IV) (78, 97, 98). The VOPP interventions were mainly directed to community-living residents and reached the nursing home residents in the community only to some extent by information from the nurses and the physiotherapist employed by the municipality. According to a recent study about fall and injury prevention a multifactorial and interdisciplinary prevention could reduce the number of residents who fell, the total number of falls and hip fractures amongst older people living in residential care facilities (99). Thus, if more specific resources would have been spent on reducing the number of falls among nursing home residents the hip fracture incidence rates might have become lower than was showed in study VI.

Several investigations have shown that counselling and encouragement regarding adequate physical activity might restore confidence in old people who have experienced a fall (90, 94, 100, 101). The fear of falling often leads to decreased mobility and reduced independence among old people (93). It was observed in the VOPP balance-training study that the participants included in the exercise group became more self-assured and tried more difficult balance exercises after some weeks of training (Study II). Opportunities for the population to participate in training and walking groups increased during the VOPP intervention period (Study I, Study II and Study IV). These interventions seem to have influenced the elderly to take part in more physical activity, according to the answers given on the VOPP questionnaire at the second follow-up (Study IV).

Continuous evaluation of intervention efforts provides information that constitutes both a base and a guide for subsequent interventions. The choice of a control community is important, as this makes it possible to evaluate the effects of the community-based interventions in the intervention community. In the VOPP study the control community was selected because of its similarity to the intervention community in terms of population structure and health care. The two communities are neighbouring communities which makes it possible to influence the control community not to start an intervention aimed at preventing osteoporosis, as the PHCC in that municipality is supervised by the same county council. However, a situation of this type also entails a disadvantage, namely, the risk of dissemination of the intervention message from the study to the control community, before the results of the investigation are evaluated (Study IV) (10, 37). There are somewhat more people living in the intervention than in the control community (a difference of about 1 600 in 1989). However, the proportion of elderly persons aged ≥ 65 years is slightly higher in both the intervention (22%) and the control (21%) community than the mean of the Swedish population (18 %) (21).

BONE MASS MEASUREMENTS AND PHYSICAL ACTIVITY QUESTIONNAIRES (Study III and Study V)

Increased interest in the prevention of osteoporosis has arisen because scientific progress has made it possible to measure the skeleton using different technique for measuring bone and to treat osteoporosis with various pharmaceutical agents (102). The ambition of the community-based intervention programme was to reach all community residents. However, teenagers were not invited to the bone mass measurements, as there is no exact age at which bony accumulation reaches peak bone mass in the different regions of the skeleton. The process of achieving peak bone mass seems to be at least 95% complete by the age of 17 years in girls

and some (2-3) years later in boys (20, 103). Thus we chose to invite persons aged ≥ 20 years to the screening of bone mass (Study III and Study V).

The use of forearm scanning has become a widely applied screening procedure for the detection of generalised osteoporotic bone loss. The peripheral location of the human forearm and its relatively small amount of surrounding tissue improves the accuracy and the precision of bone mass measurement (68). Forearm BMD seems to predict osteoporotic fractures at the forearm itself as well as at the hip and at the spine. BMD measurements of the non-dominant forearm was chosen to assess general bone mineral status. This site was chosen because it might provide BMD values that correlate better with systemic determinants of bone mass than BMD measurements made at weight-bearing sites (Study I, Study III and Study V) (10, 41, 104, 105). The most valuable technique for evaluation of bone mass is DXA (dual-energy X-ray absorptiometry) performed at the hip and the lumbar spine. However, the SPA (single photon absorptiometry) technology was available for the VOPP screening of forearm bone mass in persons aged 20–69 years in 1989 and at the subsequent registrations at the PHCC facilities. Also, the equipment was portable and could be rented at an acceptable cost (45, 106). Obviously, it was important to use the same technology and the same measurement site during follow-up periods. In addition, the only long-term data on fracture prediction involves SPA-scans (107). Bone mass measurements at weight-bearing sites such as the calcaneus, which is composed of mainly trabecular bone, might better represent bone strength at the weight-bearing sites for instance at the lumbar spine (102). Thus, in addition to the SPA screening of the forearm, quantitative ultrasound (QUS) of the heel was introduced as a supplementary screening in 1999. This equipment was also portable and provided a quick measurement reply with information on the structural organisation of bone in addition to bone mass. Another advantage is that the QUS does not use ionising radiation (Study V) (102, 108).

Administering a questionnaire is a feasible, practical and inexpensive method of quantifying physical activity levels in a population. Interventions aimed at increasing the amount of physical activity among the population may be followed and facilitated by the use of a questionnaire (109, 110). In the present studies two short multiple-choice questions were used both at baseline and at the following VOPP registrations to estimate physical activity levels (Appendix A) (Study III, Study IV and Study V). The physical activity levels amongst participants aged ≥ 65 years in the intervention and the control samples were registered at base-line, and followed to the year 1994 in study IV. The VOPP questionnaire included a leisure-time physical activity question with a six-grade scale. The scale is a further development of a four-grade scale presented earlier by Saltin and Grimby. The original four-grade scale has proved to be a valid measure of leisure-time physical activity levels in middle-aged men (48, 111). According to an evaluation conducted within the IVEG study, the validity of the six-grade scale seems to be acceptable for assessing physical activity levels in elderly women and men (49). The question relies on estimates of habitual leisure-time physical activity and it is easy for participants to fill in a feasible alternative. This six-grade scale has apparently not been used in previous investigations of bone mass. A positive association was found between reported moderate leisure-time physical activity levels and forearm BMD in men according to study III. No such association was found between forearm BMD and reported physical activity levels in study V in 1999. However, reported moderate and high physical activity levels in both genders were positively associated with calcaneal stiffness (Study V). The different proportions of cortical and trabecular bone at the two measurement sites might explain the results. About 80–90% of bone at the measurement site of the radius (measured by SPA) is of the cortical type while 10–20% is of the trabecular type. The calcaneus is composed of 90% trabecular bone and has a higher metabolic turnover rate than cortical bone. Hence, trabecular bone will manifest bone metabolic changes before

cortical bone (17, 42, 44). The results in the VOPP cross-sectional studies can be compared with the findings of a Swedish population-based study of BMD and physical activity levels in subjects aged 15–42 years, in which the original four-grade leisure-time physical activity scale was used. In the cited investigation, physical activity levels were dichotomised into low and high levels. No correlation was found between BMD values at the forearm (measured by SPA) and reported physical activity levels in subjects aged 21–42 years, whereas men who reported high physical activity levels had higher BMD values at the hip (measured by DXA) than those who reported low levels (112).

Further development and validation of physical activity questionnaires that account for possible age and gender differences is inquired. Many questionnaires in use to assess physical activity levels, were originally designed to assess aerobic work or energy expenditure, but may fail to reflect the loads experienced by the skeleton (63, 109, 111–113). Misclassification can be expected in the attempt to classify physical activity by type, intensity, frequency, duration and complexity. There is also a certain risk that some persons could overestimate their physical activity levels in order to place themselves in favourable light (56, 67, 109). Competitive sports might be more accurately recalled than ordinary number of blocks walked per day (113). Reported recent or temporary changes in physical activity level might sometimes be misleading in studies of bone mass, as a recently changed level will not be detected by bone mass measurement, because of the slow bone formation (Study III and Study V) (17, 63). A moderate physical activity level might be the most difficult level to classify in physical activity questionnaires (Study III and Study V) (56). The six-grade scale, used in the VOPP as well as in the IVEG study, also included household activities (49). This probably meant that some women who reported a moderate physical activity level more often would have reported a low level, if household activities had not been included in the scale (Study III and Study V). This is in agreement with another study where housework and gardening accounted for about 80% of the reported physical activity in postmenopausal women (114). Three questions about leisure-time physical activity were added to the VOPP questionnaire at the final registration in 1999. The frequency of brisk walking/jogging for at least 30 minutes was estimated for the summer and the winter seasons separately, and the third question was about the frequency of physical exercise wearing track-clothes. There were four exposure categories as follows: daily, at least twice a week, once a week, and never (109). At the final registration about 31% of the women and 24% of the men reported that they went for a brisk walk or jogging daily in the summer, while the corresponding figures for the winter were 22% of the women and 16% of the men. It was also found that 36% of the women and 37% of the men reported that they exercised wearing track-clothes once a week or more frequent. These results may be compared with another Swedish study in which 40% of the women and men at the age of 40 years reported engaging in regular physical exercise at least once a week in which the level of exertion corresponded to at least a brisk walk (109).

It is not known if the association between moderate/high physical activity levels and the calcaneus (measured by QUS) meant a genuine decreased risk of hip fracture in the participants included in the intervention community. Such an association might be studied in the future. However, other studies have confirmed a causal relationship between physical inactivity and hip fracture. An important risk factor for hip fracture was decline in physical activity levels over time, while being physically active at a moderate level provided protection against later hip fracture (56, 73, 115).

FOREARM AND HIP FRACTURE INCIDENCE IN THE COMMUNITY (Study VI)

The incidence of fractures was evaluated in the intervention community (population about 7 500 in 1989) and in the control community (population about 5 917 in 1989) during the study period 1987–2001. Forearm and hip (trochanteric and cervical) fractures were included in the subsequent survey of fractures in middle-aged and elderly persons. Vertebral fractures were excluded from the survey, because a significant proportion of vertebral fractures is considered as asymptomatic and cannot be properly estimated. There is also a difficulty in achieving consensus about the definition of vertebral deformities from radiographs (71, 116). There was no information in the files at the Department of Radiology concerning the circumstances to an occurred fracture. This meant that it was not possible to determine if low-energetic or high-energetic trauma had caused a fracture.

Forearm fractures are very common. A distal forearm fracture in a middle-aged woman may be a fragility fracture. Many studies have shown that individuals with forearm fractures have lower bone mass than controls. In a study of fractures in a community in southern Sweden it was found that women and men with a previous radial fracture were at higher risk of sustaining a hip fracture compared to the total population of the same community (95). Low BMD, poor vision, number of falls, and frequent brisk walking are risk factors for upper limb fractures in women with a history of falling (95, 117). Falls leading to distal forearm fracture occur outdoors more often than falls resulting in hip fracture (95). A seasonal variation in fall incidence may partially explain the variation in types of forearm fracture (118). However, different seasonal variation between the intervention and the control areas is not likely in the VOPP study, because the two communities are only 30 km (18 miles) apart, and both communities are located close to Lake Vättern and therefore have identical climate (10). In the intervention community forearm fracture incidence decreased in women and there was also a tendency of decreasing forearm fracture incidence in men during the late intervention period. No similar change was found in the control community.

Osteoporotic hip fractures occur most frequently in the very elderly. The dramatic increase in trochanteric hip fracture incidence in the Östergötland County for the period 1940–1986 was most pronounced in people aged > 80 years (28). Notably, the majority of hip fractures occur indoors and are due to falls that seem to be associated with essentially routine activities (13). The incidence of hip fractures in women at all ages beyond 50 years is about twice that in men (18, 27). A woman has a 3% annual risk of hip fracture by the age of 80 years (22). The gender difference was obvious in the VOPP survey of fractures (Tables 6, 7 and 8). There was a tendency towards a decreased incidence of trochanteric hip fracture in both sexes during the late intervention period in the intervention community. A recent study of hip fractures in Östergötland in 1982–1996, showed decreasing incidence in women, while male trochanteric hip fractures continued to rise (34). Another study in the southern Sweden indicated that the incidence of hip fractures was no longer increasing in women and men in 1992–1995. Multifactorial causes of this trend-break have been suggested, such as successful osteoporosis prevention information to the public and increased use of medical treatment for established osteoporosis (30). The limited size of the communities and the small numbers of fractures occurring during the VOPP study period made it difficult to discern any differences between the intervention and the control communities. Experience from the injury prevention project conducted in the municipality of Motala indicates that a community-based prevention programme must be regarded as a long-term project, preferably covering a period of more than ten years (119). Thus, it is likely that the effect of the VOPP on fracture incidence will take time to appear, and assessment of the post-intervention period should therefore be extended.

Local politicians were contacted at an early stage before initiating the VOPP intervention programme. However, perhaps this should have been repeated as a reminder to ensure continued support over the whole ten-year intervention period (7, 8, 10, 36). The Swedish municipalities are responsible for the care of all people living in nursing homes since the elderly reform act (called the “ÄDEL” reform) was implemented in 1992 (120). About 40–50% of the people receiving geriatric care have falls once or several times each year, and hip fractures are often caused by falls (13, 18, 99, 121, 122). Consequently, an important task for the municipality should be to implement strategies to prevent falls in the elderly in order to reduce the number of hip fractures (2, 4, 93, 99, 117, 123). Falling laterally (sideways) increases the risk of hip fracture, and approximately 50–70% of such falls result in a hip fracture (32). It is appropriate to recommend hip protectors to mitigate such falls among frail persons (38–40, 100). Acceptance and compliance are two major problems associated with the use of hip-protector (39). Information about the positive effect of wearing hip protectors to prevent fractures was included in the late intervention period of the VOPP and was aimed primarily at the elderly residents and the staff of nursing homes (Study VI). Calcium and vitamin D supplementation was given to the very elderly at nursing homes in the intervention community for a short period in 1998 (124). Prolonging such a general intervention might be sufficient to achieve long-term improvement of bone health and reduction of hip fractures in the elderly (18, 125, 126).

In recent years, the information disseminated by the media in Sweden has led to interest in preventing osteoporosis, falls and fractures. This background “noise” might have influenced both the intervened and the control populations. The VOPP study used a combination of community-based interventions (population-wide strategy) and individual interventions (high-risk strategy). A high-risk strategy, which would have been directed at targeted groups of very frail elderly individuals in the community might have been the quickest way to reduce falls and hip fractures. However, the VOPP study had a more long-term aim and focused on primary prevention of osteoporosis, foremost by informing and educating the public about the importance of a healthy lifestyle. Secondary and tertiary prevention were also important interventions included in the VOPP (Study I, Study II and Study IV) (10, 36). Professionals in primary health care play an important role in the prevention of osteoporosis, falls, and fractures, because they encounter individuals of all ages in the clinical setting. Secondary prevention of osteoporosis involves clinical consultations and care of osteopenic/osteoporotic patients, whereas tertiary prevention concerns the prevention of repeated fractures in patients with established osteoporosis. In Vadstena today, medical check-ups for osteoporosis are routinely performed by a district nurse at the PHCC.

The VOPP interventions have probably within the community increased the awareness of the possibility of influencing bone health by choosing a healthy lifestyle, and by modifying behaviour to prevent accidents that involve falls. The VOPP has also in all probability led to increased preventive awareness among the health care staff of the Vadstena PHCC. These professionals have been active in the intervention programme for at least ten years, thus the work to prevent osteoporosis and fractures is no doubt well rooted and will therefore continue in the future.

CONCLUSIONS

The studies presented in the thesis are all part of the prospective study entitled the Vadstena Osteoporosis Prevention Project (VOPP). The main conclusions that can be drawn from the results of the present studies are as follows:

- Training programmes aimed at increasing bone mass should be conducted for a period of more than one year, because the skeletal adaptation is rather slow (Study I).
- Adults with low bone forearm BMD seem to benefit from weight-bearing training performed twice a week (Study I).
- Short-term training including specific balance exercises improves balance performance in healthy community-dwelling older people (Study II).
- The standard Romberg test, (i.e. standing steadily with the eyes open or closed), is not difficult enough to challenge the limits of stability in healthy older people, but the sharpened Romberg test with the eyes closed might be a challenge (Study II).
- Use of the one-leg stance test with the eyes open seems to be an appropriate way to screen for unsteadiness in community-dwelling elderly (Study II).
- It may be feasible to use a questionnaire to assess physical activity levels in a population. However, there is a need for further development (Study III and Study V).
- The community-based intervention alone used in the VOPP is not sufficient to attain behavioural changes in elderly people, but it may be effective if combined with individual interventions (Study IV).
- The osteoporosis and fall risk prevention programme used in the VOPP may influence people aged ≥ 65 years to increase physical activity and use fall-prevention equipment such as spikes (Study IV).
- It may be suitable to measure the calcaneus to monitor the effects of physical exercise in osteoporosis prevention programmes, because there seems to be a rather strong association between physical activity level and calcaneal stiffness (Study V).
- Ultrasound measurements of the calcaneus indicate a positive association between leisure-time physical activity levels and calcaneal stiffness in both women and men, which supports the assumption that increasing physical activity in a population will help prevent osteoporosis (Study V).
- The community-based ten-year VOPP intervention programme decreased the incidence of forearm fractures in middle-aged and elderly women, and there was also a tendency towards decreasing incidence of trochanteric hip fractures (Study VI).
- A community-based intervention programme aimed at reducing the incidence of osteoporotic fractures should be regarded as a long-term project, preferably including an extended post-intervention period (Study VI).

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APPENDIX A

Table 1. Number of invited persons and participants in the Vadstena Osteoporosis Prevention Project at base-line and at the follow-ups.

	1989 Invited persons	1989 Participants in the VOPP number (%)	1992 Invited persons	1992 Participants in the VOPP number (%)	1994 Invited persons	1994 Participants in the VOPP number (%)	1999 Invited number	1999 Participants in the VOPP number (%)
Intervention community	860	603 (70)	1418	978 (69)	870	685 (79)	2438	1395 (57)
Control community	650	505 (78)	1156	826 (71)	659	392 (59)	660	387 (59)

Table 2. The question used for assessing physical activity level during daily work.

One's work may mean different kind of physical efforts. Please classify your daily work (also work at home) according to one of the alternatives listed below:

- Mainly sedentary work
- Work that demands a large amount of standing and walking, but does not demand physical effort.
- Work that involves standing and walking, but also includes lifting and carrying.
- Heavy manual work.

Table 3. The question used for assessing leisure-time physical activity level.

Please classify your physical activity during leisure-time according to one of the alternatives below:

- Hardly any physical activity.
- Mostly sedentary, sometimes a walk, light gardening or similar tasks. Sometimes light household activities such as heating up food, vacuum cleaning and clearing away things.
- Light physical exercise about 2-4 hours a week, such as walks, fishing, dancing, ordinary gardening and walks to and from shops several times a week. Main responsibility for light domestic work such as cooking, dusting, clearing away things, and making beds. Performs or takes part in weekly cleaning.
- More strenuous physical exercise 1-2 hours a week such as jogging, swimming, gymnastics, heavier gardening, home repairs or light physical activities more than 4 hours a week. Responsible for all domestic activities, light as well as heavy. Weekly cleaning including vacuum cleaning, washing floors and window cleaning.
- More strenuous physical exercise at least 3 hours a week such as tennis, swimming, jogging, etc.
- Hard physical exercise on a regular basis several times a week with strenuous physical exertion such as in jogging, skiing, etc.

APPENDIX B

Table 1. Hazard checklist against osteoporosis and fractures.

I drink milk and eat cheese every day.	<input type="checkbox"/> yes	<input type="checkbox"/> no
I'm outdoors at least 15 min/day.	<input type="checkbox"/> yes	<input type="checkbox"/> no
I have removed slippery and loose rugs.	<input type="checkbox"/> yes	<input type="checkbox"/> no
I wear sturdy shoes indoors instead of loose shoes.	<input type="checkbox"/> yes	<input type="checkbox"/> no
I wear non-slippery shoes and spikes outdoors in the wintertime when necessary.	<input type="checkbox"/> yes	<input type="checkbox"/> no
I keep frequently used household appliances within easy reach to avoid climbing up on chairs, etc.	<input type="checkbox"/> yes	<input type="checkbox"/> no
There is a suction-rubber mat in the bathtub/shower.	<input type="checkbox"/> yes	<input type="checkbox"/> no
There is a grab bar on the wall close to the bath.	<input type="checkbox"/> yes	<input type="checkbox"/> no
I wipe up wet spots on the floor immediately.	<input type="checkbox"/> yes	<input type="checkbox"/> no
There is good lighting on the stairways and in the lavatory.	<input type="checkbox"/> yes	<input type="checkbox"/> no
I have a telephone in the room, where I spend the most time.	<input type="checkbox"/> yes	<input type="checkbox"/> no

Each statement, with a "no" answer, indicates an increased risk of fracture.

Table 2. Questions about home environment answered by participants aged 65 ≥ years.

If you are 65 years of age or over, please answer the following questions.

- Have you improved the lighting in your home (more lamps or stronger bulbs) during the last five years?
 - yes
 - no
- Have you added a suction-rubber mat in the bath and mats with non-slip backing to your home during the last five years?
 - yes
 - no
- Have you removed loose rugs from your home during the last five years with the aim of preventing accidents?
 - yes
 - no
- Do you use spikes on your shoes and/or on a cane/crutch when it is slippery outside?
 - yes
 - no
- How much time on average do you spend outdoors per week during the summer?
 - I am never outdoors
 - Less than 15 minutes
 - Between 15 and 30 minutes
 - Between 30 minutes and 1 hour
 - Between 1 and 2 hours
 - Between 2 and 3 hours
 - More than 3 hours
- How much time on average do you spend outdoors per week during the winter?
 - I am never outdoors
 - Less than 15 minutes
 - Between 15 and 30 minutes
 - Between 30 minutes and 1 hour
 - Between 1 and 2 hours
 - Between 2 and 3 hours
 - More than 3 hours