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Fall prediction and a high-intensity functional exercise programme to improve physical functions and to prevent falls among older people living in residential care facilities

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”Just like the Olympic athlete, the elderly person must perform, frequently and consistently, at the very limit of their physical ability. The 85-year-old can therefore benefit from the study of athletic training methods...”

(Archie Young, 1997)

CONTENTS

ABSTRACT

Impairments in balance, mobility, and lower-limb strength are common in the growing population of older people and can lead to dramatic consequences for the individual, such as dependency in activities of daily living, admission to nursing home, falls, and fractures. The main purposes of this thesis were, among older people in residential care facilities, to validate a fall-risk assessment tool and to evaluate a high-intensity functional weight-bearing exercise programme regarding its applicability as well as its effect on physical functions and falls.

The prediction accuracy of the Downton fall risk index within 3, 6 and 12 months was evaluated among 78 residents, aged 65 years or more, at one residential care facility. The participants were assessed as having either a low or high fall risk according to the index and were followed-up for falls using two different fall definitions related to the cause of the fall. With all falls included, a significant prognostic separation was found between the low- and the high-risk group at 3, 6 and 12 months. A definition in which falls precipitated by acute illness, acute disease, or drug side-effects were excluded did not improve the accuracy of the fall prediction.

The effect on physical functions of a high-intensity functional exercise programme was evaluated in a randomised controlled trial among 191 older people, dependent in activities of daily living, with a Mini-Mental State Examination score of ten or more, and living in nine residential care facilities. Participants were randomised to an exercise programme or a control activity, including 29 supervised sessions over 3 months, as well as to an intake of a milk-based 200 ml protein-enriched energy supplement (7.4 g protein per 100 g) or a placebo drink immediately after each session. The Berg Balance Scale, usual and maximum gait speed, and one-repetition maximum in lower-limb strength in a leg press machine were followed up at 3 and 6 months by blinded assessors and analysed using the intention-to-treat principle. Significant long-term effects of the high-intensity functional exercise programme were seen in balance, gait ability and lower-limb strength in comparison with the control activity. The intake of the protein-enriched energy supplement did not increase the effect of the training.

The evaluation of the applicability of the exercise programme showed that there was a high rate of attendance, a relatively high achieved intensity in the exercises, and only two serious adverse events, neither of which led to manifest injury or disease, despite that most of the participants had severe cognitive or physical impairments. The applicability of the programme was not associated with the participants' cognitive function.

The evaluation of the fall-prevention effect of the exercise programme, during the 6 months following the intervention, showed that neither fall rate nor proportion of participants who sustained a fall differed between the exercise programme and the control activity, when all participants were compared. However, among participants who improved their balance during the

intervention period, a significant reduction in fall rate was seen in favour of the exercise group.

In conclusion, among older people living in residential care facilities, the Downton fall risk index appears to be a useful tool for predicting residents sustaining a fall, irrespective of the cause of the fall, even with a perspective of only a few months. A high-intensity functional exercise programme is applicable for use, regardless of cognitive function, and has positive long-term effects on balance, gait ability, and lower-limb strength. An intake of a protein-enriched energy supplement immediately after the exercise does not appear to increase the effect of the training. Participants who improve their balance function due to the exercise programme may reduce their risk of falling.

Keywords: aged, frail elderly, cognition disorders, residential facilities, randomized controlled trials, exercise, exercise therapy, nutrition, predictive value of tests, accidental falls: prevention & control

SVENSK SAMMANFATTNING (SUMMARY IN SWEDISH)

Försämrad balans och gångförmåga samt nedsatt benstyrka är vanligt förekommande bland den allt större andelen av äldre människor i samhället. Dessa funktionsnedsättningar kan leda till dramatiska konsekvenser för individen såsom beroende av hjälp vid dagliga aktiviteter, flytt till särskilt boende, fall och frakturer. Träning med hög intensitet har visat sig vara effektivt för att förbättra balans, gångförmåga och benstyrka bland äldre personer. Träningseffekten förefaller bli större om man intar ett proteintillskott i samband med träningen. De allra flesta av dessa träningsstudier har dock utförts bland äldre personer i eget boende. Det saknas därför kunskap om högintensiv träning är genomförbar och effektiv även för äldre personer som bor i särskilda boenden till exempel på servicehus eller på gruppboende för personer med demenssjukdom. Dessa äldre personer har ofta flera kroniska sjukdomar, är beroende av hjälp i dagliga aktiviteter samt har en hög risk för fall och frakturer. Fallförebyggande arbete är viktigt bland dessa personer och en del i det arbetet är att identifiera vilka personer som har en hög risk för att falla. Syftet med denna avhandling var att bland äldre personer på särskilda boenden utvärdera ett instrument som skattar fallrisk samt att utvärdera genomförbarheten av ett högintensivt funktionellt träningsprogram samt dess effekter på fysiska funktioner och fall.

Precisionen att förutsäga fall med Downtons fallriskindex utvärderades bland 78 personer, 65 år eller äldre, på ett särskilt boende. Deltagarna skattades enligt indexet att antingen ha en låg eller en hög risk för att falla. Fallolyckor följdes upp efter tre, sex och tolv månader med två olika falldefinitioner som utgick från orsaken till fallet. 48 deltagare (62%) föll under året och totalt inträffade 148 fallolyckor. När en falldefinition användes som inkluderade alla fall, hade en signifikant större andel av deltagarna i högriskgruppen fallit i jämförelse med lågriskgruppen vid samtliga tre uppföljningstillfällen. Säkerheten i skattningen förbättrades inte när en falldefinition användes som inte inkluderade de fall som bedömdes bero på akut sjukdom eller läkemedelsbiverkan.

Ett högintensivt funktionellt träningsprograms effekter på fysiska funktioner utvärderades vid nio särskilda boenden. De 191 äldre personer som deltog var alla beroende av hjälp vid aktiviteter i dagliga livet. Två tredjedelar av deltagarna kunde inte resa sig upp från en stol utan stöd och hälften av deltagarna hade demenssjukdom. Deltagarna erbjöds efter lottning antingen ett högintensivt funktionellt träningsprogram eller en kontrollaktivitet som inte innehöll fysisk träning. Både träningen och kontrollaktiviteten inkluderade 29 grupptillfällen, som leddes av sjukgymnast respektive arbetsterapeut, under totalt tre månaders tid. Deltagarna lottades även till att antingen få ett 200 ml mjölkbaserat proteinrikt näringstillskott eller en placebodryck, som intogs omedelbart efter varje tränings- respektive aktivitetstillfälle. Den fysiska förmågan följdes upp tre respektive sex månader efter studiens start med Bergs balansskala, 2,4 meters gångtest samt test av maximal benstyrka i benpress. De som utförde mätningarna visste inte vilken aktivitet eller dryck deltagaren hade fått. Resultaten analyserades enligt "intention-to-treat" principen d v s att alla personer ingick i analyserna oavsett hur mycket de deltagit. Analyserna visade att träningsprogrammet gav långtidseffekter vad gäller förbättring i balans, gångförmåga och benstyrka vid jämförelse med kontrollaktiviteten. Det proteinrika näringsstillskottet ökade inte träningseffekten.

Utvärderingen av genomförbarheten av träningsprogrammet visade att det var en hög närvarograd, en relativt hög intensitet i träningen samt endast totalt två allvarliga biverkningar under träningen varav ingen ledde till en bestående skada eller sjukdom. Deltagare med demenssjukdom genomförde träningen på ett liknande sätt som deltagare utan demenssjukdom.

Träningsprogrammets fallförebyggande effekt utvärderades under de sex månaderna som följde efter aktivitetsperioden. Resultaten visade varken på skillnad i antalet fall eller i andelen deltagare som fallit, mellan träningsgruppen och kontrollgruppen, när alla deltagare ingick i analyserna. Däremot var det en minskning av antalet fall i träningsgruppen bland de deltagare i studien som hade förbättrat sin balans under aktivitetsperioden.

Sammanfattningsvis förefaller Downtons fallriskindex vara ett användbart instrument inom särskilda boenden för att förutse vilka personer som kommer att falla, redan vid uppföljning efter några månader. Orsaken till fallen verkar inte påverka säkerheten i skattningen. Ett högintensivt funktionellt träningsprogram är genomförbart för äldre personer inom särskilda boenden, även för personer med demenssjukdom. Träningsprogrammet ger positiva långtidseffekter vad gäller balans, gångförmåga och benstyrka. Dessa förbättringar kan vara av stor betydelse för den äldre personen i det dagliga livet, antingen genom en ökad aktivitet eller genom ökad självständighet. Ett intag av ett proteinrikt näringstillskott omedelbart efter träningen verkar inte ge en förbättrad träningseffekt i denna grupp. Fallolyckor är ett stort problem bland äldre personer i särskilda boenden, men risken förefaller kunna minska genom en förbättrad balans efter ett högintensivt funktionellt träningsprogram.

ABBREVIATIONS

ADL	Activities of daily living
ANCOVA	Analysis of covariance
BMI	Body mass index
CI	Confidence interval
ES	Effect size
FAC	Functional Ambulation Categories
FOPANU Study	Frail Older People – Activity and Nutrition Study in Umeå
HIFE Program	High-Intensity Functional Exercise Program
HR	Hazard ratio
IRR	Incidence rate ratio
MIF chart	Mobility Interaction Fall chart
MMSE	Mini-Mental State Examination
MNA	Mini Nutritional Assessment
NPV	Negative predictive value
OR	Odds ratio
OT	Occupational therapist
PPV	Positive predictive value
PSEP	Prognostic Separation index
PT	Physiotherapist
PY	Person years
RM	Repetition maximum
SD	Standard deviation
SE	Standard error

ORIGINAL PAPERS

The thesis is based on the following papers, which will be referred to in the text by their Roman numerals:

I. Rosendahl E, Lundin-Olsson L, Kallin K, Jensen J, Gustafson Y, Nyberg L. Prediction of falls among older people in residential care facilities by the Downton index. Aging Clin Exp Res 2003;15:142-7.

II. Rosendahl E, Lindelöf N, Littbrand H, Yifter-Lindgren E, Lundin-Olsson L, Håglin L, Gustafson Y, Nyberg L. High-intensity functional exercise program and protein-enriched energy supplement for older persons dependent in ADL: A randomised controlled trial. Aust J Physiother. In press.

III. Littbrand H, Rosendahl E, Lindelöf N, Lundin-Olsson L, Gustafson Y, Nyberg L. A high-intensity functional weight-bearing exercise program for older people dependent in activities of daily living and living in residential care facilities: Evaluation of the applicability with focus on cognitive function. Phys Ther 2006;86:489-98.

IV. Rosendahl E, Gustafson Y, Nordin E, Lundin-Olsson L, Nyberg L. A randomised controlled trial of fall prevention by a high-intensity functional exercise program for older people in residential care facilities. Submitted.

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INTRODUCTION

The proportion of older people in the population is growing. Today, people aged 60 and over comprise 20% of the population in Europe and the proportion is projected to reach 35% in 50 years (1). Old age is associated with reduced function in a wide range of organ systems and functional capacities, for example, muscle mass and strength, gait speed and stability, proprioception, balance, and aerobic capacity (2). In most physiological systems, the normal aging process does not result in significant impairment or dysfunction due to a reserve capacity. However, diseases or inactivity, together with age-related reduction in the physiological system, cause impairments (2). Impairments in balance, mobility, or lower-limb strength are associated with an increased risk of dramatic consequences for the individual such as dependency in activities of daily living (ADL) (3, 4), falls and fractures (5, 6), hospitalisation (7), and admission to a nursing home (8).

In Sweden, around 110 000 (7%) of the people aged 65 years or over live in some type of residential care facility, i.e. nursing home, group-dwelling for people with dementia, old people's home, or service flat (9). Most of these people have cognitive or physical impairment and thus require supervision, functional support or nursing care. In addition, most people in residential care facilities are frail i.e. have a multi-system reduction in reserve capacity and are thus at increased risk of disability as a result of minor external stresses (10). A common major health problem in older people living in residential care facilities is low energy intake and malnutrition (11, 12), which is associated with lower psychosocial well-being, impaired muscle function and poorer recovery from diseases (13, 14).

Falls are common among older people and pose a major threat to health and independence. Among people aged 65 years and over, one third of those living in the community (i.e. in their own homes) fall each year (15-17), almost half the accidents result in an injury (16, 18), and around one in twenty in a fracture (15, 16). In Sweden, with a population of around 9 million, about 19 000 people sustain hip fractures each year of which the vast majority are caused by accidental falls in old age (19). In older people, falls are the leading cause of death from injury (20). Psychological consequences of falls are also common, one third of older people who sustain a fall are worried about falling again (21). Fear of falling leads to an increased risk of inactivity and a reduction in the ability to perform activities of daily living as well as to increased risk of falling (22, 23). Among older people living in residential care facilities, almost two thirds fall each year (24, 25) and they experience falls three times as frequently as older people living in the community (17). In addition, the incidence rates for both fall-related major soft tissue injuries and fractures are more than twice as high for this group of older people (26).

Lower-limb muscle strength (force-generating capacity of muscle) and muscle power (product of force and velocity of movement) are two closely related aspects of muscle function that seem to play a central role in the maintenance of mobility in old age, since they are associated with gait ability (27, 28) and balance function (29, 30). However, the association between lower-limb strength or power and everyday activities such as gait is not linear (27, 31). The association appears to be more distinct among people with impaired muscle strength. There seem to be threshold values where a further loss of strength may make it impossible to perform some everyday activity without assistance (32). Consequently, this also indicates that a small gain in strength may result in a significant improvement in daily activities (27, 32). On average for both men and women, based mainly on results in cross-sectional studies, maximal strength is reduced by 20-40% at 60-70 years of age and by 50% or more at 80 years and over (33), and the decline in muscle power is even greater (34). However, in a longitudinal study, on average no reduction in knee extensor strength for people aged 75 years was seen when they were followed up for 5 years (35). Maintenance of strength was associated with a maintained level of physical activity over the time period. In another study, older people (mean age 68 years) who regularly carried out strength training had a strength similar to that of young, sedentary people (36). It is of special importance that older women, compared with older men, have around 40% less absolute lower-limb strength (37), as well as less lower-limb power, even when adjusted for body weight (28, 38). This emphasises the extra importance for women to retain their muscle strength and muscle power since they are, in general, closer to the thresholds for impaired mobility and disability (28, 38).

Exercise

In the 1980s and early 1990s, it was demonstrated in small, mainly uncontrolled, studies that older people could also increase their strength (39-41) and their muscle mass (42, 43) through strength training. These studies were followed by larger controlled studies in the middle of 1990s with similar positive findings (44, 45), which in their turn have been followed by many randomised controlled trials that have confirmed these effects, as summarized in recent reviews (46, 47). Both older men and women seem to show a similar relative increase in strength and muscle mass as younger people (48, 49). Nowadays, there are also studies which show positive effects of strength training in people with diagnoses common in old age, such as osteoarthritis in hip or knee (50, 51), hip fracture (52-54), heart failure (55) and stroke (56). Similar to strength training, controlled studies concerning the possibility of improving balance and gait ability among older people were presented in the middle of 1990s (57-59). In addition to improvements in strength, balance, and gait ability, exercise in older people has produced positive results regarding many other outcomes such as increased aerobic capacity (60, 61), reduced depressive symptoms (62, 63), and increased cognitive function (64).

Furthermore, physical activity is important in preventing and treating many disability-related diseases and syndromes, such as, diabetes mellitus type 2, hypertension, coronary heart disease, and osteoporosis (65-67). In fact, physical activity may well be the most universal and effective treatment for chronic illness in old age, despite many of the recent developments in medical care through advanced technology (67).

In all the studies targeting various types of exercise programmes in old age the participants were mainly older people living in the community and with moderate or no physical and cognitive impairments. Thus, there is a need for exercise studies targeting older people living in residential care facilities and with severe cognitive or physical impairment.

Frequency, exercise period and volume

No consensus has been reached regarding the optimal frequency (e.g. number of sessions per week), length of exercise period, and volume (e.g. total number of exercises, length of exercise session) in different training methods for older people. However, most strength training studies have used interventions with sessions 2-3 times per week for a total of 8-12 weeks but the number of exercises has varied widely (47). A small (n=46) randomised controlled study of strength training in older men indicated that training once a week results in a similar effect on strength as training two or three times per week (68). In contrast, a meta-analysis on studies of various age-groups concluded that untrained participants experience maximum effects from strength training each muscle group 3 times per week; the corresponding frequency for trained participants was twice a week (69). In addition, the results in the meta-analysis indicated an advantage if at least two sets of each exercise were performed. This was also shown in a small (n=28) randomised study among older men and women, where strength training using three sets of each exercise resulted in a greater gain in strength than training using only one set (70). The use of a strength exercise period of at least eight weeks seems to be related to the time period needed for muscle hypertrophy to occur (71), although the increase in strength is also due to central nervous system activation and motor skill coordination (72). A continuing increase in strength was seen in a strength-training programme lasting two years, with the greatest gain occurring in the first three months (73). The length of an exercise session is normally between 30 to 60 minutes for most training methods (74), but can be up to 6 hours for movement therapy following stroke (75, 76).

Intensity

The intensity seems to have a great impact on the result of the training. A recent Cochrane review concluded that strength training with high intensity among older people has a greater effect on strength than lower intensity strength training (47). This finding is supported by earlier reviews which, for different training methods, have recommended exercise with a high intensity in relation to the individual's maximum capacity (46, 77). However, a contradictory result was recently presented in a review on exercise among older people with cognitive impairment and dementia. In this review, the result presented indicated a negative association between intensity and effect, even if the difference was non-significant (74). It is important when interpreting these results to remember that intensity is a concept that is described in a variety of ways. The intensity can be described, for example, as related to the individual maximum capacity in a body function (e.g. related to maximum muscle function or aerobic capacity), as the individual's exertion, or as the quantity of the training (e.g. number of weeks or length of exercise session) (74, 77, 78). In the Cochrane review, the definition used for high-intensity training was notably not explicitly presented but only studies "in which the participants exercised their muscles against an external force that was set at specific intensity for each participant" were included (47). This indicates that the definition of high intensity used was related to the individual. In the review regarding older people with cognitive impairment, intensity was instead described as the length of the exercise session and, thus, was less related to the participant's performance or maximum capacity (74). It is probable that using a definition of exercise intensity less concerned with the participant's ability or performance during the exercise session has less association with the effect of the training than an intensity definition which is related to the individual. Thus, the lack of positive impact by higher exercise intensity in the review regarding older people with cognitive impairment might be due to the definition used.

Intensity of strength exercises. As early as 1945, DeLorme presented "repetition maximum" (RM) as a way of measuring strength and determining an appropriate exercise load. 1 RM was defined as the "maximum weight that can be lifted with one repetition" and 10 RM as "that weight which requires maximum exertion to perform ten repetitions" (79). DeLorme recommended high-intensity strength training based on 10 RM to strengthen weak muscles following injuries to the knee or femoral fractures (79-81). Even after more than 50 years, DeLorme's presentation of high intensity strength training is valid, today 8-12 RM is a commonly used recommendation for older people living both in the community and in residential care facilities (46, 77).

Over the years values for 2 RM and more have been presented as percentages of 1 RM, often as models in different tables or graphs. The idea of these models is that, by testing the load for 1 RM before or during the exercise period, the percentage of the maximum load at a given number of repetitions can be used. However, the values presented are not consistent, for example in one study 12 RM is described as approximately 60% of 1 RM and in another study 15 RM is described as approximately 70% of 1 RM (69, 82). Thus, there seems to be a lack of consensus and, to my knowledge, these models describing the association between number and percentages of RM have not been evaluated in any population. It could be questioned whether the percentages of 1 RM have any practical use. Instead, when describing the intensity as solely the number of RM, the performance of the exercise can be adjusted at each exercise session with no need to test 1 RM before or during the exercise period (if it is not used as an outcome measure). Using the number of RM facilitates the exercises being performed at the planned intensity at each session and, thus, that the training is as effective as possible.

Intensity of balance exercises. The intensity of balance exercises is rarely described, probably because balance is a more complex function than muscle strength. Fiatarone Singh has described three ways to increase the intensity in balance exercises by progressively challenging the balance system; by reducing the base of support, by reducing other sensory input (e.g. closing eyes), or by perturbation of the centre of mass (e.g. leaning forward) (77). This challenges the individual's postural stability i.e. the ability to maintain the position of the body within specific limits of space, referred to as stability limits (30). Consequently, a high intensity in balance exercises can be described as balance exercises performed near the limits of maintaining postural stability.

Adverse events

Although training, and especially high-intensity training, has proved successful for older people, safety issues are of great importance. As no serious adverse events in high-intensity exercise programmes among older people have been reported, prescribing exercise is recommended even for frail older people (77, 83). Contra-indications for exercise, such as acute febrile illness, unstable chest pain, and rapidly terminal illness are similar for frail older people and for young people (48, 77). Even in frail older people, being sedentary appears to be a far more dangerous condition than physical activity (48, 77). However, systematic and accurate registration of adverse events is often lacking in exercise studies so careful assessments of adverse events is an important issue for future research (47).

Design and supervision of an exercise programme

There are many components in the design, progression and performance of a strength-training programme, for example, selection and order of exercises, loading, the velocity of the movement, length of rest periods, and the actual performance of the exercises, all of which are important for the safety and effectiveness of the training (46). It is therefore recommended that trained specialists should be involved in this process (46). Many of these components are also present in balance training, but aspects of motor learning seem even more important, for example, the use of different types of feed-back (e.g. intrinsic or extrinsic) or practice conditions (e.g. random or blocked order of the tasks) (30). Bearing in mind that older people, especially in residential care facilities, often have impairments and diseases which can affect applicability, it seems important that trained exercise specialists (e.g. physiotherapists) who are also experienced in working with frail older people should be involved in the planning and performance of their exercise programme (84). The exercises could preferably be performed in groups, even if they are supervised one-to-one, so as to be less time-consuming for the supervisor and to provide an opportunity for social interaction among the participants (84).

Specificity of the training

The concept of specificity of training means that the effects of the training are specific to the stimulus applied i.e. in strength training regarding muscles groups trained, speed of movement, range of motion, and posture (46, 85, 86). Thus, the most effective training programs are those which train the specific tasks or activities that are targeted for improvement, although there does appear to be some carry over of training effects (46). However, the carry over effects seem to be mainly limited to people with impairments in physical functions who, as a result of strength training, improve their strength beyond a threshold value and thus, instead of needing assistance, manage independently to, for example, rise from a chair or walk (32). This is supported by studies among older people with moderate physical impairments living in nursing homes, where strength training of the knee and hip extensor muscles, or knee extensor muscles only, apart from improvements in strength, have also resulted in carry over effect of improving gait ability and stair-climbing (44, 87). In contrast, in older people with no physical impairments living in the community, strength training resulting in improvements in lower-limb strength has resulted in small or no improvements in gait ability, rising from a chair, and climbing stairs (88, 89).

Functional weight-bearing exercise

Mobility problems among older people are often related to a combination of impairments in balance, gait, and lower-limb strength, which are also risk factors for falls (5, 90). It is therefore important to design an exercise programme aimed at improving all three functions. Functional weight-bearing exercise programmes have been shown to have wide-ranging effects on physical function among older people with moderate or no impairments (91-94). This training method consists of functional-based exercises for muscle strength, balance, and gait ability in weight-bearing positions. Clinical experience suggests that the exercises also are suitable for frail older people in residential care facilities, including those with severe cognitive impairment. The exercises are easy to follow and there is no need for specific exercise facilities. In addition, it is possible to achieve high intensity in strength and balance exercises for each participant by exercising with high load on the lower-limb muscle groups and near the limit of postural stability. The load can be increased, for example, by adjusting the performance of the exercise or by using free weights such as a weighted belt. The use of functional weight-bearing exercises, with or without free weights, may result in a pattern of coordination that mimics the movement requirements of a specific everyday task, in contrast to training with machines (46). Thus, the training method which includes everyday tasks such as rising from a chair or climbing stairs, creates favourable conditions for transferring the improvement in physical functions to performance in daily living (46, 85, 86).

Exercise to improve physical function in residential care facilities

While there is a large number of studies about the effect of exercise programmes in people living in the community, fewer studies have been performed to evaluate their effect for older people living in residential care facilities. These studies have been summarised in a recent review (95). As for people living in the community, studies in residential care facilities using an exercise intervention of high intensity (44, 96) have better results regarding strength and balance than studies using a lower intensity (97, 98). This was also shown in a small (n=22) 10-week study where high-intensity strength exercise for older people in nursing homes produced a better effect in strength, muscle endurance and walking distance, than low-intensity strength exercise (87). However, this does not mean that low-intensity exercise is not beneficial at all since also the low-intensity group improved their muscle and functional performance compared with a placebo-control group.

There are quite a few exercise studies among older people with severe cognitive or physical impairments (99-107), of which most are directed to people living in residential care facilities. A recent meta-analysis presented positive effects from exercise in older people with cognitive impairments and dementia (74). However, most studies reviewed had important deficiencies in methodological quality, e.g. regarding blinding procedure, and the impact of the different training methods used (e.g. high-intensity strength or light aerobic exercises) was not considered. To my knowledge, there are only two studies of a high-intensity exercise programme involving older people with severe cognitive and physical impairments (101, 106). In one of these studies the exercising was only one aspect of a multi-factorial fall-prevention programme (106) and in the other study no information about the applicability was presented (101). Therefore, knowledge concerning the applicability and effect of a high-intensity exercise programme is very limited for older people with severe cognitive and physical impairments. It may be difficult for older people with severe cognitive or physical impairments to participate in a high-intensity exercise programme due to, for example, dependency on assistance during the exercise session. In addition, applying appropriate exercise intensity may be difficult because of the older peoples' impaired functions, fluctuating health status, and high prevalence of such diseases as depression, heart failure and osteoporosis (108). These characteristics may also lead to a high risk of serious adverse events (47).

Protein supplement to increase the effect of the training

Strength training in both young and older people stimulates muscle protein synthesis, which is required for muscle hypertrophy, and an intake of protein after exercising has a synergistic effect (109, 110). The increase of protein synthesis after strength training is reduced over time (111). It seems therefore preferable to have an early intake of protein after training, as shown in a study among healthy older men where an immediate intake of 10 g protein after strength exercising had a significant effect on muscle hypertrophy and strength compared with an later intake of protein which only had effect in one of the two strength outcome measures (112). Among frail older people, combinations of strength training and protein-energy supplement have not shown any interaction effects on physical function (44, 113). In these studies, however, the supplement was not taken directly in connection with the exercise session. Therefore, the effect of an immediate intake of protein after strength exercises among frail older people is still unknown.

The impact of the methodological quality in exercise studies

Even randomised control trials may have severe methodological shortcomings. In order to increase the internal validity in a study, it is important to have a design which includes intention-to-treat analyses (i.e. includes all participants in the analyses regardless of whether they received the intervention or not), blinded assessors, and concealed randomisation (114). According to a systematic review of randomised controlled strength training trials among older people, studies with at least one of these design features have lower effect sizes than studies with lower methodological quality (47, 114). Thus, low-quality studies tend to overestimate the effect of the intervention (47, 114). Surprisingly, the use of attention control groups was not shown to have a significant impact on the effect size. This may be explained by the varying amount of attention the control groups received in the reviewed studies. For example, in one study the control group received only one tenth of the number of sessions that the intervention group received and in another study the number of sessions was equal. It is also important for internal validity to have an equal loss of participants to follow up. In the review, the number of drop-outs in the exercise groups were in total more than 50% higher than in the control groups (47, 114). In addition, when reporting from an exercise intervention study it is very important for the implications of the results for researchers and clinicians, to describe in detail the characteristics of the participants, the training method, the intensity, and compliance with the prescription (77).

Fall prediction

Identification of individuals at a high risk of falling is important for the design of fall-prevention programmes (115). A large number of risk factors have been identified in the literature, illustrating the complex causality of falls.

Impairments regarding balance, gait, muscle strength, vision, or cognition, as well as medical conditions, drug use, and environmental hazards are frequently suggested as important risk factors (5, 90). The risk of falling consistently increases as the number of risk factors increases for the individual (15, 18). On the basis of this knowledge, a number of fall-risk assessment tools, screening for well-established risk factors, have been presented but only a few have been validated externally, as summarised in a recent review (115). A validation of a fall-risk assessment tool on new data in a different centre or facility, preferably by other researches, prevents an overestimation of the prediction accuracy from the results of the original data (116).

The follow-up period varies in studies of fall-risk assessment tools from one day or one week up to one year (117-119), but how the prediction accuracy varies with the length of the follow-up period is not yet known. In addition, different fall definitions are used in the literature, e.g. in relation to the cause of the fall (120). The influence on the outcome of using different definitions is scarcely evaluated but data from fall-prevention intervention studies indicate that it may have a significant influence on the result (120). When applying a fall-risk assessment tool, it could be important to know whether the prediction accuracy differs if a fall definition is used which includes all falls, compared to a definition limited to falls not precipitated by acute illness, acute disease, or drug side-effects. Among frail older people, these are common precipitating factors for falls which might be difficult to predict using a fall-risk assessment tool (25).

Fall prediction in residential care facilities

Few fall-risk assessment tools have been developed among older people living in residential care facilities (119, 121-123). Of these, the Tinnetti fall-risk index seems too complex to be conveniently used in clinical practise (121), and only a part of the index in a modified version, the Tinetti balance scale, has been validated externally (124). The Mobility Interaction Fall (MIF) chart is easy to complete, but the prediction accuracy was lower when it was validated in an independent sample than in the developmental sample (123, 125). However, when the MIF chart was combined with the staff's judgement of the resident's fall risk or fall history, the accuracy improved (125). Becker et al. have recently developed a fall-screening instrument, with different risk factors depending on the resident's ability to transfer and history of falls, which has not yet been externally validated (119). The Downton index was developed in a small sample (n=28) of older people in a continuing care ward but includes well-documented risk factors and therefore offers satisfactory content validity. In addition, it seems to be easy to administer. The index has only been validated among stroke patients in geriatric rehabilitation (126), where a moderate prediction accuracy was found. Thus, the index needs to be validated among older people living in residential care facilities.

Fall prevention

There is currently strong evidence that multifactorial intervention programmes, based on individual screening for risk factors, have a preventive potential among older people living in the community (127, 128). This seems quite logical considering the large number of fall-risk factors. Exercise interventions including balance and strength exercises have proved to be an important part of multifactorial preventive interventions (128, 129) and have also been effective as single interventions in older people living in the community (130-133) as well as in retirement villages (134). However, a larger number of exercise studies among older people living in the community have failed to show a fall-prevention effect than have succeeded in showing such, as summarised in a recent Cochrane review (127). It seems important for achieving a positive effect that the exercises are individually tailored, that they target both strength and balance, and are mainly performed in weight-bearing positions. A non-traditional form of exercise, Tai Chi group interventions, have been successful in preventing falls in older people living in the community (135, 136), but not in older people who are transitioning to frailty and living in congregate living facilities (137). Other single interventions that have been beneficial in older people living in the community are, for example, home hazard assessment and modification for people with a history of falls or poor vision, as well as the withdrawal of psychotropic medication (127, 138).

Fall prevention in residential care facilities

Among older people living in residential care facilities, evidence of the effectiveness for multifactorial interventions programmes is weaker since contradictory results have been reported (98, 108, 139-143). However, two studies concerning multifactorial interventions have been successful in reducing falls (108, 140). In both these studies, high-intensity strength and balance exercises formed a part of the fall-prevention programme.

In nursing homes and in other residential care facilities, different exercise interventions which failed to show significant effects on balance and strength have not succeeded in preventing falls (97, 144). One controlled study using computerised high-intensity dynamic balance training, which led to an improvement in functional balance (145), was successful in reducing falls (146). However, as stated by the author, the sample size was small (n=27) which limits the external validity of the results. Thus, in older people living in residential care facilities, there is a lack of knowledge about the fall-prevention effect of a high-intensity exercise programme that targets strength and balance and is successful in improving these risk factors for falls.

Rationale for the thesis

Impairments in balance, mobility, and lower-limb strength are common in the growing population of older people and can lead to dramatic consequences for the individual, such as dependency in ADL, admission to a nursing home, falls, and fractures. Most people living in residential care facilities have cognitive or physical impairment and are dependent in ADL. They fall frequently and are prone to sustain fractures. An improvement in physical function might be of great importance for individuals in residential care facilities, through achieving a higher activity level, more independence, or fewer falls. Despite these important potential effects, few studies concerning exercise interventions have been performed in these kinds of settings.

Identification of individuals with a high risk of falling is often an important part of prevention programmes. Many fall-risk assessment tools have been presented but only few have been developed among older people living in residential care facilities. The Downton index was developed for older people in continuing care wards and includes well-documented risk factors for falls, but it needs to be validated externally in residential care facilities. The follow-up period in studies of fall-risk assessment tools has varied widely, but how the prediction accuracy varies with the length of the follow-up period is not yet known. Furthermore, the influence on the outcome of using different fall definitions is scarcely evaluated. When applying a fall-risk assessment tool, it could be important to know whether the prediction accuracy differs if a fall definition is used which includes all falls, compared to a definition limited to falls not precipitated by acute illness, acute disease, or drug side-effects. Among frail older people, these are common precipitating factors for falls that might be difficult to predict.

High-intensity exercise programmes have been shown to improve strength, balance and gait ability in older people with moderate or no impairments, and an immediate intake of protein after the training seems to increase the effect on strength. However, knowledge concerning the applicability and effect of high-intensity exercise programmes is limited for older people with severe cognitive or physical impairments. This group is characterised by a fluctuating health status, poor nutritional status and a high prevalence of diseases, which may lead to difficulties in applying appropriate exercise intensity, as well as to a high risk of serious adverse events. Clinical experience suggests that functional weight-bearing exercise is suitable for frail older people in residential care facilities, including those with severe cognitive impairment. The functional exercises are easy to follow and there is no need for specific exercise facilities. In addition, it is possible to achieve high intensity in the training for each individual.

Multifactorial interventions have been successful in preventing falls among older people living in the community. Exercise programmes seem to be an important part of these interventions and have also been successful as single interventions in this group. It seems important for achieving a positive effect that the exercises are individually tailored, that they target both strength and balance, and are mainly performed in weight-bearing positions. Among older people living in residential care facilities, evidence of the effectiveness of multifactorial intervention programmes is weaker, although two studies that include high-intensity exercises have demonstrated success in reducing falls. In these kinds of settings, only one small study has presented a positive effect of exercise as a single fall-prevention intervention. However, non-successful exercise interventions have failed to show any significant effects on balance and strength. Thus, in older people living in residential care facilities, there is a lack of knowledge about the fall-prevention effect of a high-intensity exercise programme that improves strength and balance.

AIMS OF THE THESIS

This thesis targeted older people living in residential care facilities. The main purposes were to validate a fall-risk assessment tool and to evaluate a high-intensity functional weight-bearing exercise programme regarding its applicability as well as its effects on physical functions and falls.

Specific aims

- to evaluate the prediction accuracy of the Downton fall-risk index at 3, 6 and 12 months, using two different fall definitions related to the cause of the fall (Paper I).

- to evaluate whether a high-intensity functional exercise programme improves balance, gait ability, and lower-limb strength in a short- and a long-term perspective, as well as whether an intake of a protein-enriched energy supplement immediately after the exercises increases the effects of the training (Paper II).

- to evaluate the applicability of a high-intensity functional exercise programme with regard to attendance, achieved intensity, and adverse events, and further to analyse whether or not cognitive function was associated with the applicability (Paper III).

- to evaluate whether a high-intensity functional exercise programme reduces falls (Paper IV).

METHODS

Setting and participants

Two main study samples of residents living in residential care facilities in Umeå, a town in northern Sweden, were included in this thesis. The first sample (Paper I) comprised 78 participants and the second sample (Papers II-IV) 191 participants (Figure 1).

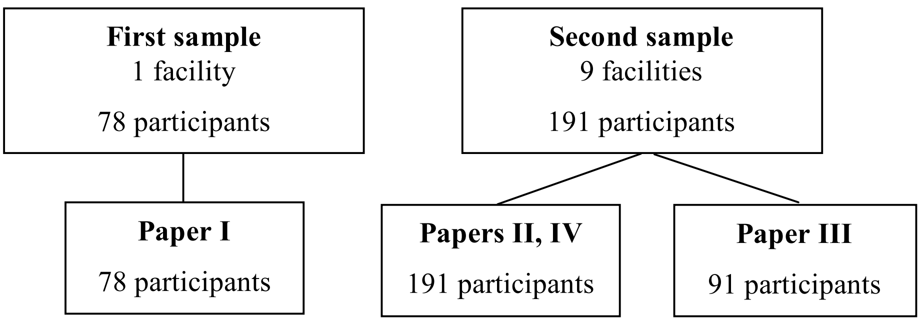

Figure 1. The two main study samples in Papers I-IV

The participants either lived in staffed units, with private rooms but shared dining and living rooms, or lived in private flats with access to dining facilities, alarms, and on-site nursing and care. In Paper I, the participants lived in one residential care facility, which comprised four staffed units (of which one was for people with dementia) as well as private flats. In Papers II-IV, participants lived in nine residential care facilities which all comprised private flats. Four facilities also included units for people with dementia (in total eleven units).

Paper I

Paper I included residents aged 65 years or over. Seventy-eight residents, of the 83 living at the facility in February 1994 or who moved in during the following one-year period, were included. Of the five residents not included, three were younger than 65 years and two declined to participate.

Papers II-IV

Inclusion criteria in Papers II-IV were: aged 65 or over, dependent on assistance from a person in one or more personal ADL according to the Katz Index (147), able to rise from a chair with armrests with the help of no more than one person, a Mini-Mental State Examination (MMSE) (148) score of ten or more, and approval from the resident's physician. All residents (n=487) were screened by a physiotherapist (PT) during the first two months of 2002 (Figure 2).

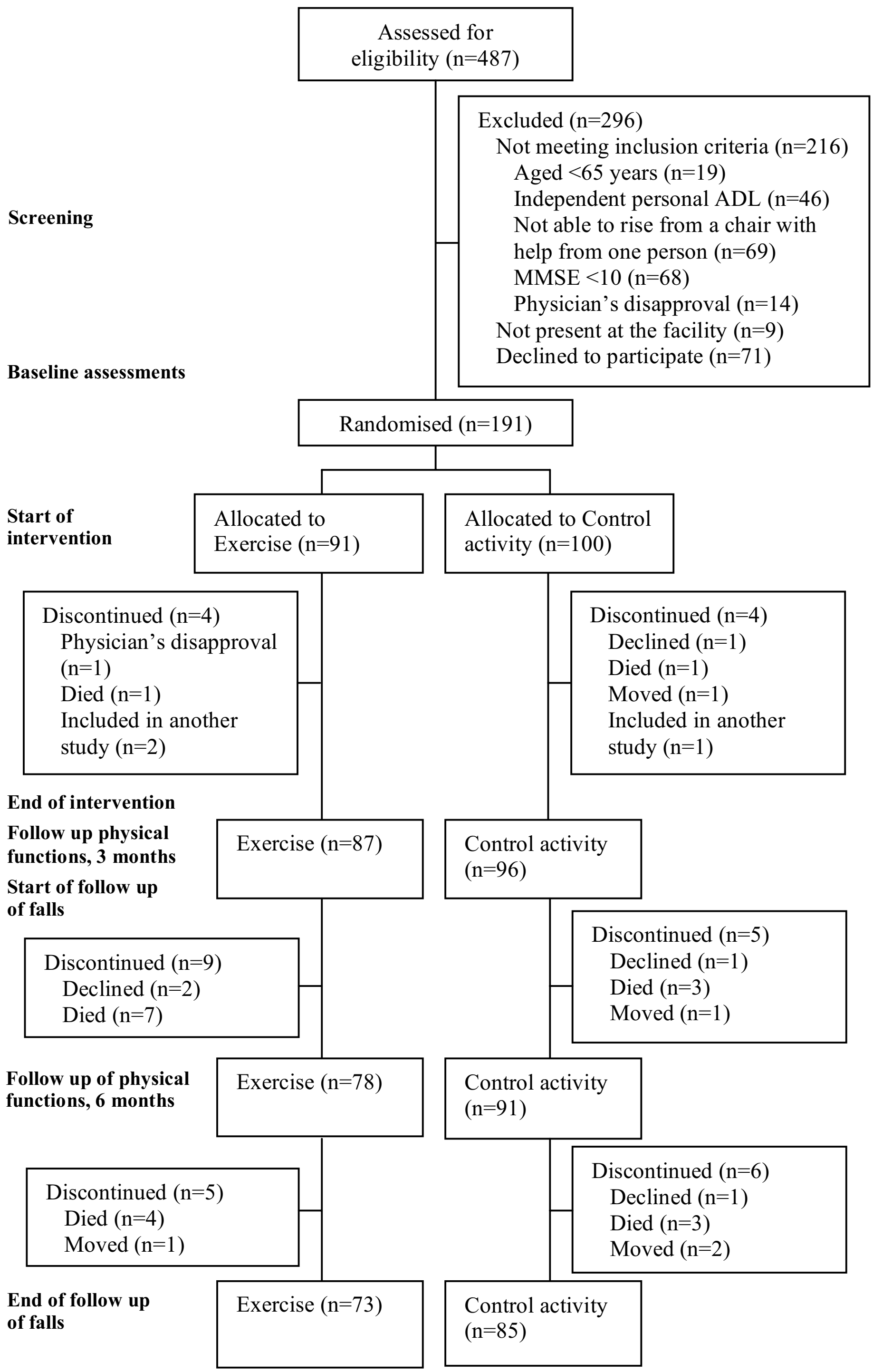

Figure 2. Flow of participants, Papers II-IV

Papers II and IV included 191 people (Figure 2). There were no differences regarding age, sex, and Katz ADL Index score between those included and those who declined to participate. At the follow up of physical functions at 3 months, also the start of the follow up of falls, 183 (96%) of the 191 participants remained in the study (Papers II and IV). The corresponding figure at the follow up of physical function at 6 months was 169 (88%) participants (Paper II).

Paper III included the 91 participants randomised to the exercise intervention (Figure 2).

Ethical approval

The studies were approved by the Ethics Committee of the Medical Faculty of Umeå University (§84/94 and §391/01). The residents who met the inclusion criteria were given written and oral information about the study (Papers I-IV). The residents, or their relatives when appropriate due to cognitive impairment, gave their informed oral consent to participation.

Study design

An overview of the study designs in Papers I-IV is presented below (Table 1).

Table 1. Overview of the study design, evaluation target, control, outcome, and outcome measures in Papers I-IV

	Paper I	Paper II	Paper III	Paper IV
Design	Prospective cohort study	Randomised controlled trial	Prospective cohort study	Randomised controlled trial
Evaluation target	Downton index	High-intensity functional exercise Protein supplement	High-intensity functional exercise	High-intensity functional exercise
Control	–	Control activity Placebo drink	–	Control activity
Outcome	Fall prediction	Balance Gait ability Lower-limb strength	Applicability	Fall prevention
Outcome measures	Proportion of participants sustaining a fall Time to first fall	Berg Balance Scale Gait speed, usual and maximum 1 RM in leg press	Attendance Intensity Adverse events	Fall rate Proportion of participants sustaining a fall

RM=repetition maximum

Paper I

Paper I was a prospective cohort study designed to validate the Downton fall-risk index. The staff at the facility were blinded for the total score.

Papers II-IV

Papers II-IV were parts of the Frail Older People – Activity and Nutrition Study in Umeå (the FOPANU Study), which was a stratified cluster randomised controlled trial comprising both an exercise intervention compared with a control activity as well as a nutrition intervention compared with placebo in a 2 x 2 factorial model. For all outcome measures in Paper II, assessors were blinded to group allocations. The exercise intervention and control activity were presented to participants and staff at the facilities without indication of the study hypothesis. Regarding the nutrition intervention, participants as well as therapists, who administered the nutrition intervention and supervised the exercise or control activities, were blinded. The randomisation was performed after the inclusion of participants and baseline assessments. To reduce contamination by the exercise intervention, 34 clusters, comprising 3 to 9 participants living on the same floor, or in the same wing, or unit, were randomly assigned to the exercise intervention or control activity. The randomisation was stratified to include both groups in each facility, in order to minimise the risk of any impact from factors associated with the facility. Within each cluster the nutrition intervention was individually randomised. Researchers not involved in the study performed the randomisation using lots in sealed non-transparent envelopes.

Evaluation target

Downton index (Paper I)

The Downton fall-risk index includes 11 risk items (Table 2), which are scored one point each and added to give a total index score (122). A score of 3 or more is taken to indicate a high risk of falls (122).

Table 2. The Downton fall-risk index

Item	Score*
Known previous falls	
No	0
Yes	1
Medications	
None	0
Tranquillizers/sedatives	1
Diuretics	1
Antihypertensives (other than diuretics)	1
Antiparkinsonian drugs	1
Antidepressants	1
Other medications	0
Sensory deficits	
None	0
Visual impairment	1
Hearing impairment	1
Limb impairment	1
Mental state	
Orientated	0
Confused (cognitive impairment)	1
Gait	
Normal (safe without walking aids)	0
Safe with walking aids	0
Unsafe (with/without walking aids)	1
Unable	0

*Item scores are added to give a total index score, ranging from 0 to 11, where ≥3 is taken to indicate a high risk of falls.

No explicit operational definitions were provided with the Downton fall-risk index (122). Therefore, the definitions used in this study were specified. A physician made almost all the assessments for the index. The history of falls during the preceding year was obtained from medical records and from the participants themselves, or from family members or caregivers. Medications were grouped according to the Downton index categories. "Visual impairment" was noted if the participant, with or without glasses, was unable to read a couple of words in 5 mm block letters at reading distance. "Hearing impairment" was noted if the participant, without a hearing aid, was unable to hear a conversation at normal voice level at a distance of 1 meter. "Limb impairment" was assessed by a PT and defined as the presence of an amputated limb, signs of extremity pareses, muscle weakness, or sensory impairments. Regarding mental state, the term "cognitive impairment" was used instead of "confused". The well-established MMSE cut-off score of ≤23/30 points was used as a diagnostic criterion indicating "cognitive impairment" (149), instead of the cut-off score of <7/10 points in the Abbreviated Mental Test score (150) (used in the original publication of the index). The participant's ability to walk safely was rated by a PT according to the following categories: normal (safe without walking aids), safe with walking aids, unsafe, or unable. Safe gait was noted when the participant was able to move easily and safely when, for example, opening and closing the door, meeting people in the hallway and approaching a chair to sit down. Unsafe gait designates that the participant moved in an uncontrolled way, staggered or stumbled.

Exercise intervention and Control activity (Papers II-IV)

Exercise intervention (Papers II-IV). The intervention was based on the High-Intensity Functional Exercise Program (the HIFE Program), which was developed for this study by PTs (151).

The HIFE Program was based on exercising in functional weight-bearing positions. The programme included lower-limb strength and balance exercises performed while standing and walking, at a high intensity, if possible, for each participant. The collection of exercises was developed according to three criteria: 1) applicable without access to special exercise facilities, 2) adaptable for frail older people with different functional levels, including independent walkers and those needing help with all mobility, and 3) possibility for progression of the exercises in two ways; either to increase the difficulty in a specific exercise or to change to another, more challenging, exercise. In all, 41 exercises, distributed over five categories, were included in the collection of exercises (Table 3).

Table 3. Collection of exercises in the High-Intensity Functional Exercise Program (the HIFE Program): categories and examples

Category	Name	Examples of exercises
A	Static* and dynamic[†] balance exercises in combination with lower-limb strength exercises	Squat in a parallel or walking stance Step-up on to boxes Forward or side lunge
B	Dynamic balance exercises in walking	Walking over obstacles Walking on a soft surface Walking with numerous turns
C	Static and dynamic balance exercises in standing	Turning trunk and head Body weight transfer in a parallel or walking stance Side step and return
D	Lower-limb strength exercises with continuous balance support	Squat in a parallel or walking stance Standing-up from sitting Heel-raise
E	Walking with continuous balance support	Walking in various directions Walking with numerous turns

The load in the lower-limb strength exercises can be increased by adjusting the performance of the exercise (e.g. by doing deeper squats or doing step-ups onto a higher box) or by using a weighted belt worn around the waist, loaded with a maximum of 12 kg. The difficulty of each balance exercise can be increased, for example, by standing or walking with a narrower base of support or by standing or walking on a more challenging surface.
*Static balance exercises: fixed base of support.
[†]Dynamic balance exercises: changing base of support.

For the selection of exercise categories, a hierarchical model in the HIFE Program, based on the participant's walking ability without a walking aid, was used as a guideline (Table 4). Within each category, the PTs selected exercises for each participant according to their functional deficits. The intensity of the exercises was self-paced, although the participants were encouraged by the PTs to exercise at a high intensity and to progressively increase the load or the difficulty in each exercise. The exercises were adjusted for each session depending on changes in functional and health status. It was recommended that the participants perform at least two lower-limb strength and two balance exercises in two sets at each session and that the exercises be preceded by a warm-up for five minutes while sitting. Strength exercises were intended to be performed at 8–12 RM, thus increasing the load as soon as the participant performed more than 12 repetitions. For the first two weeks, 13–15 RM was recommended as a build-up period. The load of the leg-extensor muscle groups was determined, for each strength exercise separately, during each session according to the participant's performance. The load was increased through adjusting the performance of the exercise (e.g. by doing deeper squats or step-ups on to a higher box) or by using a weighted belt worn around the waist, loaded with a maximum of 12 kg. The balance exercises were intended to fully challenge the participant's postural stability, i.e. to be performed near the limits of maintaining postural stability. The difficulty of each balance exercise was increased, for example, by standing or walking with a narrower base of support or by standing or walking on a more challenging surface. For safety reasons, the participants used a belt with handles worn around the waist so that the PT could more easily prevent the participant from falling when challenging postural stability. All exercise equipment was portable. In the end of the exercise period, physical tasks were introduced for the participant, in cooperation with a staff member, in order to maintain physical function. The tasks were to be integrated into daily life activities and were individually recommended regarding type (e.g. walking, squats, and standing without balance support), number (one to four) and frequency (weekly up to daily). The tasks were followed up after three months, by interviewing staff about the compliance during the previous two weeks.

Table 4. Model in the High-Intensity Functional Exercise Program (the HIFE Program) for selection of exercise categories

Physical function group*	Recommended categories in the collection of exercises
1) Walking without any physical support or supervision (n=27)	A. Static and dynamic balance exercises in combination with lower-limb strength exercises
	B. Dynamic balance exercises in walking
2) Walking with supervision or minor physical support from one person (n=35)	A. Static and dynamic balance exercises in combination with lower-limb strength exercises
	B. Dynamic balance exercises in walking
	C. Static and dynamic balance exercises in standing
3) Walking with major physical support or not able to walk (n=29)	C. Static and dynamic balance exercises in standing
	D. Lower-limb strength exercises with continuous balance support
	E. Walking with continuous balance support

*The participant's need for personal support when walking a short distance (5–10 meters) without a walking aid. Number of participants categorised to the physical function group shown in parentheses.

Control activity (Papers II and IV). The control activity programme was developed for this study by occupational therapists (OTs) and included activities performed while sitting, e.g. watching films, reading, singing, and conversation. The programme was based on themes, e.g. the old country shop, famous people, and games from the past, and was expected to be interesting and stimulating for older people including those with severe cognitive impairment.

Procedure for Exercise intervention and Control activity (Papers II-IV). The exercise intervention and the control activity started in March 2002 and were performed in groups of 3–9 participants supervised by two PTs (exercise) or one OT (control). After each session the supervisors registered any adverse event for each participant on a structured report form. Both the exercise and the control activity were performed within the facility at a similar distance from the participants' flat or room. The sessions lasted approximately 45 minutes each and were held five times every two weeks for 3 months, in total 29 occasions. A schedule for all sessions was provided to the participants as well as to the staff at the facility. When needed, a verbal reminder or help with transfer to the session was given by the staff at the facility, the PTs, or the OT. When a participant did not attend a group session, the supervisor of the participant's group offered individual activity, if possible.

During the intervention period, five PTs were working full-time and two shared one full-time post. Two OTs were working full-time and one 75% of a full-time post. All PTs and OTs were experienced in working with older people with impaired physical and cognitive function. Educational meetings were held for the PTs and OTs, respectively, before the intervention in order for them to learn each programme. Meetings were also held during the intervention period in order to follow-up the implementation of each programme.

Nutrition intervention and Placebo (Paper II)

The nutrition intervention consisted of a protein-enriched energy supplement. The supplement was a milk-based 200 ml drink that contained 7.4 g protein, 15.7 g carbohydrate, 0.4 g lipid and 408 kJ (96 kcal) per 100 g. The placebo drink (200 ml) contained 0.2 g protein, 10.8 g carbohydrate, < 0.01 g lipid, and 191 kJ (45 kcal) per 100 g. Both drinks were served in the same type of non-transparent package and had similar flavours. The nutrition drinks were offered (by the group supervisor) within five minutes after each exercise or control activity session. If the participant did not attend the session, the drink was still offered, if possible. All drinks were collected after 15 minutes and the weight of the remaining drink was registered.

Outcome and outcome measures

An overview of the outcome and outcome measures in Papers I-IV is presented in Table 1.

Paper I

Proportion of participants sustaining a fall and time to first fall were the outcome measures in evaluating the prediction accuracy of the Downton index at 3, 6, and 12 months, using two different definitions of a fall.

Follow up of falls. The participants were followed up prospectively regarding indoor falls at the residential care facility for a total period of 12 subsequent months from inclusion in the study, or until they moved or died. The number of observation days was calculated for each individual at 3, 6 and 12 months after inclusion in the study. A participant's absence from the facility (if more than two days) was subtracted from each participant's observation time.

Fall definitions and registration. Two different definitions of falls were used; 1) An indoor event in which the resident unintentionally came to rest on the floor regardless of whether or not an injury was sustained. 2) Falls precipitated by acute illness, acute disease, or drug side-effects were excluded. The staff were briefly informed about the fall registration and the importance of reporting all falls that came to their knowledge. They registered each fall on a form, specially developed for this study, and reported each incident to a study nurse, who immediately followed up each fall. The study nurse, who was employed at the facility and also worked part-time in this study, supervised and encouraged the staff to report falls as accurately as possible. One of the authors of the paper was the geriatrician at the residential care facility, and together with the study nurse, as soon as possible and at least within a few days, he followed up each fall and evaluated possible precipitating causes of the fall. Acute illness was regarded as a precipitating factor when the resident showed symptoms of illness such as impaired balance or delirium before the fall, and the symptoms disappeared when the illness was treated. Acute disease was regarded as a precipitating factor when a stroke or cardiac infarction was discovered in connection with the fall. A drug was judged to have precipitated the fall when there were reports of side effects from a recently prescribed drug and the symptoms disappeared after discontinuation of the drug treatment.

Paper II

Balance, gait ability and lower-limb strength were the outcomes in evaluating the exercise programme regarding its effects on physical function.

Balance was assessed using the Berg Balance Scale, consisting of 14 static and dynamic balance tasks common in everyday life, e.g. sitting, rising from sitting, or reaching forward while standing (152, 153). Each task is scored 0 to 4 with a total maximum score of 56. Lower scores are given when there is a need for physical contact or supervision during the task or if the given time limit is exceeded.

Gait ability was measured by a 2.4 meter timed test (8), starting from a standing position, first twice at usual gait speed and then twice at maximum speed. The participants used their ordinary walking aid and walked to a visible goal approximately 3 meters away (to avoid deceleration). The timing, with a digital stopwatch, was stopped when the participant's chest crossed the finish line marked on the wall. The assessor walked beside the participant if necessary for safety reasons, but no physical contact was allowed.

Lower-limb strength was measured by establishing 1 RM (79), in a leg press machine (Steens Industrier AS, Norway). The test was performed, normally bilaterally, from a 90 degree knee angle to the participant's complete knee extension. A unilateral 1 RM was established if the participant, e.g. due to paresis, was unable to use both legs. The load was increased by 10 kg per attempt with 45 s rest between. When the participant failed in an attempt, the load was increased by 2 kg from the last successful attempt, until 1 RM was obtained. For safety reasons, participants with a hip fracture sustained within the past 6 months or a hip prosthesis were not assessed.

Baseline values of the outcome measures are presented in Table 5.

Table 5. Baseline values of the outcome measures in Paper II

Outcome measure	Total (n=191)	Exercise (n=91)	Control (n=100)
Berg Balance Scale, points, mean±SD (n=190)	26.6±14.8	26.6±15.3	26.6±14.4
Gait speed, usual m/s, mean±SD (n=188)	0.36±0.20	0.35±0.20	0.37±0.20
Gait speed, maximum m/s, mean±SD (n=187)	0.55±0.31	0.54±0.32	0.55±0.31
1 RM in lower-limb strength, kg, mean±SD (n=128)	89.5±38.7	87.6±38.6	91.8±39.0

Numbers after a measure indicates that there are missing assessments.
SD=standard deviation, RM=repetition maximum

A modified chair-stand test (8), the ability to stand up once from a chair, was used as an additional outcome measure of lower-limb strength because of expected missing values in 1 RM. The arms were held in front of the body since no support was allowed.

Follow-up procedure. The outcome measures were assessed at baseline, 3 months, and 6 months by trained PTs blinded to group allocations and previous test results. To reduce the risk of broken blindness, most participants were informed by the supervisors of the group activities of the importance of not mentioning to the assessors the intervention they had received. In addition, the supervisors were instructed to remove any trace of the intervention that could reveal the participants' group allocation. The participant's use of walking aid, position in the leg press machine, and chair height were equal on the test occasions. Interrater reliability for the Berg Balance Scale and 2.4 meter timed test, calculated by Intra Class Correlation (ICC 3.1), ranged from 0.99 to 1.00.

Evaluation of the blindness of the assessors. The blinding of the assessors was evaluated after the follow ups. At 3 months, the assessors correctly guessed activity allocation in 60% of the cases (110/182, Kappa coefficient 0.21) and nutrition allocation in 50% (91/182, 0.004). At 6 months, the corresponding figures were 69% (114/166, 0.37) and 47% (78/166, -0.06). The participant's assessor was replaced at 6 months if that assessor stated that the blinding was broken at 3 months. This was the case for 11 (6%) participants. At 6 months, the blinding was stated as being broken for two (1%) participants.

Paper III

Attendance, intensity of lower-limb strength and balance exercises, as well as occurrence and seriousness of adverse events were the outcome variables in evaluating the applicability of the exercise programme.

Registration and definitions. After each exercise session the PTs filled in a structured report for each participant including the exercises performed, reason for not attending the exercise session, estimated intensity of the lower-limb strength and balance exercises (Table 6), reason for not achieving high intensity, and adverse events. Adverse events were defined as experiencing discomfort during the exercise session that manifested itself or became worse because of the exercises. The adverse events were either expressed spontaneously by the participant or observed by the PT. In addition, the PT asked participants during the exercise session if they experienced any discomfort.

Table 6. Intensity scales of the lower-limb strength and balance exercises*

	High intensity	Medium intensity	Low intensity
Lower-limb strength exercises	Sets of 8–12 repetition maximum	Sets of 13–15 repetition maximum	Sets of >15 repetition maximum
Balance exercises	Postural stability fully challenged†	Postural stability not fully challenged or fully challenged in only a minority of the exercises	Postural stability in no way challenged

The intensity scales were developed for this study.
*Intensity for each participant was estimated by the physiotherapist for lower-limb strength and balance exercises separately, as an average for each exercise session.
†Postural stability fully challenged=balance exercises performed near the limits of maintaining postural stability.

Categorisation of adverse events. The seriousness of the adverse events was assessed by three people (two specialists in geriatric medicine, of whom one was not involved in the study, and one PT) independently in four different categories: 1) minor and temporary, 2) serious symptoms (potential risk of severe injury or life-threatening), 3) manifest injury or disease, and 4) death. In cases of disagreement between assessors a consensus was reached after a discussion.

Paper IV

Fall rate and the proportion of participants sustaining a fall were the outcome measures in evaluating the fall-prevention effect of the exercise programme. The nutrition intervention was not evaluated since it did not increase the training effect on physical functions in Paper II. The follow-up period was preplanned to last in six months from the end of the intervention. A participant's absence from the facility was subtracted from the total observation days. In order to observe a possible adverse effect of the intervention, falls were also registered during the 3-month intervention period.

Fall definition and registration. A fall was defined as an indoor event in which the participant unintentionally came to rest on the floor, regardless of whether or not an injury was sustained or what caused the fall. Thus, all falls were included in the study, even those resulting from e.g. acute disease or epileptic seizure. The falls were documented by the staff on report forms that included information about injuries i.e. fractures, strains, cuts, bruising, abrasions, pain, and "unspecified physical discomfort", as well as whether the fall resulted in hospital treatment. This was a routine that already existed within the facilities. The regular charts were reviewed, to further improve the reporting of falls.

Baseline descriptive assessments

The assessments used as baseline descriptive are presented below (Table 7).

Table 7. Overview of the baseline descriptive assessments in Papers I-IV

Measure	Paper I	Paper II	Paper III	Paper IV
Previous falls	X			X
Diagnoses and medical conditions	X	X	X	X
Drugs	X	X	X	X
Vision and hearing	X			X
Cognitive function	X	X	X	X
Activities of daily living	X	X	X	X
Gait ability	X	X	X	X
Balance			X	X
Nutritional status	X	X	X	X
Self-perceived health		X	X	X
Depressive symptoms		X	X	X

Previous falls. Histories of falls during the preceding 12 months were obtained from medical records, the participants themselves, or family members or caregivers in Paper I. In Paper IV, a licensed practical nurse or a nurse's aide who knew the participant well was questioned about the history of falls the preceding 6 months.

Diagnoses and medical conditions. In Paper I, all participants were thoroughly examined by a physician. Medical data were also collected by means of interviews with the participants' relatives, staff at the facility, and from medical records. In Papers II-IV, a registered nurse from each facility completed a questionnaire regarding diagnoses and medical conditions. A specialist in geriatric medicine evaluated the documentation of diagnoses, drug treatments, assessments, and measurements for completion of the final diagnoses. Dementia and depression were diagnosed using the DSM-III-R criteria (154) in Paper I and the DSM-IV criteria (155) in Papers II-IV.

Drugs. Information about prescribed drugs was obtained from the participants' medical records and categorised by a physician (Papers I-IV).

Vision and hearing. Vision and hearing were assessed by a physician in Paper I (previously described) and by a PT in Paper IV (in the same manner).

Cognitive function. Cognitive function was assessed by a physician (Paper I) or by a PT (Papers II-IV) using the Mini-Mental State Examination with a maximum score of 30 (148). A score of 18 to 23 indicates mild cognitive impairment and a score of less than 18 indicates severe cognitive impairment (149).

Activities of daily living. The Barthel Index with a maximum score of 20 was used to assess ADL (156, 157). In Paper I, a registered nurse, employed at the facility and also working part-time on the project, performed the assessment. In Papers II-IV a licensed practical nurse or a nurse's aide who knew the participant well was questioned about ADL using the Barthel Index.

Gait ability. In Papers I-IV, ability to walk independently indoors (with or without walking aid) was noted according to one item in the Barthel Index. The Functional Ambulation Categories (FAC) was used to measure walking ability (with no account taken of any walking aid used) in six levels (0–5) in Papers II and III (156). A score of 3 (verbal supervision or standby help from one person without physical contact) or less was chosen as indicating severe physical impairment. In Paper III, the need for personal support when walking a short distance (5–10 meters) without a walking aid was estimated by a PT, using an assessment developed for this study. This assessment of basic motor skills in walking was used when selecting exercise categories in the programme for each participant (Table 4).

Balance. The Berg Balance Scale (previously described) was used as a descriptive assessment at baseline in Papers III and IV.

Nutritional status. In Paper I, body mass index (BMI) was calculated (kg/m^2). A dietician assessed nutritional status in Papers II-IV using the Mini Nutritional Assessment (MNA) which includes BMI (158). The MNA has a maximum score of 30, a score of 24 to 30 indicates a good nutritional status, 17 to 23.5 a risk of malnutrition and a score below 17 a presence of protein-calorie malnutrition (159).

Self-perceived health. Self-perceived health in relation to age peers was assessed according to one item in the MNA (Papers II-IV).

Depressive symptoms. In Papers II-IV, depressive symptoms were screened by a PT using the Geriatric Depression Scale (GDS-15) (160). A score of 5 to 9 indicate mild depression and a score of ten or more moderate to severe depression (161). The scale has shown high sensitivity and specificity in indicating clinical depression among older people aged 85 years and over (162).

Baseline characteristics of the participants are presented in Table 8.

Table 8. Baseline characteristics of the participants

	Paper I	Papers II, IV	Papers II–IV	Papers II, IV
Characteristic	Total n=78	Total n=191	Exercise n=91	Control n=100
Age, mean±SD	81±6	85±6	85±6	84±7
Female sex, n (%)	56 (72)	139 (73)	67 (74)	72 (72)
Previous falls*, n (%)	37 (47)	75 (43)	36 (44)	39 (42)
Diagnoses and medical conditions, n (%)				
Depression	35 (45)	116 (61)	55 (60)	61 (61)
Dementia	37 (47)	100 (52)	47 (52)	53 (53)
Previous stroke	25 (32)	54 (28)	26 (29)	28 (28)
Heart failure	24 (31)	52 (27)	25 (28)	27 (27)
Angina pectoris	–	53 (28)	27 (30)	26 (26)
Drugs for regular use				
Analgesics, n (%)	–	111 (58)	56 (62)	55 (55)
Proton pump inhibitors, n (%)	–	40 (21)	17 (19)	23 (23)
Number of drugs, mean±SD	–	9±4	9±5	9±4
Functional assessments				
Visual impairment, n (%)	17 (22)	56 (29)	32 (35)	24 (24)
Hearing impairment, n (%)	27 (35)	46 (24)	24 (26)	22 (22)
Mini-Mental State Examination (MMSE), mean±SD	19±9	18±5	18±5	18±5
Severe cognitive impairment (MMSE ≤17), n (%)	26 (33)	92 (48)	47 (52)	45 (45)
Barthel ADL Index, mean±SD	14±5	13±4	13±5	13±4
Independent gait indoors (with or without walking aid)†, n (%)	64 (82)	121 (63)	56 (62)	65 (65)
Functional Ambulation Categories (FAC), median (interquartile range)	–	4 (3–4)	4 (2–4)	4 (3–4)
Severe physical impairment (FAC ≤3), n (%)	–	81 (42)	40 (44)	41 (41)
Severe cognitive or physical impairment, n (%)	–	130 (68)	63 (69)	67 (67)
Berg Balance Scale, mean±SD		27±15	27±15	27±14
Body mass index, mean±SD	25±4	25±5	25±4	25±5
Mini Nutritional Assessment, mean±SD	–	21±4	20±4	21±4
Health, self-perceived as better than age peers‡, n (%)	–	77 (41)	30 (33)	47 (48)
Geriatric Depression Scale (GDS-15), mean±SD	–	4±3	5±3	4±3

*Paper I previous falls in last 12 months, Paper IV in last 6 months.
†Assessed with the Barthel ADL Index.
‡Assessed with the Mini Nutritional Assessment.
SD=standard deviation

Statistical methodology

All statistical tests were 2-tailed; $p<0.05$ was considered to indicate statistical significance (Papers I-IV). Analyses were performed using the SPSS software (SPSS Inc., Chicago, IL), version 6.1 (Paper I) and 10.0 (Papers II-IV), as well as Stata software, version 9.1 (StataCorp, College Station, Texas) (Papers II and IV).

Statistical power. Paper II was designed to have 80% power to detect a significant difference ($p=0.05$, two-sided) between groups of ≥3 points in the Berg Balance Scale, considering an estimated dropout rate of 20%. In Paper IV, post-hoc analysis, revealed a power of slightly over 50% to show a 20% significant reduction in falls ($p=0.05$, two-sided and using Poisson regression).

Intention-to-treat and imputations. All analyses were based on the intention-to-treat principle, using all participants (Papers I-IV). In Paper I, all participants were included at each time point in the calculations of proportions. In Paper II, imputations with 0.01 m/s were made in cases where the participant was unable to perform the test of gait speed because of impaired physical function (as noted on the test protocol). No other imputations were made in any of the papers.

Clustering. The results of the outcome analyses in Papers II and IV are presented without adjustments for the randomisation in clusters. The rationale for this is that the cluster randomisation was stratified and, further, that there were few participants per cluster (mean 5.6±1.6 participants) and that the intervention was directed to the individuals instead of to the clusters (163). Nevertheless, the possibility of a cluster effect was examined in additional analyses by adjusting the outcome regression analyses for clustering (164).

Evaluation of the Downton fall-risk index (Paper I)

Proportion of participants sustaining a fall. Sensitivity, specificity, positive and negative predictive values, using both fall definitions, were calculated at 3, 6, and 12 months after inclusion in the study. At the same points in time, the Prognostic Separation index (PSEP), as suggested by Altman and Royston (116), was calculated. Briefly, PSEP is the difference between the probabilities of an event occurring in the group with the worst predicted prognosis and in the group with the best. The optimal value is 1.0. For all proportions, a 95% confidence interval (CI) was calculated using binomial distribution.

Time to first fall. The time to occurrence of the first fall (the event-free time) was calculated as the number of observation days until the first fall (if any). The association between the time to first fall (dependent variable) and the allocation to high or low fall-risk group (independent variable) was analysed using Cox regression with calculation of the hazard ratio (HR). The same analysis was also performed using each item score as the independent variable. A Kaplan-Meier analysis with the log rank test for statistical significance was used to evaluate the association between the time to first fall and the allocation to fall risk group at 3, 6 and 12 months.

Evaluation of an exercise programme regarding effect on physical functions (Paper II)

Gait speed. The mean of the two attempts at usual gait speed and the best time measured for maximum speed, were chosen. If there was only one time measured, this was used.

Baseline comparison and within-group differences. Baseline characteristics were compared between allocation to activity (exercise/control) and nutrition (protein/placebo) group by one-way analysis of variance (ANOVA) or the chi-square test. Within-group effects were analysed by paired sample t-tests, comparing outcome measures at baseline (pre-intervention) with 3 and 6 months (post-intervention), respectively.

Between-group differences. Outcome measures were evaluated at 3 and 6 months in between-group analyses by 2 x 2 factorial analysis of covariance (ANCOVA), in which the post-intervention value was the dependent variable. Fixed factors were allocation to activity and nutrition groups. The other independent variables were the pre-intervention value, age, sex, and covariates adjusting for differences ($p \leq 0.15$) between the groups at baseline (angina pectoris, proton pump inhibitors, Barthel ADL Index, and self-perceived health). The analyses were tested for interactions between allocation to activity and nutrition groups. Effect sizes were calculated as the difference between the marginal means divided by the pooled standard deviations of the difference between post- and pre-intervention values (square root of the mean square error). The chair-stand test was evaluated by logistic regression with the same independent variables as in the ANCOVA.

Evaluation of an exercise programme regarding the applicability (Paper III)

Applicability. An attendance rate was calculated for each participant as the number of attended sessions divided by total number of sessions (n=29). Intensity rates were calculated for each participant as the number of sessions of the specific intensity divided by total number of attended sessions. Likewise, an adverse event rate was calculated for each participant as the number of sessions with an adverse event divided by total number of attended sessions.

Association with cognitive function. Dementia diagnosis and MMSE score were the variables used to evaluate whether cognitive function was associated with the applicability of the programme. Rates for attendance, intensity (of high-intensity lower-limb strength and balance exercises), and adverse events were compared between participants with and without dementia using the Mann-Whitney U Test (due to skewed distribution). The correlations between these rates and the MMSE score were analysed using the Spearman rank correlation.

Evaluation of an exercise programme regarding effect on falls (Paper IV)

Baseline comparison. Baseline characteristics were compared between allocation to exercise intervention and control activity by the Student *t* test or the chi-square test.

Between-group differences. A negative binominal regression was used to determine difference between groups in fall rate by calculating incidence rate ratios (IRR) with 95% CI. Negative binomial regression is a generalisation of the Poisson regression which attempts to take into account the dependence of events by the same individual and it is recommend for use in the evaluation of fall prevention (165). Logistic regression analysis was used to determine difference between groups in the proportion of participants who sustained at least one fall by calculating odds ratio (OR) with 95% CI. Both the negative binominal and the logistic regression analyses were adjusted for age, sex, and differences between groups ($p \leq 0.15$) at baseline (visual impairment and self-perceived health).

Additional subgroup interaction analyses. To evaluate the effect between groups for participants with effect on physical function (as a measure of response) and with a higher attendance (as a measure of compliance), respectively, subgroup interaction analyses were performed in the negative binominal and logistic regression analyses. For both the exercise group and the control group, the median (for all participants) of the difference in the Berg Balance Scale score (between post- and pre-intervention) was chosen to divide the participants into one group who responded and one group who did not respond. This resulted in participants with an improvement in the Berg Balance Scale of 2 points or more during the 3-month intervention period being placed in the responding group. A variable of four categories was formed by study group (exercise/control) and effect on physical function (responding/not responding) and was added to the outcome analyses. Likewise for attendance, the median was chosen to divide the sample of participants into one group with higher compliance (attended 23 or more of the 29 sessions) and one group with lower compliance. A variable of four categories was formed by study group (exercise/control) and attendance (higher compliance/lower compliance) and was added to the outcome analyses.

RESULTS

Fall prediction by the Downton index - Paper I

Among the residents, 48 out of 78 (62%) suffered at least one fall, and 30 (38%) fell twice or more. The number of falls per person ranged from 0 to 22. The observation period of falls for each resident ranged from 12 to 365 days, the total number of observation days was 24 536. In all, 148 indoor falls occurred during the 12-month period, which corresponds to an incidence rate of 2.2 falls per person years (PY). Thirty-two falls were regarded as being precipitated by acute illness, eight falls by acute disease, 12 falls by drug side-effects, and two falls were regarded as precipitated by both acute illness and drug side effects. When all these falls (n=54) were excluded to conform to the second definition of falls, a total of 94 falls remained among 35 residents.

The median score on the Downton index was 4 (interquartile range: 2–5, range: 0–9). Fifty-seven (73%) participants scored 3 or more on the index, thereby reaching the suggested cut-off score for high risk of falls.

Proportion of participants sustaining a fall

As can be seen in Table 9, with all falls included, the sensitivity ranged from 81 to 95% with the highest value at 3 months, while the specificity ranged from 35 to 40%. PSEP ranged from 0.26 to 0.37 at the three different time points. The highest positive predictive value was 68% (12 months), and the highest negative predictive value was 95% (3 months).

Table 9. Prediction accuracy of the Downton fall-risk index, with two different fall definitions, at 3, 6 and 12 months

	All falls included			Falls not precipitated by acute illness, acute disease or drug side-effects		
	3 months	6 months	12 months	3 months	6 months	12 months
Sensitivity (95% CI), %	95 (76–100)	91 (75–98)	81 (67–91)	100 (77–100)	91 (72–99)	77 (60–90)
Specificity (95% CI), %	35 (23–49)	39 (25–55)	40 (23–59)	33 (22–46)	35 (22–49)	30 (17–46)
PPV (95% CI), %	35 (23–49)	51 (37–64)	68 (55–80)	25 (14–38)	37 (24–51)	47 (34–61)
NPV (95% CI), %	95 (76–100)	86 (64–97)	57 (34–78)	100 (84–100)	90 (70–99)	62 (38–82)
PSEP (95% CI)	0.30 (0.08–0.52)	0.37 (0.12–0.61)	0.26 (0.01–0.50)	0.25 (0.05–0.44)	0.27 (0.04–0.50)	0.09 (-0.16–0.34)

CI=confidence interval, PPV=positive predictive value, NPV=negative predictive value, PSEP=Prognostic Separation index

When excluding falls precipitated by acute illness, acute disease or drug side effects, sensitivity was 100% at 3 months, decreasing to 77% at 12 months. PSEP ranged from 0.09 to 0.27, the value at 12 months was statistically non-significant (Table 9).

Time to first fall

The time to first fall, with all falls included, differed significantly between low- and high-risk groups at 3, 6 and 12 months (Figure 3). The risk of falling within 3 months was 36% in the high-risk group and 5% in the low-risk group. Within 12 months, the risk was 76% and 47%, respectively. The hazard ratio was 2.5 (95% CI: 1.2–5.2, p=0.01) with all falls included and 2.3 (95% CI: 1.1–4.8, p=0.02) when falls precipitated by acute illness, acute disease or drug side effects were excluded.

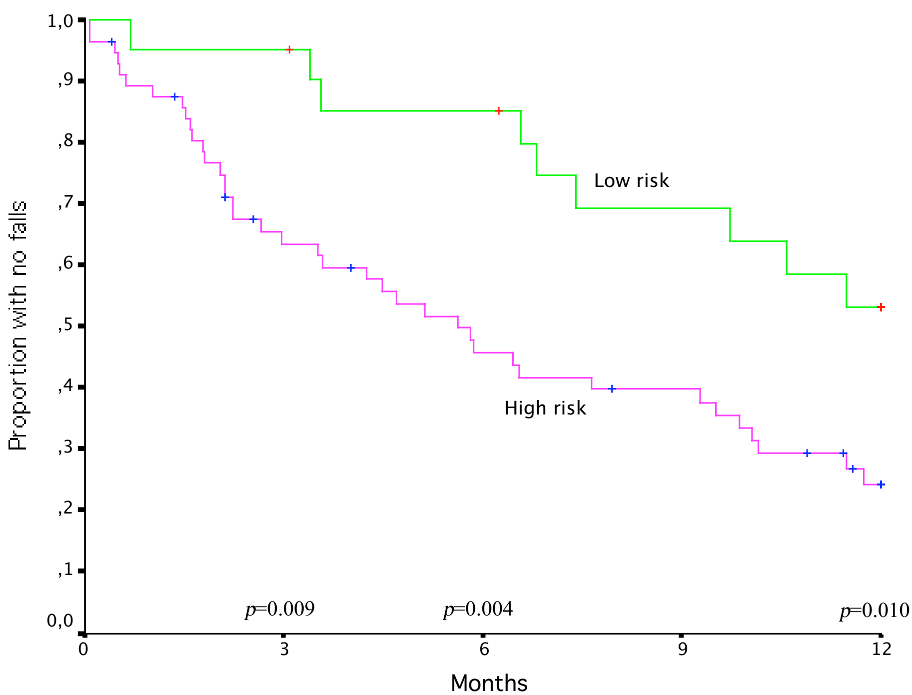

Figure 3. Kaplan-Meier curves of time to first fall, with all falls included, among the participants in the high risk (n=57) and low risk (n=21) groups. The p-values refer to log rank tests at 3, 6 and 12 months, respectively.

When analysing each item, with all falls included, "antidepressants", "visual impairment", "cognitive impairment", and "unsafe gait" were significantly associated with time to first fall (Table 10). In addition, when added together in groups, medication items as well as sensory deficit items were significantly associated with the time to first fall.

Table 10. Association between separate Downton fall-risk index items and time to first fall during 12 months with all falls included

Risk item	Participants without falls (n=30), %	Participants with falls (n=48), %	HR (95% CI)	*p*
Known previous falls	33	56	1.67 (0.94–2.95)	0.08
Tranquillizers/sedatives	43	58	1.66 (0.93–2.96)	0.08
Diuretics	43	42	1.15 (0.65–2.05)	0.63
Antihypertensives (other than diuretics)	10	12	1.22 (0.52–2.88)	0.65
Antiparkinsonian drugs	3	8	1.45 (0.52–4.05)	0.48
Antidepressants	10	33	1.93 (1.05–3.52)	0.03
All medication items (0-5)	–	–	1.36 (1.04–1.78)	0.03
Visual impairment	7	31	3.14 (1.69–5.84)	<0.001
Hearing impairment	30	38	1.61 (0.90–2.89)	0.11
Limb impairment	33	38	1.04 (0.58–1.87)	0.89
All sensory deficit items (0-3)	–	–	1.54 (1.11–2.13)	0.009
Cognitive impairment	47	71	2.27 (1.21–4.25)	0.01
Unsafe gait	30	50	1.34 (1.11–1.63)	0.003

HR=hazard ratio

Effect on physical functions by a high-intensity functional exercise programme – Paper II

In total, the attendance was 72% for the exercise group and 70% for the control group. No adverse event during the sessions led to a manifest injury or disease. Eighty-one participants in the exercise group were given 2.0±0.8 (mean±SD) physical tasks in the end of the exercise period. At the follow-up, 29 of the remaining 74 participants (39%) had performed one task or more as frequently as recommended, and 29 (39%) had not done any task. The protein-enriched energy supplement was taken on 82% of the occasions and the placebo drink on 78%. The package was completely emptied in 80% of these occasions.

Between group effects

At 3 months, the exercise group had significantly improved the usual gait speed compared with the control group (Table 11). At 6 months, significant improvements in favour of the exercise group were obtained in the Berg Balance Scale, usual gait speed, and 1 RM in lower-limb strength. Regarding the nutrition intervention, there was a significant difference in usual gait speed in favour of the placebo group at 6 months. No significant interaction effects were seen between the exercise and nutrition interventions for any of the outcome measures at any of the follow ups (data not shown).

Within-group effects

All groups showed within-group improvements in the Berg Balance Scale and in 1 RM in lower-limb strength at both follow ups (Table 12). These improvements were in most cases statistically significant for the exercise groups, but not for the control groups.

Additional analyses

At 6 months, the exercise group had improved significantly in the chair-stand test compared with the control group (p=0.01, adjusted for baseline values). In the exercise group, 43/75 (57%) participants were able to stand up once compared with 37/85 (44%) participants in the control group. Corresponding figures at baseline were 36/75 (48%) versus 39/85 (46%). At 3 months, 43/81 (53%) participants in the exercise group were able to stand up once compared with 45/91 (49%) participants in the control group (p=0.27, adjusted for baseline values).

Outcome analyses adjusted for cluster randomisation produced essentially the same results, compared to unadjusted analyses (data not shown).

Table 11. Outcome analyses, between-group differences based on the intention-to-treat principle*

Outcome measure	Follow up	n	Exercise mean±SE	Control mean±SE	Difference mean (95% CI)	*p*	ES	Protein mean±SE	Placebo mean±SE	Difference mean (95% CI)	*p*	ES
BBS, points	3 mo	172	29.5±0.7	28.0±0.7	1.5 (-0.4 to 3.4)	0.13	0.24	28.2±0.7	29.3±0.7	-1.1 (-3.1 to 0.8)	0.26	-0.18
	6 mo	161	31.0±0.7	29.1±0.6	1.9 (0.004 to 3.8)	**0.05**	0.33	29.8±0.7	30.3±0.7	-0.6 (-2.5 to 1.4)	0.56	-0.10
Gait speed, usual, m/s	3 mo	166	0.40±0.01	0.36±0.01	0.04 (0.01 to 0.08)	**0.02**	0.36	0.38±0.01	0.38±0.01	0.00 (-0.04 to 0.04)	0.96	-0.01
	6 mo	156	0.41±0.01	0.37±0.01	0.05 (0.01 to 0.08)	**0.009**	0.44	0.37±0.01	0.41±0.01	-0.04 (-0.07 to -0.003)	**0.03**	-0.37
Gait speed, maximum, m/s	3 mo	165	0.57±0.02	0.54±0.02	0.03 (-0.02 to 0.08)	0.30	0.17	0.54±0.02	0.57±0.02	-0.04 (-0.09 to 0.01)	0.16	-0.23
	6 mo	154	0.62±0.02	0.59±0.02	0.03 (-0.03 to 0.09)	0.30	0.17	0.58±0.02	0.62±0.02	-0.04 (-0.10 to 0.02)	0.16	-0.24
1 RM in lower-limb strength, kg	3 mo	103	102.9±3.0	97.9±3.2	5.1 (-3.9 to 14.0)	0.26	0.23	99.7±3.0	101.1±3.2	-1.4 (-10.3 to 7.5)	0.76	-0.06
	6 mo	97	105.4±3.3	94.5±3.3	10.8 (1.3 to 20.4)	**0.03**	0.49	100.0±3.2	99.9±3.4	0.2 (-9.4 to 9.7)	0.97	0.01

No interaction effects were seen between the exercise and nutrition interventions for any of the outcome measures at any of the follow ups (data not shown).
*Between-group effects analysed by 2 x 2 factorial ANCOVA in which the post-intervention value was the dependent variable. Independent variables were the allocation to activity (exercise/control) and nutrition (protein/placebo) groups, pre-intervention value, age, sex and covariates adjusting for differences between the groups at baseline (angina pectoris, proton pump inhibitors, Barthel ADL Index and self-perceived health). Effect sizes were calculated as the difference between the marginal means divided by the pooled standard deviations of the difference between post- and pre-intervention values (square root of the mean square error).
SE=standard error, ES=effect size, CI=confidence interval, BBS=Berg Balance Scale, RM=repetition maximum.

Table 12. Within-group differences between post- and pre-intervention values, based on the intention-to-treat principle

		Exercise and Protein			Exercise and Placebo			Control activity and Protein			Control activity and Placebo		
Outcome measure	Follow up	n	mean±SD	*p*	n	mean±SD	*p*	n	mean±SD	*p*	n	mean±SD	*p*
BBS, points	3 mo	44	1.3±7.5	0.26	38	3.3±6.0	**0.001**	45	0.3±6.0	0.71	46	2.0±5.7	**0.02**
	6 mo	41	2.4±6.2	**0.02**	36	3.5±5.7	**0.001**	40	0.8±5.8	0.38	45	1.8±6.1	0.06
Gait speed, usual, m/s	3 mo	42	0.02±0.12	0.36	36	0.02±0.13	0.32	44	0.00±0.12	0.91	45	-0.02±0.12	0.18
	6 mo	39	0.00±0.11	0.80	36	0.05±0.12	**0.02**	40	0.00±0.11	0.81	42	-0.01±0.11	0.47
Gait speed, maximum, m/s	3 mo	42	-0.03±0.15	0.18	36	0.03±0.17	0.33	44	-0.03±0.19	0.26	44	-0.01±0.14	0.69
	6 mo	39	-0.02±0.22	0.63	36	0.07±0.20	**0.03**	40	0.01±0.17	0.68	40	0.00±0.13	0.87
1 RM in lower-limb strength, kg	3 mo	31	11.3±21.2	**0.006**	24	10.9±18.0	**0.007**	25	7.1±22.9	0.13	23	8.2±24.7	0.13
	6 mo	28	11.6±28.8	**0.04**	22	10.1±20.6	**0.03**	23	1.5±20.9	0.74	24	2.8±17.4	0.43

SD=standard deviation, BBS=Berg Balance Scale, RM=repetition maximum.

Applicability of a high-intensity functional exercise programme – Paper III

Attendance

The attendance rate for each participant was in median (interquartile range) 76% (62–93%). Six percent of the sessions were performed individually. The participants performed 5.1±1.4 (mean±SD) different exercises per attended session. The most common reasons for not participating in an exercise session were the participant's lack of motivation (7% of the total sessions for all participants), acute disease (7%), hospital treatment or visit to the primary healthcare centre (3%), and pain (3%).

Intensity

Lower-limb strength exercises of high intensity were performed in median (interquartile range) 53% (17–72%) of the attended exercise sessions and medium or high intensity in 92% (85–100%). Corresponding figures for balance were 73% (40–89%) for high intensity and 96% (89–100%) for medium or high intensity. In 42% (14–68%) of the attended sessions, both high-intensity lower-limb strength and balance exercises were performed. The most common reasons for not achieving high intensity for lower-limb strength and balance exercises were pain (11% and 4% of the attended sessions, respectively), lack of motivation (9% and 8%), build-up period in the start of the intervention period or after a disease or injury (8% and 5%), and fatigue (4% and 4%).

Adverse events

In all, 179 adverse events occurred in 166 (9%) of the 1906 attended exercise sessions among 57 (63%) participants. The rate for each participant of sessions with adverse event per attended session was in median (interquartile range) 5% (0–14%). All but two adverse events were assessed as "minor and temporary" and none led to manifest injury or disease. Two were assessed as "serious symptoms"; one participant stopped training during an exercise session because of pain in the chest, and in one case the PTs prevented a fall by gently helping a participant down to the floor because of loss of balance. The adverse events were "musculoskeletal" (53%) e.g. pain or soreness, "dizziness" (22%), "respiration/circulation" (18%) e.g. breathlessness or discomfort from the chest, "general/unspecified" (4%) e.g. stomach pain, "psychological" (3%) e.g. fear of falling, and "near fall accident" (described above) (1%).

Association with cognitive function

Regarding attendance, intensity, and adverse events, no significant differences were observed when comparing participants with dementia (n=47) to participants without (n=44), nor was there any significant correlation to the MMSE score (Table 13).

Table 13. Applicability of the exercise programme related to dementia and cognitive function

Variable	Participants with dementia (n=47)	Participants without dementia (n=44)	*p*	Correlation with the MMSE score	*p*
Attendance rate*, %	76 (59–93)	76 (63–93)	0.62	0.022	0.83
High-intensity rate in strength and balance exercises†, %	29 (12–64)	50 (16–70)	0.51	0.115	0.28
Adverse event rate‡, %	7 (0–19)	4 (0–8)	0.09	0.073	0.49

*Median (interquartile range): number of attended sessions divided by total number of sessions (n=29) for each participant.
†Median (interquartile range): number of sessions of high-intensity strength and balance exercises divided by total number of attended sessions for each participant.
‡Median (interquartile range): number of sessions with an adverse event divided by total number of attended sessions for each participant.
MMSE=Mini-Mental State Examination

Effect on falls by a high-intensity functional exercise programme – Paper IV

During the 6-month follow-up period, 95 (52%) of the 183 participants sustained one fall or more and 57 (31%) participants fell twice or more. Falls per participant ranged from 0 to 26. One hundred and fourteen (62%) of the participants had a full 6-month observation period for falls. A total of 341 falls occurred during 29 978 observation days. The corresponding fall rate was 4.2 per PY. One hundred forty-five (43%) of the falls resulted in an injury (64 in the intervention group and 81 in the control group), of which 10 falls resulted in a fracture (exercise group four and control group six). Three falls resulted in a hip fracture (all in the control group) and 26 falls resulted in hospital treatment (exercise group 9 and control group 17).

During the 3-month intervention period, 84 (44%) of the 191 participants sustained one fall or more, 39 participants (43%) in the exercise group and 45 (45%) in the control group. Falls per participant ranged from 0 to 16. A total of 193 falls occurred during 16 204 observation days. The corresponding fall rate was 4.4 falls per PY (exercise group 4.6 falls per PY and control group 4.2 falls per PY). Seventy-eight (40%) of the falls resulted in an injury (39 in each group), of which 9 falls resulted in a fracture (exercise group five and control group four). Four falls resulted in a hip fracture (two in each group) and 19 falls resulted in hospital treatment (exercise group seven and control group 12).

Between-group analyses

During the 6-month follow-up period, when all participants were compared, no statistically significant differences between the groups were found for fall rate (exercise group 3.6 falls per PY and control group 4.6 fall per PY) or proportion of participants sustaining a fall (exercise group 53% and control group 51%) (Table 14). Among participants who responded, the exercise group had a lower fall rate than the control group (2.7 falls per PY and 5.9 falls per PY, respectively), IRR (95% CI) 0.44 (0.21–0.91), p=0.03 (Table 14 and Figure 4). In this subgroup, 42% of the participants in the exercise group fell compared with 56% in the control group, OR (95% CI) 0.50 (0.20–1.24), p=0.13 (Table 14). No significant difference was found between the groups among participants with higher compliance (data not shown).

Table 14. Outcome analyses on fall rate and proportion of participants falling by comparing all participants in the exercise group with the control group, as well as by additional subgroup interaction analyses

Group	Fall rate*	IRR[†] (95% CI)	*p*	Any fall[‡], n (%)	OR[§] (95% CI)	*p*
Control activity (n = 96)	4.6	1.00, reference		49 (51)	1.00, reference	
Exercise (n = 87)	3.6	0.82 (0.49–1.39)	0.46	46 (53)	0.95 (0.52–1.74)	0.86
Group and response to the intervention[¶]						
Control – responding (n=39)	5.9	1.00, reference		22 (56)	1.00, reference	
Exercise – responding (n=43)	2.7	0.44 (0.21–0.91)	**0.03**	18 (42)	0.50 (0.20–1.24)	0.13
Control – not responding (n=52)	3.9	0.75 (0.38–1.50)	0.42	27 (52)	0.85 (0.36–2.00)	0.72
Exercise – not responding (n=39)	4.3	0.83 (0.40–1.76)	0.64	25 (64)	1.18 (0.46–3.02)	0.72

*Falls per person years.
[†]IRR=incidence rate ratio according to negative binomial analysis adjusted for age, sex, and differences between groups ($p \leq 0.15$) at baseline (visual impairment and self-perceived health).
[‡]Participants who sustained at least one fall.
[§]OR=odds ratio according to logistic regression analysis adjusted for age, sex and differences between groups ($p \leq 0.15$) at baseline (visual impairment and self-perceived health).
[¶]Responding=participants with an improvement (between post- and pre-intervention) of 2 points or more in the Berg Balance Scale during the 3-month intervention period. Data for Berg Balance Scale were complete for 173 participants.
CI=confidence interval

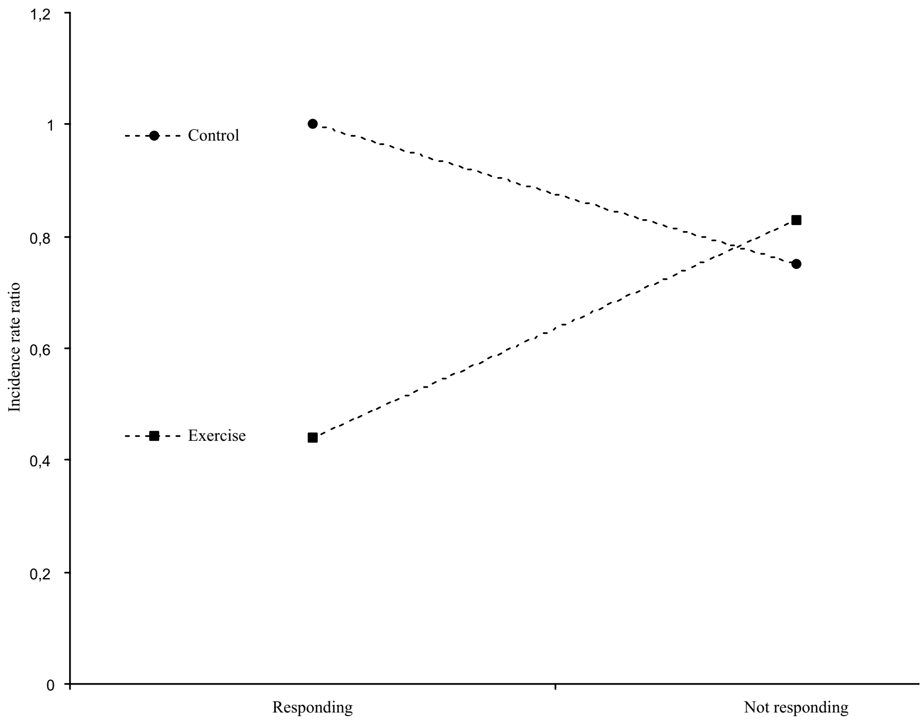

Figure 4. Subgroup interaction analysis comparing the effect of the intervention (responding/not responding) and study groups (exercise/control). "Responding"; participants with an improvement (between post-and pre-intervention) of two points or more in the Berg Balance Scale during the 3-month intervention period. "Responding-Control" is the reference group. Incidence rate ratios were: "Responding-Exercise" 0.44 (95% CI 0.21–0.91), "Not responding-Control" 0.75 (95% CI 0.38–1.50), and "Not responding-Exercise" 0.83 (95% CI 0.40–1.76).

Additional analyses

Outcome analyses adjusted for cluster randomisation produced essentially the same results compared to unadjusted analyses (data not shown).

Nineteen drop-outs occurred during the study due to deaths (12 in the exercise group and 7 in the control group), with two occurring during the 3-month intervention period (Figure 2). The relation between cause of death and the study (intervention and test procedure) was evaluated by a specialist in geriatric medicine. In one case, association with the study could not definitely be excluded. This participant died suddenly of an acute ruptured abdominal-aortic aneurysm one week after the follow-up tests for physical function at 3 months were performed.

DISCUSSION

This thesis revealed that the Downton index, when validated externally, showed a high sensitivity but a low specificity in predicting falls among older people living in residential care facilities. With all falls included, a significant prognostic separation was found between the low- and the high-risk groups at 3, 6 and 12 months. A definition in which falls precipitated by acute illness, acute disease, or drug side-effects were excluded did not improve the accuracy of the fall prediction.

Positive long-term effects in physical functions by the high-intensity exercise programme were seen, in comparison with a control activity, among older people who were dependent in ADL, living in residential care facilities, and had an MMSE score of ten or more. However, the effect of the training was not seen to be increased by an intake of the protein-enriched energy supplement immediately after the exercises.

The high-intensity functional weight-bearing exercise programme was shown to be applicable for use. Although most of the participants had severe cognitive or physical impairments, there was a high rate of attendance, a relatively high achieved intensity in the exercises, and only two serious adverse events, neither of which led to manifest injury or disease. The applicability of the programme was not associated with the participants' cognitive function.

Neither fall rate nor proportion of participants who sustained a fall differed between the exercise programme and the control activity, when all participants were compared. However, in a subgroup interaction analysis among those who responded, a significant reduction in fall rate was seen in the exercise group.

Prediction accuracy of the Downton index

The prediction accuracy of the Downton index was at least on the same level as other external validations of fall-risk assessment tools developed among older people in residential care facilities. A validation of the Downton index among stroke patients in geriatric rehabilitation, follow-up time range 3–289 days, showed a sensitivity of 91% and a specificity of 27% (126). In an external validation of the Tinetti balance scale, a part of the Tinetti fall-risk index, with a 12-month follow up among older people living in the community, the most accurate cut-off score found resulted in a sensitivity of 70% and a specificity of 52% (124). The MIF chart showed a high specificity (69%) in a validating sample with a 6-month follow-up period, but the sensitivity was low (43%) (125). However, the prediction accuracy increased when the MIF chart was combined with the staff's judgment of the resident's fall risk or fall history.

Sensitivity is a significant quality of a fall-risk assessment tool, especially if the prediction forms the basis for recruiting individuals to preventive programmes. The high sensitivity of the Downton index shown in Paper I implies that relatively few individuals, of those sustaining a fall, are falsely predicted as being at low risk of falling. The low specificity of the index (due to the fact that many of the participants who did not sustain a fall were falsely predicted as being at high risk of falling) is more acceptable than a low sensitivity would be, as long as the fall intervention does not involve doing any harm to the individual, for example through the use of physical restraints, or take up too much staff time (119).

The Downton fall-risk index showed the highest sensitivity at 3 months. The highest PSEP value was found at 6 months (0.37), but a statistically significant prognostic separation, almost as wide (0.30), was already seen at 3 months when around one out of three in the high-risk group had sustained a fall, compared with one in 20 in the low-risk group (all falls included). A PSEP of 0.30 implies that in a facility comprising 60 people, with an equal number of people with high and low risk of falling, nine more people will sustain a fall in the high-risk group (116). It is likely that changes in health status occur over one year that may have an effect on the fall risk and also on the index score among frail older people in residential care facilities. Therefore, it may be recommended to screen for fall risk every third month.

In contrast to what was expected, the Downton fall-risk index did not improve in accuracy when falls judged as precipitated by acute illness, acute disease and side effects from a recently prescribed drug were excluded. It may be that the Downton index marks frailty and thus susceptibility to these precipitating factors for falls. The result of the study indicates that the Downton index might predict falls irrespective of their cause.

The analyses of each of the eleven items of the Downton index revealed that seven of them were not significantly associated with fall risk. Even if a combination of different items may contribute more to the fall risk than each item individually, it might be disputed whether every item makes any significant contribution to the prediction. Five items in the Downton index reflect medication as a predisposing factor, of which only “antidepressant” was individually associated with fall risk. This might indicate an overestimation of medication as an important predisposing fall-risk factor, although medication items when added together were significantly associated with fall risk. This is supported by two meta-analyses that call in question whether there is a strong association between analgesic, cardiac, psychotropic drugs, and falls (166, 167). In addition, the Downton index does not categorise sub-groups of people living in residential care facilities, according to their physical function, as do two recently developed fall-risk instruments (119, 123). This may reduce the prediction accuracy of the Downton index since people in residential care facilities with different physical functional abilities might also have different fall risk factors (119). Maybe, a categorisation into subgroups regarding cognitive function also may be useful since predisposing fall-risk factors among people with dementia might differ from those among people without dementia (168). This may be one important reason why falls among people with dementia seem more difficult to predict using established fall-risk assessment tools (169), even though the prediction accuracy of the Downton index needs to be evaluated in this group.

Effect on physical functions by a high-intensity functional exercise programme

The positive effects on physical functions of a high-intensity exercise programme are novel as most participants had severe cognitive or physical impairment and the methodological quality of the study was high. Previous high-intensity exercise studies with a positive result targeting frail older people have included people with higher physical abilities than in the present study (44, 87, 96, 170) and only one of these studies included people with severe cognitive impairment (96). Contradictory results have been presented in a study among older people with severe cognitive and physical impairments where no improvements in physical function were seen (101). However, a reduction in ADL decline was found. The study design must be considered when interpreting the results. Only two of the studies mentioned above provide information that intention-to-treat analyses were used (44, 170), two that assessors were blinded for all outcome measures (96, 170), and none that randomisation was concealed. The effect sizes in the present study seem rather high compared with the studies using intention-to-treat analysis, blinded assessors, or concealed randomisation in a systematic review of strength-training studies among older people (114). A direct comparison is, however, not applicable since the effect sizes in the review and in the present study are calculated in different ways.

The positive long-term effects in the present study are in accordance with another study of a functional exercise programme in older people, a study that targeted healthy women (94). The long-term effect may be caused by the effects of this training method on physical function influencing performance in daily life, which might preserve the exercise effects. This hypothesis is supported by the concept of specificity of training and by the fact that older people perform activities of daily living near their maximal capabilities (38, 46, 171). The lack of reserve capacity in daily life activities is probably more evident in older people with physical impairments. A recent study of a fall-prevention programme including high-intensity exercise in residential care facilities resulted in long-term effect on mobility six months after the exercise intervention had ended (106). Thus, if given the chance to improve a physical function in a manner that improves their functional ability in daily living, frail older people may perform preserving functional training at a high intensity in their everyday life when, for example, transferring to the dining room at the residential care facility. The physical tasks, introduced in the end of the exercise period in the present study, might also have had a preserving effect. However, compliance regarding these tasks was low.

The lack of an increased effect of the training by an intake of protein immediately after the exercises is in contrast to a study among healthy men aged 70-80 years (112). One possible explanation for this difference may be that a large proportion of the participants in the present study had a poor nutritional status, indicating a negative energy balance. Thus, the protein might have been used as energy in compensating for this. In addition, the majority of the participants were women, aged over 80 years, and had many diseases and drug treatments that might have affected the absorption and metabolism of the protein. Several hormones that contribute to the muscle protein synthesis also decrease with age (109). Further research is needed regarding interventions that combine exercise and nutrition in older women as well as in frail older people. It is important in these groups, to discover what conditions are required for optimal assimilation of a protein supplement leading to an increase in training effects. Probably the nutrition intervention, like the exercise intervention, should be individualised in order for it to be successful in frail older people.

In contrast to what was expected, no decline in function was seen in the control group during the study period (101, 106). One possible reason for this is that the control activity programme has an effect on physical function in this sedentary group, e.g. through the impact of social stimulation, a meaningful activity, or by transferring to another location in the facility when participating in the group activity. The use of this elaborate control activity strengthens the interpretation that the differences between groups regarding physical outcomes were mainly due to the training itself.

The supervision of experienced PTs who also prescribed exercises for each participant might have contributed to the positive result of the exercise program, even if this aspect was not specifically evaluated. Both the amount and quality of the supervision appears to be important, especially among older people with impairments in physical and cognitive function. A trend towards better results with more supervision of a strength-training programme for frail older people has been demonstrated in a study with a small sample size and, thus, as noted by the authors, more and larger studies are needed to clarify this (172).

Applicability of a high-intensity functional exercise programme

Attendance of the exercise programme in the study seems high considering the use of intention-to-treat analysis and that most participants had severe cognitive or physical impairments. The attendance appears somewhat lower than that in other studies of high-intensity exercise interventions among frail older people

(44, 87, 96, 170). However, none of these studies provided an attendance rate which included participants who dropped out before the post-intervention assessment. This factor may have influenced the attendance figures, but so also could the fact that all these studies targeted participants with less physical and cognitive impairment.

One important factor for the high attendance rate in this study, especially for the participants with severe cognitive impairment, was probably that reminders were used. In addition, help with transfer to the exercise location, few serious adverse events, and the positive effects of the exercise were other factors that probably had a positive influence on the attendance rate. The impact of these factors on attendance is supported by the results in another study among older people (173).

The rates for high intensity were high for balance exercises but moderate for strength exercises. The most common reason for not achieving high intensity in lower-limb strength exercises was pain, which was nearly three times more frequent as a reason compared with balance exercises. The high prevalence of pain conditions (indicated by common regular use of analgesics), osteoarthrosis, and osteoporosis might indicate difficulties in exercising with higher loads.

The number of adverse events, including only two serious ones, may be seen as acceptable in this frail population, considering the relatively high intensity achieved. Although adverse events were only noted in connection with the exercise sessions and participants with severe cognitive impairment were included, the number of registered adverse events seems valid since information was collected by the PT in different ways (by observing and asking the participants). There was no systematic registration of adverse events provided in other high-intensity exercise studies among frail older people. Thus, a direct comparison between these studies and the present study is not applicable regarding adverse events. In the present study, there was a non-significant tendency for people with dementia to experience more adverse events. However, no such tendency was observed when adverse events were correlated to the MMSE score. The approval of the participants' physicians prior to the study were probably important for the participants' safety as well as the supervision by PTs who were experienced in working with frail older people and adjusted the exercises for each session depending on changes in the participants' health status. The low occurrence of serious adverse events during the sessions strengthens an interpretation that the tendency towards more drop-outs due to deaths in the exercise group was a random effect, especially considering that only two of these (one in each group) occurred during the 3-month intervention period.

Prevention of falls by a high-intensity functional exercise programme

The absence of a general fall-prevention effect through exercise as a single intervention in this study is in accordance with most other exercise studies in various types of residential care facilities (97, 144). Only one study has shown a reduction in falls in this kind of setting (146). In that study, which had a small sample size, residents with a dementia diagnosis were excluded and the participants' balance function was considerably better than in the present study (145). Among people living in the community or in retirement villages, several studies have shown positive fall-prevention effects resulting from exercise as a single intervention (130-134). Thus, it seems that exercise as a single fall intervention is less likely to be successful in older people living in residential care facilities than in older people living in the community. One possible explanation for this difference in effect might be the broad spectrum of predisposing and precipitating factors for falls in older people living in residential care facilities (25). This indicates the advantages, in this setting, of combining exercise with other fall-prevention interventions, an approach which has been shown to be successful in two studies (108, 140).

One interesting finding from the subgroup interaction analyses was that among those participants who had improved their balance during the intervention period, the exercise group had a significantly lower fall rate than the control group. Furthermore, among those who responded, a 50% non-significant reduction in the proportion of participants who sustained a fall was seen in the exercise group. This highlights a lack of direct association between improvements assessed by balance measures and improved control of balance in real-life circumstances i.e. situations that cause a fall risk (174). The comparison with individuals who had improved their balance, as well as received an elaborate control activity, strengthens the interpretation that the fall-prevention effect was the result of an interaction between the training and the improvements in balance. The functional weight-bearing exercise programme, which includes everyday tasks such as rising from a chair or climbing stairs, may have created favourable conditions for transferring the improvements in physical function to a safer performance of daily living. The participants may have perceived their own capabilities and learned strategies for avoiding falls during physical tasks that fully challenged stability limits. The fall-prevention effect for the entire exercise group might have improved if task-specific training carried out in the participant's everyday environment had been added to the exercise programme, especially considering that many of the participants had cognitive impairments which might have obstructed the transferring of the performance of a task in a supervised exercise session to its performance in everyday life. Learning more about specific responses to exercise and other fall-prevention interventions with regard to the varying characteristics of the participants is important, especially concerning people with a dementia diagnosis, one group of older people for whom no fall intervention has so far proved successful (175).

A high fall rate was found among the participants in Papers I and IV, which is consistent with earlier studies in similar types of residential care facilities (25, 176). The fall rate was even higher among the participants in Paper IV than in Paper I, despite both studies appearing to have a similarly high accuracy of fall reporting. In fact, even the exercise-responding group, which had the lowest fall rate in Paper IV, had a higher fall rate (2.7 falls per PY) than the total sample in Paper I (2.2 falls per PY). However, a direct comparison may not be applicable since the samples differed, for example, more participants had cognitive impairment in Paper IV, indicated by a lower mean score in the Mini-Mental State Examination. Furthermore, both those with a presumably high physical function (independent in ADL) and those with a very low physical function (needing the help of more than one person to rise up from a chair) were excluded in Paper IV. Thus, in Paper IV many participants had a moderate physical function which implies the highest fall risk (177), compared with Paper I where all residents were included.

Ethical considerations

Inclusion of people with severe cognitive impairment or dementia. The inclusion of people in Papers II-IV with MMSE scores as low as 10 might be questioned since traditionally people with considerably higher cognitive function, than most of the participants in the present study, have been excluded from exercise studies (178). However, the limit of 10 or more was based on the clinical experience that those people could follow simple instructions, provide reliable responses to uncomplicated questions regarding their current experiences, and express an unwillingness to participate in a assessment or an activity. This clinical experience is supported by studies which have shown that people with severe cognitive impairment can respond adequately to questions about their quality of life (179, 180) or the presence of depressive symptoms (181). Thus, the assessments in this thesis of physical and psychological functions as well as of adverse events during the intervention seem valid. In addition, as a way of limiting stress and anxiety, all assessments and interventions were performed at the facility. When appropriate because of cognitive impairment, oral consent to participation was also collected from the residents' relatives in order to confirm the will of the resident. Furthermore, the supervisors were experienced in working with older people with impairments in cognitive function. It is important to emphasise that exclusion of people with dementia would not only limit the external validity, but the study would then also fail to target those who most need, and would perhaps also benefit most from an intervention (178).

Risk of injuries. Applying a high-intensity exercise programme on a sample of older people with multiple diseases required consideration. However, clinical experience and experiences from a previous research project supported its appropriateness for this group of older people (106). To minimize the risk of serious adverse events, only PTs with experience in working with frail older people supervised the exercise sessions and an approval from the participant's physician was obtained prior to the intervention. In addition, the participant's physician and registered nurse could be (and were) consulted during the intervention period if a participant showed symptoms that the PT judged needed further consideration.

Further methodological considerations

Methodological quality. One of the strengths of Papers II and IV was the high methodological quality, which increased the internal validity, including intention-to-treat analyses, blinded assessors, concealed randomisation, and the use of an attention control group. There was also a similar loss of participants to follow up in the exercise and control groups.

Statistical power. A major limitation in Paper IV was low statistical power. Despite this, an evaluation of falls seemed important in addition to the evaluation of physical function outcomes in Paper II (for which the study had 80% power). However, more participants or a longer follow-up period would certainly have been preferable for the evaluation of falls. Power calculations are lacking in Papers I and III. In Paper I, the sample size seems too small to allow for certain conclusions regarding the impact on the fall accuracy of the length of the follow-up and different fall definitions.

Effects size. There appears to be a lack of consensus in the literature regarding calculations of effect sizes (182). In a recent Cochrane review of strength training studies among older people, the effect and standard deviation at the follow up were used to calculate the effect sizes (47). In this thesis, the change from baseline to follow up was used (Paper II). The calculation of effect size used in this thesis takes into account any differences between groups in baseline values and, thus, ensures that the effects size is not influenced by the result of the randomisation. Even more importantly, this way of calculating is less dependent on variation in ability between participants. Using a calculation where the effect is divided with the variation in ability between participants (at baseline or follow up) may underestimate the effect in studies with broad inclusion criteria, which in the worst case may lead to incorrect treatment recommendations. In addition, effects sizes can also be presented based on within-group effects (56). This produces less valid effect sizes than using between-group effects, especially in a frail population where maintenance of a function may be a potential treatment effect that will not be revealed by within-group analyses.

Clustering effect. To reduce contamination by the exercise intervention, which could be held in a specific unit at the facility, randomisation was performed in clusters in Papers II and IV. Despite this, there were few differences between groups at baseline that had to be adjusted for in the outcome analyses. A contributory factor to this might be that the randomisation was performed after the inclusion of participants, which eliminated the risk of selection bias. In addition, the randomisation was stratified so that each facility had both groups and was also performed using a relatively large number of clusters. Not surprisingly, especially considering that the intervention was directed to the individuals instead of to the clusters, the additional outcome analyses adjusting for clustering produced essentially the same results as analyses without this adjustment.

Outcome measures. When evaluating the exercise intervention, almost half the available participants were not assessed for lower-limb strength using 1 RM. The loss of assessments was mainly due to safety concerns; participants who had sustain a hip fracture within the preceding 6 months or with a hip prothesis were not approved to do this assessment regarding maximum load. However, the positive long-term effect on lower-limb strength was confirmed by analysis of the proportion of participants able to perform a chair-stand test. To minimise the loss of assessments in bilateral 1 RM, a unilateral test of 1 RM could have been used or an estimation of 1 RM using an equation based on repetitions to failure using less than the maximum load. However, large errors can occur when these equations are used (183). An even better alternative to bilateral 1 RM, for minimising the loss of assessments, might have been to evaluate the lower-limb power, for example, in a seated leg press with no external load (184). This outcome might be even more closely associated with functional performance than lower-limb strength, although the difference in these relations has only been evaluated in older people living in the community (31).

One limitation in Paper III was that the scales used to assess the intensity of strength and balance exercises were not tested for interrater reliability. However, the scales were defined before the intervention started, and all PTs were instructed in how to use them. In Paper I, an assessment of the interrater reliability of the Downton index would have been preferable. In Paper II, interrater reliability among the assessors was high for gait speed and the Berg Balance Scale.

Regarding evaluation of a fall-prevention programme, the relevance of using the proportion of participants who sustained a fall as an outcome measure, in addition to fall rate, could be argued since all falls are likely to cause injury or have other adverse consequences (165). However, the total extent of the psychological consequences might be higher if 20 people sustain one fall each instead of one person sustaining 20 falls. It might therefore be relevant to evaluate both the fall rate and the proportion of participants sustaining a fall. In addition, fear of falling would have been an interesting outcome measure in Paper IV.

Evaluation of the blindness of the assessors. In Paper II, the blinding of the assessors was not complete, which might constitute a study limitation. However it does not seem likely that this affected the outcome since there were few cases of broken blindness and no more than slight agreements between the assessors' guesses and the group allocations (185). The success of blinding is rarely evaluated in trials, even those published in leading medical journals, although unsuccessful blinding may lead to an overestimate of the treatment effect (186). It seems important that authors interpret the success of blinding and its effect on the study results (186), in addition to describing how the blinding was done (187).

Clinical implications

Older people living in residential care facilities and with severe cognitive or physical impairment can be offered functional exercise programmes with high intensity performed in small groups supervised by physiotherapists. The exercise programme is likely to result in a positive long-term effect on physical function and those who respond to the intervention may also be at less risk of falling. This is especially important for people with dementia since cognitive decline is associated with a decline in physical performance (188, 189), as well as with an increased risk of falls (5, 90). The improvements in physical function may be of great importance in daily life, through achieving a higher activity level or more independence. The ability to be active and independent in daily living have been shown to be important factors for satisfaction with life in frail older people (190). The exercise effects may seem small in absolute values but when related to the low baseline values, they appear to be of clinical importance considering the threshold values indicating that even a small gain in strength may result in a significant improvement in daily activities (32). The high-intensity functional exercise programme can easily be implemented in residential care facilities as the exercises are described clearly, the procedure of selection of exercises for each individual is standardised, and all necessary exercise equipment is portable. The use of intention-to-treat analyses in combination with fairly wide inclusion criteria suggests that the effect might be applicable to many older people, implying a substantial impact from a public health perspective (191).

The Downton index appears to be a useful tool in identifying older people in residential care facilities at a high risk of falls, which is an important part of fall-prevention interventions. The index can easily be implemented in usual care, especially when some items are already covered in routine assessments or the information can be obtained from medical records.

Implications for future research

There is an urgent need for further research in older people living in residential care facilities to prevent mobility limitations, falls, and dependency in daily life activities.

The applicability and the effect of a high-intensity functional exercise programme have been evaluated in this thesis. Future research is needed to evaluate whether the applicability of the exercise programme and the nutrition intervention are associated with the effects, and whether the programme is as applicable and effective for women as for men. A further evaluation is whether people with different diagnoses and conditions such as dementia, depression, or malnutrition, achieve similar effects of the interventions. Identifying what characterises people who are likely to respond seems important since the resources for the care of older people are limited and that participants who improve their balance due to the exercise programme may also have a reduced risk of falling. Most important aspects to evaluate are whether the programme has any effects on ADL, by achieving a higher activity level or more independence, on satisfaction with life, or on depressive symptoms. The results concerning the effect on dependency in ADL could also be used for a cost-benefit analysis of the exercise programme as distributed in the present study.

Further development of the high-intensity exercise programme could be considered, such as including more specific components of eccentric or explosive strength training which might increase the effect on functional performance (46, 192-194). Evaluating alternative ways to distribute the programme is also of great interest, for example, involving the staff at the facility in the supervision or progress of the training. If effective, this could reduce the cost of the programme and also increase the continuity of the training. It is very important to evaluate the exercise programme when combined with a nutritional intervention with protein that is individually targeted depending on the participant's nutritional status, as well as to follow the energy balance during the intervention period. It could also be interesting to evaluate the participant's physical function more often or over a longer period of time in order to learn more about when the exercise effects are present and for how long they last. This is valuable knowledge for future evaluations of the optimal frequency and length of an exercise intervention in frail older people.

Future research also needs to improve tools for fall prediction and fall prevention among older people in residential care facilities, especially in people with dementia for whom falls are especially difficult to predict and prevent. In addition, the impact of the length of the follow up for falls on the accuracy for the Downton index, as well as on other fall-risk assessment tools, needs to be further investigated in a large sample. This knowledge seems important for future recommendations of the optimal interval to screen for fall risk.

GENERAL CONCLUSIONS

Among older people living in residential care facilities:

- The Downton fall-risk index appears to be a useful tool for predicting residents sustaining a fall, irrespective of the cause of the fall, even with a perspective of only a few months. The prediction accuracy of the index is, however, limited by a low specificity.

Among older people who are dependent in ADL, living in residential care facilities, and have an MMSE score of 10 or higher:

- A high-intensity functional exercise programme is applicable for use, regardless of cognitive function, and has positive long-term effects on balance, gait ability, and lower-limb strength.

- An intake of a protein-enriched energy supplement immediately after the exercises does not appear to increase the training effects on physical function in this group of older people, of whom a large proportion have a poor nutritional status.

- The frequency of falls is high. Residents who improve their balance function due to a high-intensity functional exercise programme may reduce their risk of falling.

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