Physical exercise and mental health among older people
- measurement methods and exercise effects focusing on people living in residential care facilities

Mia Conradsson
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Mia Conradsson
To my grandparents,
Ulla and Ake, in memoriam
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ABSTRACT

The aim of this thesis was to study the effects of exercise on mental health among older people living in residential care facilities. The aim was also to study the reliability of an assessment scale for balance function and the usefulness of an assessment scale for depressive symptoms among older people, including people with cognitive impairments.

The Berg Balance Scale (BBS) is frequently used to assess balance in older people, but knowledge is lacking about its absolute reliability. The BBS (0-56 points) was assessed twice among older people living in residential care facilities by the same assessor, at approximately the same time of day, and with 1-3 days in between. The absolute reliability was calculated as being 7.7 points, using 95% confidence level, and the Intra Class Correlation coefficient (ICC) was calculated to 0.97.

Depression is common among older people and is often not detected and not treated adequately. The Geriatric Depression Scale 15-item version (GDS-15) was designed to assess depressive symptoms among older people, but there is limited knowledge about the usefulness of the scale among people with varying degree of cognitive impairment. A sample of people aged 85 years and over was divided into groups according to cognitive function using their Mini-Mental State Examination (MMSE) scores; 0-4, 5-9, 10-14, 15-19, 20-24, 25-27, and 28-30. In total, 650 (78%) of the 834 participants completed the GDS-15. The lower the cognitive function, the smaller the proportion who completed the GDS-15 assessment; for the two MMSE groups with scores of < 10, the proportions who completed the GDS-15 were 1% and 42%, respectively, compared to 64–95% in people with MMSE scores of ≥ 10. The level of correlation between the GDS-15 and a scale of psychological wellbeing, the Philadelphia Geriatric Center Morale Scale (PGCMS), did not differ between MMSE groups with scores of ≥5 compared to people in the group with the highest scores (MMSE 28–30).

Exercise has been suggested as effective in influencing mental health among community-dwelling older people, but there is a need for a well-designed study to establish the effects among older people living in residential care facilities. A high-intensity functional exercise programme was evaluated for effects on depressive symptoms and psychological wellbeing among older people dependent in activities of daily living (ADL) and living in residential care facilities. The study was a cluster-randomised controlled study. Participants were randomised to either a high-intensity functional weight-bearing exercise program (HIFE Program) or a control activity. Sessions were held in groups, for approximately 45 minutes, five times over each two-week period for three months, a total of 29 times. The outcome measures, the GDS-15 and the PGCMS, were blindly assessed at
baseline, 3- and 6-month follow-up. There were no differences between the groups at the 3- or 6-month follow-ups in the total sample. However, sub-groups analyses showed a difference in PGCMS scores in favor of the exercise group among people with dementia at the 3-month follow-up.

Regarding older people living in residential care facilities, including people with cognitive impairments, there is a lack of evidence showing that exercise has a positive influence on mental health. This may either be due to a lack of effect, or an insufficient amount of effect of exercise on physical capacity or dependence in ADL, which could be two important mediating factors for influencing mental health. The association between changes in physical capacity (BBS) or dependence in ADL (Barthel ADL Index) and changes in mental health (GDS-15 and PGCMS) was evaluated. The results showed no significant associations between change in physical capacity or dependence in ADL, and change in depressive symptoms or psychological well-being. Further, interaction analyses showed no moderating effects for dementia disorder.

In conclusion, despite a high ICC value, the result of the absolute reliability evaluation shows that a change of 8 BBS points is required to reveal a genuine change in function among older people who are dependent in ADL and living in residential care facilities. This knowledge is important in the clinical setting when evaluations are made of an individual’s change in balance function over time in this group of older people. The GDS-15 seems useful in assessing depressive symptoms among very old people with MMSE scores of ten or above. More studies are needed to strengthen the validity among people with MMSE scores of 10-14, and for people with lower MMSE scores than ten there may be a need to develop and validate other measurements. Furthermore, a high-intensity exercise programme offered 2-3 times/week seems not to generally influence mental health among older people living in residential care facilities. However, the exercise programme may have a short-term effect on well-being among people with dementia. A change in physical capacity or dependence in ADL does not appear to be associated with a change in depressive symptoms or psychological well-being among older people who are living in residential care facilities. These results may explain why studies of using exercise to influence mental health have not shown effects in this group of older people. In future research, there is a need for studies that evaluate whether exercise offered more frequently, or interventions that aim to increase the level of physical activity in daily life, can influence mental health among older people living in residential care facilities.
SVENSK SAMMANFATTNING (Summary in Swedish)

Personer som är 80 år och äldre är den snabbaste växande gruppen i samhället, och det behövs ökad kunskap om insatser som bibehåller eller ökar hälsan och livskvalitén under den senare delen av livet. Forskning behövs för att fastställa effekter av rehabilitering och utvärdera tillförlitligheten av de mätinstrument som används inom vården av äldre personer. Syftet med denna avhandling var att studera om fysisk träning kan påverka mental hälsa bland äldre personer som bor i särskilda boenden och är beroende av hjälp i det dagliga livet. Syftet var också att studera tillförlitligheten av ett mätinstrument för balans, samt användbarheten av en skala som mäter symtom på depression.

Bergs balansskala är en välvanlig skala för att testa balanförhållande hos äldre människor, men det är inte känt hur stabil skalan är mellan upprepade testningar. Fyrtiofem äldre personer som bor i särskilda boenden genomförde två testningar med Bergs balansskala med 1-3 dagars mellanrum. Resultaten visar att skalan är stabil på gruppnivå, men den individuella variabiliteten, dvs. mätfelet mellan två testfälle, var 7,7 poäng på Bergs Balansskala vars totalpoäng går mellan 0-56.

Depression är vanligt bland äldre människor, men tyvärr inte alltid igenkänd eller adekvat behandlad i denna grupp. Geriatrisk depressionsskala (GDS) är en väl-establerad skala utformad för att upptäcka depressiva symtom bland äldre personer, men det behövs mer kunskap om hur skalan påverkas av kognitiva nedsättningar, dvs. exempelvis nedsatt förmåga att minnas och planera. Individer som medverkat i en populationsstudie bland personer som är 85 år och äldre delades i grupper enligt kognitiv funktion, mätt med Mini-Mental Test (MMT); 0-4, 5-9, 10-14, 15-19, 20-24, 25-27, 28-30. MMT har poäng mellan 0-30 där högre poäng indikerar bättre kognitiv förhållande. Totalt 650 individer (78%) av 834 möjliga kunde svara på frågorna i GDS. Andelen som kunde besvara frågorna minskade med lägre kognitiv funktion; för personer med MMT under 10 poäng kunde 1% respektive 42% svara, jämfört med 64-95% för de med MMT poäng på 10 eller mer. Samstämmigheten i svarerna på GDS och en skala för psykologiskt välbefinnande, Philadelphia Geriatric Center Morale Scale (PGCMS), skiljde sig inte mellan personer med MMT poäng på 5 eller mer i jämförelse med gruppen med högst poäng på MMT (28-30).

Fysisk träning verkar vara en effektiv metod för att påverka mental hälsa positivt, t.ex. minska symtom på depression och öka psykologiskt välbefinnande, bland hemmaboende äldre personer men kunskap saknas för personer som bor på särskilt boende. Ett högintensivt, funktionellt viktbärande träningsprogram utvärderades bland äldre personer som bor i särskilda boenden, för att undersöka effekter på förekomst av depressiva symtom och välbefinnande. Deltagarna
lottades till träning tillsammans med sjukgymnaster eller en kontrollaktivitet ledd av arbetsterapeuter. Träffar hölls i små grupper i ca 45 minuter, 2-3 ggr/vecka under tre månader med totalt 29 träffar för båda aktiviteterna. Deltagarna testades för förekomst av depressiva symtom med GDS och nivå av psykologiskt välbefinnande med PGCMS vid studiestart, efter avslutad aktivitetsperiod (3 månader) och vid ytterligare en uppföljning 6 månader efter studiestart. Resultaten visade ingen skillnad mellan grupperna i mental hälsa när alla deltagare analyserades, vare sig vid 3 eller 6 månadens uppföljning. När endast personer med demenssjukdom analyserades fanns det dock en positiv effekt på välbefinnande för träningsgruppen vid uppföljningen direkt efter avslutad träning.

För äldre personer som bor i särskilda boenden har man inte kunnat påvisa effekt av fysisk träning på symtom av depression eller välbefinnande i studier. Dessa uteblivna resultat skulle kunna bero på att träningen inte haft effekt, eller inte haft tillräckligt stor effekt på fysisk kapacitet eller graden av hjälpberoende i aktiviteter i det dagliga livet (ADL). En ökad fysisk kapacitet och minskat beroende i ADL skulle kunna vara möjliga verkningsmekanismer för hur fysisk träning kan förbättra mental hälsa. För att utreda detta undersöks förekomsten av ett samband mellan en förändring över tid i fysisk kapacitet eller nivå av beroende i ADL och förändring i depressiva symtom och välbefinnande. Resultaten visade att det inte fanns några samband mellan dessa parametrar i denna grupp av äldre personer som bor i särskilda boende och som är beroende i ADL.

Sammanfattningsvis visar resultaten att även om Bergs balansskala är tillförlitlig på gruppnivå så visades stor individuell variabilitet mellan mättillfällen, där en förändring på åtta poäng eller mer måste ske innan det kan antas att förändringen i poäng speglar en förändrad funktion. Detta är viktig kunskap för kliniker när resultat från Bergs balansskala tolkas. GDS verkar vara användbar för att mäta symtom på depression bland äldre personer som har kognitiv funktion motsvarande 10 poäng eller mer på MMT. För personer med MMT poäng mellan 10-14 behöver validiteten av GDS utvärderas mot depressionsdiagnos, och för de med MMT poäng under 10 verkar det finnas behov av att nya utvärderingsinstrument utvecklas och utvärdera. Vidare visar resultaten att ett högintensivt funktionellt viktbärande träningsprogram inte verkar påverka mental hälsa bland personer som bor i särskilda boenden och är beroende av hjälp i ADL. Dock fanns en positiv effekt på psykologiskt välbefinnande direkt efter avslutad träningsperiod när endast personer med demenssjukdom analyserades. Det verkar inte finnas något samband mellan en förändring i fysisk kapacitet eller nivå av beroende i ADL och mental hälsa bland personer i särskilda boenden. Detta skulle kunna förklara varför träningsstudier i denna grupp inte påverkat mental hälsa. I framtida forskning behövs studier som utvärderar huruvida träning erbjuden mer frekvent, alternativt interventioner som syftar till att öka den dagliga fysiska aktivitetsnivån, kan ha positiv effekt på mental hälsa i denna grupp av äldre människor.
ABBREVIATIONS

ADL  Activities of Daily Living
BBS  Berg Balance Scale
BMI  Body Mass Index
CI   Confidence Interval
DSM-IV Diagnostic and Statistical Manual of Mental Disorders, fourth edition
FOPANU Frail Older People – Activity and Nutrition Study in Umeå
GDS-15 Geriatric Depression Scale 15-item version
GERDA Gerontological Regional Database Study
ICC  Intraclass Correlation Coefficient
IQR  Interquartile Range
MMSE Mini-Mental State Examination
MNA  Mini Nutritional Assessment Scale
PGCMS Philadelphia Geriatric Center Morale Scale
REMANU Residential care facilities – Mobility, Activity and Nutrition Study in Umeå
RM   Repetition Maximum
SD   Standard Deviation
SE   Standard Error
WHO  World Health Organisation
The thesis is based on the following papers, which will be referred to in the text by their Roman numerals:


IV. Conradsson, M., Littbrand, H., Boström, G., Lindelöf, N., Gustafson, Y., & Rosendahl, E. Is a change in physical capacity or dependence in ADL associated to a change in mental health among older people living in residential care facilities? Manuscript.

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INTRODUCTION

The ongoing worldwide population ageing is a process without parallel in human history. The number of older people aged 60 and over is growing rapidly in the world, especially people over the age of 80. Increased life expectancy is adding years to life, and there is a need to promote good health and quality of life to those years. Diseases such as depression and dementia, and impairments in physical capacity and activities of daily living (ADL) are common among older people, especially those living in residential care facilities. Research is needed to provide rehabilitative actions to improve or prevent impairments, and improve mental health among older people. Research is also needed to provide reliable and valid instruments to detect impairments and symptoms and to evaluate treatment effects.

DEMOGRAPHICS

People aged 60 years and older are today the fastest growing age group in almost all the world. Improved socioeconomic status and access to health care, has led to a fall in mortality rates during childhood. This has been followed by a lower fertility rate, and combined with increased survival also in old ages; this has led to a greater proportion of older people, especially those aged 80 years and over.

Globally, the number of people aged 60 and over is expected to more than triple by 2100, increasing from 784 million in 2011 to 2 billion in 2050. In 1950, only 8% of the world population was aged 60 years or more. By 2011 that proportion had risen to 11% and it is expected to reach 22% in 2050. In ageing populations, the numbers of people in the older age groups grow faster the higher the age range considered. Thus, whereas the number of people aged 60 or over is expected to almost triple, that of people aged 80 or over is projected to increase almost eight-fold and reach 402 million worldwide in 2050. The population in Sweden is increasing, and people in the older age groups represent the largest contribution of this increase. People aged 65 and over make up 18% of the Swedish population today and this figure is projected to increase to 25% in 2060. In 2009, about half a million people in Sweden were aged 80 and over but that number will reach almost a million people by 2060, constituting approximately 9% of the total population.

“Older people” or “very old people” are common expressions used to describe people of high age. In this thesis, older people are defined as people aged 65 years and over and very old people as those aged 85 and over.

AGING

Aging is a slow process with great individual variation. Increased age is associated with decline in muscle strength, balance and gait ability. Age is also related to
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malnutrition, diseases such as depression and dementia, multimorbidity, impaired cognitive function, and dependency in ADL. These factors may lead to a reduced reserve capacity and an increased risk of developing more diseases and functional impairments. Impairments in physical function and difficulties in managing instrumental and personal ADL are also a threat to individual independence, and increase the risk of falls and fall-related injuries such as fractures and head injuries. Aging processes are not dependent on chronological age only. Lifestyle parameters such as work load, eating habits, smoking, diseases, and physical inactivity greatly impact on age-related decline.

RESIDENTIAL CARE FACILITIES

About 90,000 people, which constitutes 5% the total population of people aged 65 years and over in Sweden, lived in a residential care facility in 2010. Residential care facilities in Sweden comprise apartments or rooms with access to a common dining room, alarms, and on-site nursing and care. Some facilities have specific units for people with dementia. These residents have private rooms with close access to common rooms such as dining room and areas for activities, with staff on hand.

The majority of people living in residential care facilities have cognitive or physical impairments and require assistance in ADL such as supervision, functional support, or nursing care. Because of the high prevalence of diseases and cognitive and physical impairments, they may also have a reduced reserve capacity. Thus, they become more sensitive to both internal and external disturbances such as pain or environmental stressors. Further, the ability to manage ADL, including mobility, may depend on many factors such as pain, quality of sleep, and infections, and cause large fluctuations in performance. The presence of physical disabilities also places these people at higher risk of diseases that are related to physical inactivity, as well as the risk of falls and fall-related injuries.

MENTAL HEALTH AMONG OLDER PEOPLE

Mental health in this thesis refers to the concepts of depression, depressive symptoms and psychological well-being.

Depression

Prevalence, risk factors and associated factors

Depression is a psychological state characterized by low mood and loss of interest and enjoyment. The reported prevalence of depression has varied between 5-37% among those aged 85 and over, and up to 48% among people living in residential care facilities. Although prevalence rates are high, it has been concluded that depression is often under-diagnosed, undertreated, and that many people recieving on-going treatment remain depressed.
Female gender, sleep disturbance, disability, prior depression, and bereavement appear to be important risk factors for depression among community-dwelling people aged 50 and over. In a study among people aged 85 and over it was concluded that institutionalisation and disability increased the risk of developing depressive symptoms. Depression is common among people recovering from myocardial infarction and other heart conditions, people suffering from diabetes, hip fractures and stroke. It also complicates the rehabilitation process and worsens the outcome for these patients. Depression in community-dwelling older people is associated with reduced well-being, increased physical disability, decline in physical capacity, and both suicidal and non-suicidal mortality. A study among the very old, aged 85 years and over, showed that people diagnosed with depression had poorer well-being, a higher 1-year mortality rate, and that depression was independently associated with living in institutions and the number of medications taken.

Depression is considered to be a contributing factor in disability among older people, and disability increases the risk of depression in late life. There seems to be a reciprocal relationship between these factors and further research is needed to better understand how the two concepts interact. The term disability can be defined as experiencing difficulties in carrying out activities in any domain of life, e.g. ADL or hobbies, due to a health or a physical problem. An association between depression and disability has been shown in several cross sectional as well as longitudinal studies; both in population based studies and clinical samples. In addition, there are studies that have found that change in disability coincided with change in depression. Thus, improvement in disability was associated with improvement in depression among community-dwelling older people and worsening disability was associated with worsening depression. The association between depression and disability has been controlled for low income or education, greater burden of medical illness, and poorer social support, which are factors that may be associated with both depression and disability. However before presuming causal relationships, there are other factors with potential to moderate the relationship, e.g. dementia, subcortical lesions, or white-matter hyperintensities. In addition, physical activity has been indicated as a moderator for the relationship between depression and disability.

### Diagnostic criteria
Depression can be diagnosed using the Diagnostic and Statistical Manual of Mental Disorders, fourth edition (DSM-IV) criteria for depression. A number of symptoms are assessed, e.g. depressed mood most of the day, markedly diminished interest or pleasure in activities, weight loss, fatigue/loss of energy, insomnia or hypersomnia, feelings of worthlessness, diminished ability to concentrate, or recurrent thoughts of death. For diagnosis of major or minor depressive disorder, at least one of the two symptoms “depressed mood most of the day”, and
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“markedly diminished interest or pleasure in activities”, combined with four (major) or one (minor) other symptom, must have been present during the same 2-week period and represent a change from previous functioning. Depression among older people may differ from that in younger people. Somatic symptoms such as weight loss, sleep disturbances, and pessimism about the future can be common symptoms of depression. However, they may be less useful for diagnosing depression in this group of older people since they may be related to aging itself or to diseases. Thus, it is difficult both for older people to seek care and caregivers to recognize the symptoms of depression.

Comorbidity with other diseases and treatment

Depression among older people seems to be a heterogeneous syndrome regarding e.g. onset, symptom presentation, response to treatment, associated comorbidities, and probable underlying etiologies. Regarding comorbidities, the associations with dementia and stroke are issues of concern.

The prevalence of depression has been reported to be higher among older people with dementia than those without dementia. In people aged 85 and over, the prevalence of depression among people with dementia was reported as 43% compared to 24% among people without dementia. Depression seems to increase the risk of dementia but it is not known whether depression is a risk factor for dementia or prodromal condition. Several mechanisms have been proposed to explain the association, and vascular changes in the brain is one such mechanism. In addition, it has been proposed that the treating depression with antidepressants as the first-line treatment among people with dementia is not clinically effective when compared to placebo and should be reconsidered.

About 30-50% of people who suffer a stroke will develop depression within the first year. Poststroke depression is a significant burden and has been linked to poor rehabilitation outcome, increased mortality and impaired quality of life. The pathophysiological mechanisms are not well known, but are believed to comprise a multifactorial process involving biological, behavioral, and social factors. It has been suggested that the of concept vascular depression can describe the association between depression and cerebrovascular disease, which seems especially common in old age. The evidence for effective treatment of poststroke depression seems debatable and further research is needed in this area.

Psychological well-being

Definition and assessment

It is suggested that well-being is a part of mental health, but there is no consensus on how to define the concept. This lack of definition is accompanied by a
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discussion on the best way to measure it. Well-being is suggested to include aspects such as affect, life satisfaction, distress, loneliness, and morale. Researchers have tried to elucidate the concept of well-being by using several scales in the same study to try to find core components for the concept. It appears that positive and negative affect, or factors named in similar ways, are core components.

When it comes to measuring well-being among older people, the British Geriatric Society and the Royal College of Physicians in London have recommended the use of the Philadelphia Geriatric Center Morale Scale (PGCMS) for assessment of subjective well-being. The PGCMS was developed by Lawton to measure morale, and according to him morale is defined as a basic sense of satisfactions with oneself, a feeling that there is a place for oneself in the environment – that the people and things in one’s life offer some satisfaction to the individual – that there is a fit between personal needs and what the environment offers. High morale also means a certain acceptance of what cannot be changed. People with high morale are also active, sociable, conforming in group living, and optimistic in outlook.

Prevalence, associated factors and consequences

As the population ages, the preservation of well-being in later life becomes increasingly interesting. It is not clear whether age is related to well-being. A study among people aged 85 years and over showed no differences among people aged 85, 90 and 95 years and over. However, another study found that people aged 90 and over have greater well-being than those aged 70-89. In the latter study the authors suggest that there may be a possible survivor effect among the very old participants which could explain the higher scores on well-being.

Studies have been performed to detect factors associated to well-being. A population-based study among older people aged 65 and over found that chronic illness was associated with reduced affective well-being compared with a no-disease group, and also that there was a clear relationship with number of chronic conditions and reduced well-being. The most important conditions for reduced well-being in that study were stroke, chronic lung disease and rheumatoid arthritis. Depression is also considered to be strongly associated with reduced well-being, both in community-dwelling older people and people living in residential care facilities. Further, social support, absence of loneliness, better physical function and exercise have been associated with feelings of well-being. In a population-based study among people aged 65-84 years, a low number of chronic conditions, better mobility status and leisure activity was associated with better well-being at baseline. After an eight-year follow-up, the main factors associated with better well-being was better baseline well-being as well as better mobility status, and younger age. Regarding very old people, aged 85 and over, a low well-being has been associated with loneliness, lack of social activities, impaired indoor
and outdoor mobility, dependence in activities of daily living (ADL) and living in institutions.

**DEMENTIA DISORDERS**

**Prevalence, associated factors, and risk factors**

It has been estimated that 35.6 million people had dementia in 2010 and that the number is projected to nearly double every 20 years, reaching 65.7 million by 2030. Prevalence and incidence projections indicate that the number of people with dementia will increase, particularly in the older age groups and in countries in demographic transition will experience the greatest growth. About 142,000 people in Sweden had a dementia disorder in 2005, and the projections are that the number will increase, especially after 2020 when number of people aged 80 years and over will increase dramatically.

Dementia is a clinical syndrome of loss of memory and other cognitive abilities and can be caused by various diseases and conditions. Mild cognitive impairment is a condition where the person has problems with memory, language or other essential cognitive functions that are severe enough to be noticed. Some of these people will also develop a dementia disorder. Dementia affect people in different ways, but the most common symptom is a gradual deterioration in the ability to remember new information. As the condition worsens, individuals may also experience confusion, disorganized thinking, impaired judgment, trouble expressing themselves, and disorientation to time, space and location. The prevalence of dementia has been reported as 13% at ages 80-84 years, 24% at 85-89, 34% at 90-95, and 45% at 95 years and over. There are several different dementia disorders but Alzheimer’s disease is the most common, accounting for about 60-70% of all dementia cases. Vascular dementia accounts for about 20% and the prevalence of other subtypes such as dementia of Lewy Bodies and frontotemporal dementia is less investigated but is suggested to account for about 10%. More women than men have dementia disorders and age is the primary risk factor for developing dementia.

People with dementia experience impairments in motor function, usually more prominent in the later stages. Gait and balance disorders have been shown to be more common among people with dementia than among age-matched controls without dementia. Further, they seem to be more common among people with vascular dementia, than among those with Alzheimer’s disease, especially in the early stage.

**Diagnostic criteria**

Dementia can be defined using the DSM-IV criteria of the American Psychiatric Association, or the International Classification of Diseases, 10th Edition (ICD-10).
of the World Health Organisation\textsuperscript{77}. These definitions are similar and primarily based on clinical criteria regarding multiple cognitive deficits, including memory impairment associated with impairments in ability to manage ADL and often also personality and behavioural changes. The impairments must represent a decline from previous level of functioning and occur in the absence of disturbed consciousness such as delirium. Further, specific subtypes of dementia have specific standardized criteria. In the present thesis, the DSM-IV criteria were used where memory impairment (impaired ability to learn new information or to recall previously learned information) is required and at least one of the following cognitive disturbances: aphasia (language disturbance), apraxia (impaired ability to carry out motor activities despite intact sensory function) or disturbance in executive functioning (i.e. planning, organisation, sequencing, abstracting).

Consequences
Dementia disorders increase the risk of physical inactivity and difficulties in participating in social activities. Dementia produces intellectual decline, which in combination with the associated physical impairments, interferes with the ability to manage ADL\textsuperscript{73, 74, 78}, and to participate in social activities\textsuperscript{73, 79, 80}. These physical and cognitive impairments also contribute to increased risk of falls and fractures\textsuperscript{81, 82}.

PHYSICAL ACTIVITY AND EXERCISE

Health benefits
Increasing evidence points towards health benefits from physical activity and exercise and towards the benefits of an active lifestyle. Physical activity refers to bodily movement produced by skeletal muscles, which increases energy expenditure. Exercise is defined as planned, structural movement via skeletal muscles that results in energy expenditure, and with the aim of improving or maintaining physical fitness\textsuperscript{83}. Regular physical activity and exercise is effective in the primary and secondary prevention of several diseases including cardiovascular disease, diabetes, cancer, hypertension, obesity, depression and osteoporosis\textsuperscript{84-86}.

The focus has also turned to the risks of being physically inactive, and physical inactivity has been identified as the fourth leading risk factor for global mortality\textsuperscript{87}. A series of articles was recently presented to emphasize the risks of being physically inactive\textsuperscript{88}. Inactivity has been reported to cause 6-10\% of the major non-communicable diseases of coronary heart disease, type 2 diabetes, and breast and colon cancer\textsuperscript{89}. Further, inactivity causes 9\% of premature mortality. Taking all of this together, inactivity seems to be of similar importance as the well-established risk factors smoking and obesity. In these studies, physical inactivity was defined as not reaching the recommended levels of physical activity\textsuperscript{80}. 
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The health risks of living a sedentary lifestyle is not as well investigated as the risks of lack of physical activity, but interest in this issue seems to be increasing. A review of prospective studies concluded that there is moderate evidence for an independent relationship between sedentary time and type 2 diabetes, and strong evidence that sedentary behaviour is related to all-cause mortality and mortality from cardiovascular diseases. A recently published, large prospective cohort study among people aged 45 to 101 investigated the effect of total sitting time on all-cause mortality risk. A questionnaire was used and information was collected regarding total sitting time through self-report, together with important confounding information such as age, sex, education, Body Mass Index (BMI), physical activity, smoking, self-rated health, disability and medical status. The results show that sitting time was associated with a high all-cause mortality risk, independent of level of physical activity. A dose-response relationship was revealed where those who sat most and performed no weekly physical activity had the highest all-cause mortality risk. Sitting less than 8 hours/day and achieving the recommended amount of physical activity, defined by the WHO, protected against all-cause mortality.

Recommendations for physical activity level

The WHO presented a report in 2010 with global recommendations for level of physical activity needed for prevention of non-communicable diseases. Physical activities include leisure-time physical activity, transportation (e.g. walking), occupational, household chores, or planned exercise. Adults over 18 years, including people aged over 65, are recommended to take at least 150 min of moderate-intensity aerobic activity throughout the week, and for additional health benefits a further 150 minutes of moderate or vigorous-intensity activity. Muscle strengthening activities involving major muscle groups should also be performed on 2 or more days per week.

The Swedish summary of guidelines for physical activity in the prevention and treatment of disease are partly based on the recommendations from the WHO, and additional recommendations are made for age groups and groups of people with functional or medical deficits. They are intended for all adults aged 18 and over with no upper age limit. Older people are also recommended to perform balance training. In addition, older people or individuals with chronic diseases who have trouble meeting the general recommendations should be as active as they can. The general recommendations state that long periods of sitting should be avoided and that people who sit a lot at work or during leisure time should take regular breaks for a few minutes together with some kind of muscular activity. This recommendation also applies to those who do meet the recommendations of activity.
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Physical activity among older people in residential care facilities
Older people living in residential care facilities may have difficulties reaching up to the recommendations mentioned above. One study shows that more than a third of those who moved into a residential care facility reduced their level of physical activity during the first year. This may increase the risk of diseases and conditions related to physical inactivity. For example, physical changes in older people that are associated with inactivity are decreased muscle strength, impaired proprioception and balance, slowed gait velocity and decreased bone mass and density. A large proportion of people in residential care facilities suffer from dementia disorders, and studies of people with dementia concludes that they spend most of their time doing nothing or sitting quietly, and in another study that they were mostly passive, without engagement or well-being. People with dementia most likely have difficulties to initiate activities, including physical activities, and live in an environment that may not stimulate physical activity. Care personnel at these facilities sometimes give help to residents to save time, which leads to the problem that some people may receive more assistance from caregivers than they actually need thus putting them at risk of further inactivity.

Physical activity and exercise to influence mental health among community-dwelling older people
Exercise has been studied as an alternative treatment for depression and as an influence on psychological well-being among older people. Cross-sectional studies among older people show that a higher level of physical activity is associated with a lower prevalence of depressive symptoms, and that it is positively related to mental health and well-being. Results from intervention studies among older people generally support the existence of these relationships. It seems that both aerobic exercise and resistance exercise programmes can be effective in influencing depressive symptoms and well-being, and further that high- or moderate-intensity programmes seem more effective than low-intensity training. However, the existing evidence is limited since many studies have methodological weaknesses, such as lack of concealed allocation and blinding, and inadequate control groups, and some caution should be taken when interpreting the results because of differences in outcome definitions and exercise prescriptions.

Exercise effects among older people living in residential care facilities including people with dementia

Exercise effects on ADL and physical function
Recommendations from the American College of Sports Medicine (ACSM) states that frail or very old people should exercise to preserve reversible relevant physiological deficits such as muscle strength, muscle mass, bone density
INTRODUCTION

cardiovascular condition, balance, and gait\textsuperscript{106}. Progressive resistance strength training of high intensity, i.e. training close to the individual's maximum capacity, involving the major muscle groups of upper and lower extremities and trunk should be performed on at least two, but preferably three days/week. Balance training should also be incorporated, as part of the strength exercises using free weights to enhance balance and muscle coordination, or as a separate modality\textsuperscript{86, 106}. Further, the principles of specificity in the training, i.e. exercises being task specific, and performed in the same movement patterns as that targeted for improvement, are important regardless of age\textsuperscript{107, 108}.

Knowledge regarding the effects of exercise in people living in residential care facilities has increased over the last decade and shows that exercise has important effects in improving or maintaining physical function and the ability to manage ADL. A systematic review regarding the effects of rehabilitation aimed at maintaining or improving physical function among institutionalized older people suggests that rehabilitation shows improvements in physical function in this group regarding mobility and balance\textsuperscript{109}. Few studies were judged to be of high quality, thus the positive effects require replication in future research. Further, no recommendations were given regarding the optimal type of intervention, and there was great diversity between intervention content and outcome measures.

Resistance training seems to be of extra importance among older people in residential care facilities since they may have reduced muscle strength and thus may approach muscle strength threshold values for lower extremity performance\textsuperscript{110}. This means that a small decline in muscle strength can result in the inability to perform an activity independently, for example rising from a chair. Consequently, they could benefit more from strength exercise than healthy older people with a larger reserve capacity. A systematic review regarding exercise programmes based on progressive resistance training as a single intervention among people in residential care facilities was presented recently and concludes that significant improvements in muscle strength and functional performance occur in response to this type of training\textsuperscript{111}. The importance of aiming at high intensity rather than low intensity was indicated since studies using high intensity exercise produced greater strength gains in these people. The studies that used high intensity exercise produced positive effects on lower limb muscle strength, and functional outcomes such as gait speed, sit to stand performance, stair climbing power, and balance.

One of the studies included in the above review was the FOPANU Study in Umeå which evaluated a programme using high-intensity functional exercise, performed in weight-bearing positions in a randomised controlled study among older people in residential care facilities. The evaluation of the applicability of the programme in this group of older people, including people with cognitive impairments, shows
INTRODUCTION

high rates of attendance, a relatively high achieved intensity in the exercises, and that the programme was safe to perform\textsuperscript{112}. Positive long-term effects were seen on balance, indoor mobility, and lower limb strength compared to a control group\textsuperscript{113, 114}, and in people with dementia there was also a positive effect on overall ADL performance\textsuperscript{113}. Further, informants described during interviews a will to be active in order to avoid reduced capacity, and also experiences of improvements in body and soul\textsuperscript{115}.

Studies on the effects and applicability of exercise among older people with dementia are few, and a review presented in 2011 describes the existing evidence from randomised controlled studies in this group\textsuperscript{116}. It was concluded that walking exercises and combined exercise programmes are applicable in this group. Further, it seems that walking exercises challenging the maximum individual capacity can prevent decline in walking ability, and that combined functional exercise (including walking, balance, and lower-limb strength exercises) for 12 months reduces ADL decline and improves walking performance in people Alzheimer's disease. The results indicate that people with dementia may benefit from the exercise recommended for older people and that more high quality randomized controlled trials in this group are needed.

Exercise effects on mental health

Despite people living in residential care facilities having the highest prevalence of depression and depressive symptoms, few exercise studies have been performed with the aim of influencing depressive symptoms and well-being in this group of older people with a high prevalence of physical and cognitive impairments. A search through the literature found four randomised controlled trials\textsuperscript{95, 117-120} evaluating one or more exercise programmes, as a single intervention, that seem to have used at least moderate intensity or to have progressively increased the load or dose. However, none of these studies explicitly reported that the exercise was of high intensity. The exercise forms used were resistance training\textsuperscript{95, 117}, walking exercise\textsuperscript{119, 120}, or combined exercise\textsuperscript{117-120}. All but one of these studies excluded people who were unable to walk\textsuperscript{117-120}, and one study seems not to have included people with dementia\textsuperscript{117}. There are some methodological limitations in these studies, e.g. concealed allocation was not explicitly reported\textsuperscript{95, 119, 120}. In addition, two of the above-mentioned studies have not used control groups which included an activity performed at the same frequency as the exercise intervention group\textsuperscript{95, 118}. To evaluate the effects of exercise per se, a control group is required which receives the same amount of attention and social stimulation as that given to the exercise group. One can imagine that the effects of attention and social stimulation may be considerable especially among people with cognitive and physical impairments, because they generally have few social contacts\textsuperscript{79, 80, 121}. Considering the above-mentioned aspects, there is a need for a well-designed study to establish the effect of high-intensity exercise on depressive symptoms and psychological
well-being among older people in residential care facilities, including also people with severe physical or cognitive impairments.

**Mechanisms by which physical activity and exercise may influence mental health**

The mechanisms by which physical activity and exercise are assumed to influence mental health are both psychosocial, due to increased physical fitness, social stimulation, and the satisfaction of accomplishing new things\textsuperscript{122}, as well as psychophysiological, due to changes in levels of monoamines or neurotrophins, or hypothalamic-pituitary-adrenal (HPA) axis activity\textsuperscript{123, 124}. Impairments in physical capacity and dependence in ADL are common among older people in residential care facilities, and they may be two important mediating factors in influencing mental health through physical exercise in this group. Increased physical capacity and independence in ADL may be important for mental health through e.g. improved self-esteem and ability to participate in social activities, or by enhancing the possibilities of increasing the level of daily physical activity\textsuperscript{28, 39, 40, 125, 126}. However, people with dementia often have difficulties to initiate physical activities\textsuperscript{80, 127} which might affect the expected importance of physical capacity and dependence in ADL on mental health. The lack of positive effects on mental health in earlier exercise studies\textsuperscript{95, 117, 118, 128} may be due to a lack of effect, or an insufficient amount of effect, on physical capacity or dependence in ADL.

Another theoretical cause for the lack of positive exercise effects on mental health in this group of older people may be that physical capacity and independence in ADL are not important as mediating factors. A number of longitudinal studies support the association between physical capacity or independence in ADL and mental health among community-dwelling older people\textsuperscript{28, 36}. However, there is a lack of studies investigating this association among people living in residential care facilities including those with cognitive impairments\textsuperscript{28, 36}. Furthermore, longitudinal studies usually evaluate these associations by using a level of a variable at baseline to predict the level of another variable at follow-up\textsuperscript{28, 36}. To better understand how two variables interact, there has been a request for an analytic approach for longitudinal data that models changes over time\textsuperscript{33, 125, 129}. This analytic approach could be used to identify factors that mediate the relationship between physical exercise and mental health. Investigation of the association between changes in physical capacity or dependence in ADL and changes in mental health will provide information about the possibility for exercise to influence mental health through improvement in physical capacity or dependence in ADL.
MEASUREMENTS AMONG OLDER PEOPLE

Assessment of balance
Balance is often impaired among older people, especially among those living in residential care facilities, and assessment instruments are needed to detect impairments and evaluate rehabilitation, e.g. for detecting and reducing the risk of falls. Because of the fluctuations in health status that may occur among people in residential care facilities, the variability between repeated assessments may be large. Thus, investigation of the reliability of the assessment scale is important and will provide the clinician with information on whether a change in score between assessments is due to a real change in function or to measurement error.

Reliability
Reliability refers to the consistency of repeated measurements of an individual's performance from one time to another, and has been described as relative or absolute. Relative reliability examines the relationship between two or more measurements and the consistency of an individual's position within the group. Absolute reliability examines variability in scores in repeated measurements. The Intraclass Correlation Coefficient (ICC) is commonly used to evaluate relative reliability. However, the ICC value is of limited use to the clinician because it is not related to the actual scale of measurement and is dependent on the range of the individuals' performances. If the individuals' range of scores is low, the ICC value often will show poor reliability, and vice versa. This means that the clinician cannot be sure whether a high ICC value for an instrument actually means low variability at the individual level.

A more appropriate way of investigating the reliability of an instrument intended for use in a clinical setting seems to be to examine absolute reliability. When using absolute reliability, the assessor receives information about how much variability caused by measurement error can be expected in the scores for an individual. In 1996, Bland and Altman presented a way of calculating absolute reliability, which they referred to as the "repeatability." Other methods are also available for estimating absolute reliability, however, it appears that the same calculations are used but the outcome is given different names. The equation used by Bland and Altman also has been referred to as the "smallest detectable difference" (SDD), the "minimum detectable change" (MDC), and the "smallest real difference" (SRD).

Reliability can be tested either by having two different observers independently assessing the same individual (inter-rater reliability), or by having the same assessor performing the assessments (intra-rater reliability). When investigating variability within the assessed individual, intra-rater reliability seems preferable because the variability from the assessor is minimised.
The Berg Balance Scale

The Berg Balance Scale (BBS) was developed to measure balance among older people by assessing the performance of functional tasks\textsuperscript{138-140}. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research\textsuperscript{141}. The BBS has been evaluated in several reliability studies, of which three are concerned with intra-rater reliability among older people\textsuperscript{135, 138, 140}. Two of these, which evaluated relative reliability only, were performed among older people living in the community, in senior's residences or in a home for older people\textsuperscript{138, 140}. The ICC values in these studies were 0.98 and 0.97, respectively. To my knowledge, the absolute intra-rater reliability of the BBS has only been evaluated in one study, which was performed among people with Parkinson's disease (n=26) who were living in the community\textsuperscript{135}. The ICC was 0.87 and the absolute reliability was 2.8 BBS points (95\% confidence level). Thus, there is lack of absolute intra-rater reliability studies of the BBS among older people and absolute reliability has never been evaluated among older people living in residential care facilities.

Assessment of depressive symptoms

Impairments in mental health are common among older people and depression and depressive symptoms are areas of particular importance because of the high prevalence\textsuperscript{18-22}. Self-rating scales for assessing impairments in mental health are often used, for example for assessing presence of depressive symptoms\textsuperscript{142}. It is a matter of concern whether difficulties related to multimorbidity\textsuperscript{8}, including impairments in cognition, vision and hearing, influence such assessments.

The Geriatric Depression Scale

The Geriatric Depression Scale (GDS) is an instrument that was developed, regarding both content and design, to assess depressive symptoms and screen for depression among older people\textsuperscript{41}. Somatic symptoms such as weight loss, sleep disturbances, and pessimism about the future, are common symptoms of depression. However, these can also be related to aging itself, and are not included in the GDS, which focuses instead on psychiatric symptoms. During development of the GDS, clinicians and researchers in the geriatric field were asked to suggest items that could separate those with from those without depression. From these suggestions, 30 items were chosen for inclusion in the scale. The GDS can be self-administered or presented as an interview, and the questions have a yes/no format in order to be easy to understand for older people who may suffer from impaired cognitive function. Shorter versions have been suggested to reduce problems of completing the scale arising from fatigue or concentration difficulties. A 15-item version was presented by Sheikh & Yesavage in 1986 (GDS-15), based on the items that correlated best with depressive symptoms, and was equally successful as the 30-item version in differentiating between those with and without depression among people aged 55 years and over living in the community\textsuperscript{143}.
Cognitive impairments are common among very old people, and it is an important question whether the psychometric properties of the GDS are influenced by this. Studies have investigated validity among people with cognitive impairment or dementia and have found decreasing validity along with decreasing level of cognitive function. Cognitive impairment is defined in various ways in these studies, and it is difficult to interpret the level to which the GDS is feasible and valid since studies have used a variety of cognitive levels for inclusion and for subgroup analyses. However, the GDS (15- and 30-item versions) seems to be valid for people with cognitive impairments down to scores of 15/30 on the Mini-Mental State Examination (MMSE). There is a lack of knowledge regarding the validity of the scale among people with even lower cognitive function specifically since this, to our knowledge, has only been evaluated in two studies which both used the 30-item version. In addition, only one study has focused on very old people, aged 85 years and over, and that study included mainly people with no or only mild cognitive impairment.
RATIONAL FOR THE THESIS

People aged 60 years and older are today the fastest growing age group in almost all the world, and the older the age group considered the faster the numbers grow. With increasing age, medical conditions and dependence in ADL become more common, and many people move to a residential care facility. A large proportion of people in residential care facilities have reached a high age, and diseases such as depression and dementia disorders are common. Further, most of the residents have moderate or severe physical impairments, such as impaired balance. Research is needed to provide rehabilitative actions to improve or prevent impairments, and increase mental health among older people. Further, research is needed to provide reliable and valid instruments for detecting impairments and symptoms and evaluating treatment effects.

Maintaining balance function is important for being able to stay physically active in life and for avoiding falls and fractures. The Berg Balance Scale is an assessment tool for clinical evaluation of balance among older people; however the absolute reliability of the scale has not been well investigated among older people living in residential care facilities. Diseases and physical and cognitive impairments can lead to reductions in reserve capacity and cause day-to-day fluctuations in health status. The fluctuations can cause a large variability between repeated assessments, and investigation of absolute reliability will provide information about how much change in actual scores can be expected between assessments due to measurement error.

Depression is common among older people, especially among those with dementia, and is often not detected and not treated adequately. The Geriatric Depression Scale 15-item version (GDS-15) was designed to assess depressive symptoms among older people, but there is limited knowledge about the usefulness of the scale among very old people with varying degree of cognitive impairment.

Levels of physical activity and exercise are associated with mental health, and intervention studies show that physical exercise interventions using aerobic or resistance training of moderate or high intensity has positive effects on depression and psychological well-being among community-dwelling older people. Despite people living in residential care facilities having the highest prevalence of depression and depressive symptoms, only a few studies evaluating exercise of at least moderate intensity have been performed in this group. These studies also have limitations, e.g. methodological limitations, excluding people with physical or cognitive impairments, or have not included a control group receiving the same amount of attention as the exercise intervention. Thus, there is a need for a well-
designed study to establish the effects of high-intensity exercise on depressive symptoms and well-being among older people living in residential care facilities, including people with dementia.

Even though physical exercise programs has shown positive effects on mental health, i.e. depressive symptoms or psychological well-being among community dwelling older people, studies among people living in residential care facilities lack these positive effects. Physical capacity and dependence in ADL are potential mediators by which exercise can influence mental health among community-dwelling older people. However, it may be that these factors are not important among people in residential care facilities, including people with dementia. An analytical approach has been suggested in order to better understand how two variables interact. Investigation of associations between the changes in physical capacity or ADL dependency and mental health, using longitudinal data, will provide information about the possibility for exercise to influence mental health through the improvement of physical capacity or dependence in ADL.
INTRODUCTION

AIMS OF THE THESIS

The aim of this thesis was to study the effects of exercise on mental health among older people living in residential care facilities. The aim was also to study the reliability and usefulness of measurement instruments among older people, including people with cognitive impairments.

Specific aims

*Paper I* - to examine the absolute and the relative intra-rater reliability of the Bergh Balance Scale among older people dependent in ADL and living in residential care facilities.

*Paper II* - to investigate the usefulness of the Geriatric Depression Scale 15-item version to assess depressive symptoms among very old people with differing levels of cognitive function in a population-based sample.


*Paper IV* - to investigate whether a change in physical capacity or dependence in ADL is associated with a change in depressive symptoms and psychological well-being, among older people living in residential care facilities. A second aim was to investigate whether dementia disorders can be a moderating factor for this association.
METHODS

This thesis is based on three studies; a cohort study – the Residential care facilities — Mobility, Activity, and Nutrition Study in Umeå (REMANU Study), a randomised controlled intervention study – the Frail Older People – Activity and Nutrition Study in Umeå (FOPANU Study), and a population-based cohort study – the Umeå 85+/Gerontologic Regional Database Study (GERDA Study). The REMANU Study and the FOPANU Study were carried out in residential care facilities in the municipality of Umeå, Sweden, and the GERDA Study included participants from Umeå, and five rural municipalities in the county of Västerbotten in Sweden, and two municipalities in Pohjanmaa in Finland (Table 1).
## METHODS

**Table 1.** Overview over the studies, methods, and characteristics of participants in Papers I-IV.

<table>
<thead>
<tr>
<th></th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
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<tr>
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<td>Umeå 85+/GERDA</td>
<td>FOPANU</td>
<td>FOPANU and REMANU</td>
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<td>Cohort</td>
<td>RCT</td>
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<td>Cross sectional</td>
<td>Between-group comparison</td>
<td>Longitudinal</td>
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<td>Reliability study</td>
<td>Usefulness study</td>
<td>Exercise effects</td>
<td>Associations</td>
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<td>191</td>
<td>206</td>
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<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<td><strong>PGCMS</strong></td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<td>ANCOVA</td>
<td>Multivariate regression</td>
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**Note:** RCT = randomised controlled trial, BBS = Berg Balance Scale, GDS-15 = Geriatric Depression Scale 15-item version, PGCMS = Philadelphia Geriatric Center Morale Scale, MNA = Mini Nutritional Assessment, MMSE = Mini-Mental State Examination.
METHODS

THE REMANU STUDY

Study design
The aim of the study was to monitor changes in mobility, activity, and nutrition over a period of six months (from March to September 2004) and to evaluate the reliability and validity of a number of measures of physical function, in older people dependent in ADL and living in residential care facilities.

Inclusion
Inclusion criteria were: aged 65 years and over, dependent on assistance in one or more personal ADL according to the Katz Index\textsuperscript{151}, able to rise from a chair with armrests with help from no more than one person, a MMSE score of ten or more, and the approval of the resident’s physician. All residents went through a screening process carried out by a physiotherapist.

THE FOPANU STUDY

Study design
The FOPANU Study is a cluster-randomised controlled study, carried out from March to September 2002, which comprised an exercise intervention compared to a control activity, and a nutrition intervention versus placebo in a 2 x 2 factorial model\textsuperscript{114}. The aim of the FOPANU Study was to evaluate the effects of an exercise intervention and a nutritional supplement in older people living in residential care facilities. In this thesis, only the exercise intervention is evaluated. The rationale for this is that the nutrition intervention, in the form of a protein-enriched supplement aimed at increasing the effect of the exercise intervention, showed no effect on physical function and was not designed to influence overall nutritional status among the participants. The exercise intervention and control activity were presented to participants and staff at the facilities with no indication of the study hypothesis. Randomization was concealed to exclude the possibility of selection bias and was performed after inclusion of the participants and baseline assessments. Researchers not involved in the study performed the randomization using lots in sealed non-transparent envelopes. To reduce contamination by the exercise intervention, 34 clusters, comprising 3 to 9 participants living on the same floor, in the same wing or unit, were randomly assigned to the exercise or the control group. The randomisation was stratified so that the two groups were distributed as equally as possible in each facility, in order to minimize the risk of impact from factors associated with the facility. The assessors of the outcome measures were blinded to group allocation and previous test results.
Inclusion
Inclusion criteria and the screening process were the same as in the REMANU Study (see above).

Exercise programme and control activity
The exercise programme was based on a high-intensity functional weight-bearing exercise programme (the HIFE Program), which was developed by physiotherapists for the FOPANU Study. The purpose of the programme was to improve lower-limb strength, balance and gait ability. The HIFE Program includes 41 exercises with examples of how to increase the difficulty or the load for each exercise. A physiotherapist selected and instructed appropriate exercises for each participant, and also adjusted them to meet changes in health and functional status. The exercises were based on functional tasks that are common in everyday life and were performed in weight-bearing positions. Examples of these exercises are walking, walking over obstacles, squats, and turning the trunk and head while standing still. It was recommended in each session that every participant performed at least two lower-limb strength and two balance exercises in two sets. The participants were encouraged to perform the exercises at a high intensity by progressively increasing the load in the lower-limb strength exercises and the difficulty in the balance exercises. Strength exercises were intended to be performed at 8-12 repetition maximum (RM). The load was increased by adjusting the performance of the exercise (e.g. by doing deeper squats or step-ups onto a higher box) or by using a weighted belt worn around the waist loaded with increasing weights (maximum 12 kg). The balance exercises were intended to fully challenge the participant’s postural stability. The difficulty in each exercise was increased, for example, by standing or walking on a narrower base of support or on a more challenging surface. At the end of the 3-month exercise period, the physiotherapists introduced physical tasks for the participants, in cooperation with a member of the staff at the facility, for the purpose of maintaining physical function. The tasks were integrated into daily life activities. They were individually recommended according to each participant’s functional deficits and motivation 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 (at the 6-month follow-up), by interviewing staff about compliance during the preceding two weeks.

The control activity consisted of a programme developed by occupational therapists which included activities performed while sitting e.g. watching films, singing, reading and conversation. The programme was based on themes, e.g. the old village shop, famous people, and games from the past, that were expected to be interesting and stimulating for older people, including those with severe cognitive impairment.
Both exercise and the control activities were performed in groups of 3-9 participants, supervised by two physiotherapists and one occupational therapist, respectively. The sessions lasted approximately 45 minutes and five sessions were held within each two-week period, giving a total of 29 sessions over 3 months (13 weeks). The attendance was 72% in the exercise group and 70% in the control group. No adverse event led to any manifested injury or disease\textsuperscript{112, 114}. The achieved exercise intensity was estimated and registered by the supervisors after each session, according to predefined definitions\textsuperscript{112}. Lower-limb strength and balance exercises of high intensity were performed in a median of 53% and 73%, respectively, of the attended exercise sessions. Corresponding figure for strength exercises at medium (13-15 RM) or high intensity was 92%\textsuperscript{112}. No significant differences were observed in applicability (attendance, achieved intensity, adverse events) of the exercise programme when comparing participants with and without dementia\textsuperscript{112}. At the end of the 3-month exercise period, 81 (93%) of the remaining 87 participants in the exercise group were given 2.0 ± 0.8 (mean ± SD) physical tasks. At the 6-month follow-up, 29 (39%) of the remaining 74 participants had performed one task or more as frequently as recommended, and 29 (39%) had not done any\textsuperscript{114}.

**THE GERDA STUDY**

**Study design**

The Umeå 85+/GERDA is a collaborative population-based cohort study performed by Umeå University, Åbo Akademi University, University of Vaasa, and Novia University of Applied Sciences, Finland\textsuperscript{6, 153}. Data collection was carried out in the county of Västerbotten in the urban municipality of Umeå and in five rural municipalities during 2000-2002 and 2005-2007. Data collection was also carried out in 2005-2006 in two municipalities in Pohjanmaa, Finland.

**Inclusion**

The study included every second person aged 85 years, and the total population of people aged 90 years and 95 years and over, registered by the National Tax Board in Sweden and the Finnish Population Register Centre in Finland.

**PARTICIPANTS**

**Paper I**

All residents (n = 172) in three residential care facilities were screened and sixty three people were included in the REMANU Study. Forty-five participants completed two testing sessions with the BBS at the 6-month follow-up in September and were included in the sample in Paper I (Figure 1). The Katz ADL
scores and proportion of females/males did not differ between the participants (n = 45), and those who met the inclusion criteria but were not included in the study (n = 59). However, age differed significantly between the two groups; the participants were younger than those not included (mean age ± SD of 82.3 ± 6.6 years versus 86.3 ± 7.5, p = 0.006).

**Paper II**

Paper II included cross-sectional data for 834 participants obtained from the GERDA Study, who were assessed for cognitive function during 2000/02 and 2005/07. A flowchart of the inclusion is shown in Figure 2. A number of individuals (n = 101) participated in both Swedish data collections. For those individuals, only the data from 2005-2007 were used in Paper II with the rationale being that they would contribute with cross-sectional data from when they were older and thus expected to have lower cognitive function which was a point of interest in Paper II.

**Paper III**

All residents (n = 487) at nine residential care facilities were screened by physiotherapists, and 191 people were finally included in the FOPANU Study. Age (p=0.84), sex (p=0.64) and Katz Index score (p=0.66) did not differ between those included and those who declined to participate. Data from assessments at baseline, 3-, and 6-month follow-ups were used. A flowchart of the inclusion process for Paper 3 is shown in Figure 3.

**Paper IV**

Paper IV included participants from three groups; an exercise intervention group, a control activity intervention group (the FOPANU Study) or a usual care group (the REMANU Study). A number of individuals (n = 18) participated in both the FOPANU and the REMANU Study. For those, only data from the FOPANU Study were used. Two hundred and six individuals were included (Figure 4). Data from baseline assessments and follow-up assessments after three months were used. Assessments were performed according to the same procedure using the same assessment methods in both studies.
Figure 1. Flow chart showing the participants in Paper I.
Figure 2. Flow chart showing the participants in Paper II.
Figure 3. Flow chart showing participants in Paper III.
Figure 4. Flow chart showing participants in Paper IV.

* Participants from the FOPANU and the REMANU Study. A number of individuals (n = 18) participated in both studies. For those, only data from the FOPANU Study were used.

** Target variables include the Berg Balance Scale, Barthel Index, Geriatric Depression Scale-15 and Philadelphia Geriatric Center Morale Scale.
METHODS

PROCEDURE

Papers I, III and IV
The participants were given oral and written information about the study. The participants themselves, and the relatives of those with severe cognitive impairment, gave their informed oral consent. The REMANU Study was approved by the Regional Ethical Review Board in Umeå (§439/03), as was the FOPANU Study (§391/01).

The resident’s registered nurse used the medical records and from all other available documentation at the residential care facility to recorded diagnoses, clinical characteristics, and prescribed drugs. Most baseline assessments were performed by trained physiotherapists. A member of the staff who knew the participant well was interviewed about the participant’s ability to manage ADL. The participants were interviewed and tested in their own room/apartment, or in the corridor outside their rooms. A specialist in geriatric medicine evaluated the documentation of diagnoses, drug treatments, assessments, and measurements to complete the final diagnoses at baseline. Dementia disorders and depression were diagnosed according to the DSM-IV criteria\textsuperscript{17}. In the few cases where the participant had a high score on the GDS-15 but did not have a depression diagnosis or had a low score on the MMSE but did not have a dementia diagnosis, the specialist in geriatric medicine decided whether the participant fulfilled the DSM-IV criteria based on all available information, including assessments and information from medical records.

Paper II
Information about the study was sent as a letter to all potential participants and followed up with a phone call about one week later where informed consent to participation was obtained. For those living in institutions, staff were contacted and asked about the cognitive state of the individual. The next of kin was contacted and asked for informed consent when appropriate due to cognitive impairment. The study was approved by the Regional Ethical Review Board in Umeå (§99-326 and §05-063M) and the Ethics Committee of Vaasa Central Hospital (registration number 05-87).

A structured interview covering a variety of areas regarding health and sociodemographic data, including assessments, was carried out, in the same order, during one to three home visits\textsuperscript{6}. The assessors were trained physicians, nurses, physiotherapists or medical students who were unaware of the aim of the study. Data were also collected from relatives, caregivers and medical charts when approval was given. Diagnoses of depression and dementia were based on earlier diagnoses according to medical charts, ongoing pharmacological treatment, and on
assessments during the interviews. All information was reviewed by an experienced physician, and diagnoses of depression and dementia were set according to the DSM-IV criteria\textsuperscript{17}.

**BASELINE ASSESSMENTS**

**Papers I, III and IV**
The ability to manage ADL for each participant were assessed using the Barthel Index (range 0-20 points) after questioning a licensed practical nurse or nurse’s aide who knew the participant well\textsuperscript{154}. Cognitive function was screened for using the MMSE which is a global measure covering orientation, registration, attention and calculation, word recall, and language. The scores range between 0 – 30, where a score of 18 – 23 indicates mild cognitive impairment and a score of $\leq 17$ severe cognitive impairment\textsuperscript{155}. A dietician assessed nutritional status using the Mini Nutritional Assessment (MNA) which has scores ranging from 0 to 30\textsuperscript{156}, where 17 to 23.5 indicates a risk of malnutrition and $< 17$ indicates actual malnutrition. Visual impairment was defined as being unable to read a word written in 5 mm capital letters, with or without glasses, at reading distance. Hearing was regarded as impaired when the participant was unable to hear a conversation held at normal voice level at a distance of one meter, or used a hearing aid. The occurrence of an indoor fall in the preceding six months was recorded (yes/no) by interviewing a licensed practical nurse or nurse’s aide who knew the participant well. Information about self-perceived health was collected from the MNA scale using item P.

**Paper II**
Information regarding ADL was assessed using the Barthel ADL Index, and regarding cognitive function using the MMSE (see description above). Information about ADL was either collected from the individuals themselves or from staff when they lived in a residential care facility.

**OUTCOME AND TARGET VARIABLES**

**Paper I**

*The Berg Balance Scale*
The Berg Balance Scale was used to measure balance. The BBS consists of 14 tasks of varied difficulty, all graded on a five point ordinal scale (0-4) in accordance with detailed descriptions\textsuperscript{138-140}. The tasks are e.g. to rise from a chair, stand unsupported or reach forward, and they are all graded 0-4, giving a maximum score of 56 points. Lower points are given for people in need of supervision, physical or verbal guidance, or if given time limits are exceeded. The Swedish version of the BBS was used and the item that tests tandem standing was modified allowing two attempts\textsuperscript{157}.
METHODS

For the BBS assessments, the participants were told to wear stable and comfortable shoes. Four assessors were involved in the BBS assessments, two physiotherapists and two physiotherapy students, all of whom were given education before the study. The assessors received the test manual before the education, which consisted of a half-day session where questions were asked and a practice assessment was performed on one geriatric patient. The physiotherapists had also performed the same assessments in two previous data collections. For practical reasons, the assessor for each participant was not randomized. The BBS was administered twice for each participant, to assess intra-rater test-retest reliability. The first test (Berg A) and the retest (Berg B) were done with 1-3 days in between the tests and began at the same time of the day ± one hour. After Berg A, date and time of day were noted and the test protocol was placed in an envelope. Thus, only the date and time of Berg A were provided when Berg B were administrated.

Paper II

Feasibility and validity

The feasibility of GDS-15 was evaluated as the proportion of people who completed the scale. Construct validity refers to investigating a construct and making predictions about patterns in test results compared to other known measures of similar constructs, when no “gold standard” method is available. The construct validity of the GDS-15 was evaluated against the PGCMS which measures morale, often used synonymously with subjective psychological well-being. The rationale for using PGCMS when evaluating construct validity was that depressive symptoms are closely related to poor psychological well-being among older people. In addition, the scales are constructed in a similar way, both using the format of closed-ended questions where a yes or no answer indicates presence of symptoms.

The Geriatric Depression Scale

The 15-item Swedish version of the Geriatric Depression Scale (GDS-15) was used to assess depressive symptoms and was interview-administered to all participants. The score ranges from 0 to 15 and a score of zero to four is considered to be within the normal range, five to nine indicates mild depression, and a score of ten or more indicates moderate to severe depression. The scale has yes/no questions. The GDS-15 has shown high internal consistency among people in residential care facilities.
METHODS

The Philadelphia Geriatric Center Morale Scale
Psychological well-being was assessed using the Philadelphia Geriatric Center Morale Scale (PGCMS), and the scale was interview-administered for all participants161. The PGCMS assess morale which is often used synonymously with psychological or subjective well-being. The 17-item version was used161, where scores of 0–9 indicate low morale, 10–12 the middle range and 13–17 high morale, according to the administration and scoring instructions. High morale is described as a basic sense of satisfaction with oneself, a feeling that there is a fit between personal needs and what the environment offers, and a certain acceptance of what cannot be changed161. The PGCMS was recommended for use in assessing subjective well-being among older people by the British Geriatrics Society and the Royal College of Physicians, London54; it is suitable for use with older people living either in the community or in institutions, and the yes/no questions format facilitates understanding for people with impaired cognitive function161, 162. The PGCMS has been validated against a psychologist’s rating of life satisfaction and correlated with $r = 0.57$ among old people (mean age 78)55. A study performed among people in residential care facilities shows satisfactory internal consistency149, and a small study among people at a dementia outpatient clinic shows good agreement in test-retest reliability162.

Paper III
Symptoms of depression were evaluated using the GDS-15 and psychological well-being using the PGCMS (see above).

Paper IV
Symptoms of depression were evaluated using the GDS-15, psychological well-being using the PGCMS, and balance using the BBS (see above). The BBS was performed on one occasion, at the baseline and at the three-month follow-up.

Barthel ADL Index
Dependence in ADL was assessed using the Barthel ADL Index after interviewing a licensed practical nurse or nurse’s aide who knew the participant well. The Barthel ADL Index is a well-established and valid scale for assessing dependence in care and mobility and it measures what a person does rather than what the person can do142. The ten-item version was used with scores ranging from 0 to 20, higher scores indicating greater independence154, 163. Reliability investigated among people with physical and cognitive impairments has shown kappa values of fair to very good agreement for the items164.
**METHODS**

**STATISTICAL ANALYSES**

**Paper I**
To investigate the incidence of outliers, a boxplot of the distribution of the absolute differences between tests (Berg A and Berg B) was used. An outlier was defined as a participant with a difference of \(1.5 - 3 \times \text{IQR}\) (inter quartile range) from the upper or lower edge of the box. An extreme outlier was defined as \(>3 \times \text{IQR}\). Two subjects were considered to be outliers according to the boxplot, but since they were not extreme outliers they were included in the analyses. Their absolute differences were 9 and 11 BBS points, respectively. In Berg A they had 7 and 48 BBS points, respectively, and their MMSE scores were 12 and 13, respectively.

The absolute reliability was calculated using an analysis of variance, according to Bland and Altman, referred to as the repeatability\(^{134}\). In the one way analysis of variance, the square root of the within-people residual mean square is the within-subject standard deviation (sw), which enables the size of the measurement error to be calculated\(^{134}\). The repeatability is calculated according to the equation \(\sqrt{2} \times 1.96 \times \text{sw}\), or \(2.77 \times \text{sw}\). For 95% of pairs of observations, the measurement error is expected to be less than \(2.77 \times \text{sw}\). To be certain that a change in score is due to a change in function and not just to measurement error, the difference has to be equal to or greater than \(2.77 \times \text{sw}\). Likewise, measurement errors were calculated with 80 and 90% confidence levels (\(\sqrt{2} \times 1.28 \times \text{sw}\) and \(\sqrt{2} \times 1.645 \times \text{sw}\), respectively).

The exception to the use of this method is when heteroscedasticity occurs, i.e. when the measurement error is dependent on the size of the measurement. The occurrence of heteroscedasticity was investigated graphically by plotting the individual’s absolute differences against their mean, and by calculating a rank correlation coefficient using Kendall’s Tau-B\(^{134}\).

The relative reliability was calculated using the ICC. ICC was calculated according to a two-way mixed model, version (3,1) and a one-way random effect model for a single measure (1,1). All error is assumed to be random measurement error with ICC (1,1), and with the ICC (3,1) that systematic error is not part of the measurement error. When ICC (1,1) equals ICC (3,1), no systematic error is present\(^{165}\). The ICC value ranges from 0-1 where 1 indicates perfect agreement and 0 indicates no agreement\(^{131}\). Reliability coefficients of 0.90 or above are generally considered high\(^{131}\).

Additional analyses were performed. The impact of the participant’s cognitive function on the difference in total score between tests, was evaluated using linear regression analysis. The dependent variable was absolute difference in BBS score. The independent variables were the MMSE score and the MMSE score dichotomized into participants with severe cognitive impairment (MMSE score
METHODS

≤17) and those without, respectively. Likewise, analyses were performed evaluating the impact of the participant’s age as well as evaluating differences between assessments performed by physiotherapists and physiotherapy students. All additional regression analyses concerning participants’ cognitive function and age as well as physiotherapists versus physiotherapy students, were adjusted for initial BBS score (Berg A) by adding this as an independent variable.

Analyses were performed using SPSS software, version 10.0 (SPSS Inc., Chicago, IL). A p-value of < 0.05 was considered to indicate statistical significance.

Paper II

No imputations were made concerning missing data. Differences between those assessed using the GDS-15 (n = 691) and those who declined or were unable to answer the questions (n = 143) were evaluated regarding age and MMSE scores using independent samples t-test, and regarding sex using the chi-square test. The criterion for a complete assessment was no more than one missing answer for GDS-15 and PGCMS, respectively, i.e. answering 14 questions or more on the GDS-15, and 16 or more in the PGCMS. A logistic regression was performed to evaluate the impact of MMSE scores on completion (feasibility) of the GDS-15. Completion (yes/no) was the dependent variable and the MMSE score was the independent variable.

The sample was divided into seven groups according to MMSE scores, to compare the validity of the GDS-15 among individuals with different levels of cognitive function. Each group represented five points on the MMSE, except for the two groups with the highest scores which represented three points (0–4, 5–9, 10–14, 15–19, 20–24, 25–27, and 28–30). The rationale for choosing a smaller interval in the groups with the highest MMSE scores was that a larger proportion of the participants had high scores compared to low scores. Correlations were calculated between the GDS-15 and the PGCMS (construct validity), within each MMSE group using two-sided Pearson’s correlation presented with correlation coefficients including 95% confidence intervals (CI), and p-values. Fisher r-to-z transformation, a two-tailed test for independent samples, was used to compare the correlation values for each MMSE group with the value for the group with the highest cognitive function (MMSE scores 28–30). These analyses were also calculated using only individuals who completed all 15 questions in the GDS-15 and 17 in PGCMS, and showed essentially the same results (data not shown).

Additional analyses were performed to evaluate the impact of age on the correlation analyses, by analysing the age groups separately (85, 90, 95 and over, respectively), and likewise to evaluate the impact of sex by analysing women/men separately. In the additional analyses individuals were divided into two groups according to cognitive function; MMSE scores 10–24 and 25–30, to avoid the risk
of low power in the analyses because there were so few individuals in some MMSE groups. The Fisher r-to-z transformation test was used to compare correlation levels for sex and age, respectively, within each of the two MMSE groups. For age, correlation values were compared to that of the youngest age group, 85-year-olds.

Analyses were performed using SPSS software, version 17.0 (SPSS Inc., Chicago, IL), and a p-value of < 0.05 was considered to indicate statistical significance.

Paper III

All analyses were made according to the intention-to-treat principle using all available data from each participant according to their original group assignment, regardless of level of attendance in the intervention. Baseline differences were evaluated using independent samples t-test for continuous variables and the chi-square test for dichotomized variables. To describe change over time in total score of the outcome measures (GDS-15 and PGCMS) in each group, within-group analyses (exercise/control) were performed using paired samples t-test comparing baseline value with 3- and 6-month values, respectively.

Between-group differences in the outcome measures were evaluated at three and six months using analysis of covariance (ANCOVA) where the post-intervention value was the dependent variable. The independent variables were group, pre-intervention value (GDS-15 or PGCMS), age, sex, and covariates adjusting for differences (p ≤ 0.15) between groups regarding baseline characteristics (visual impairment and self-perceived health).

The results for the outcome analyses are presented without adjustment for the randomization in clusters. The rationale for this is that the randomization was stratified in order to ensure that both groups were distributed as equally as possible in each facility, that there were few participants per cluster (e.g. mean 5.0 ± 1.7 at the 3-month analyses of PGCMS), and that the intervention was directed to the individuals instead of to the clusters\textsuperscript{166}. Nevertheless, the cluster effect was examined in additional analyses by adjusting the outcome regression analyses for clustering\textsuperscript{167}. These analyses produced essentially the same results as the unadjusted analyses (data not shown).

Additional within- and between-group analyses, not pre-specified, were performed to evaluate the effect among those participants with symptoms of depression or reduced morale, respectively, according to cut-off values in the GDS-15 and PGCMS. Participants were defined as having significant symptoms of depression if they had GDS-15 scores of > 4 (i.e. not within the normal range), and as having reduced morale if they had PGCMS scores of < 13 (i.e. not high). The rationale for these additional analyses was that more effects have been found in exercise studies among individuals who have symptoms of depression, than in studies among
METHODS

individuals without depression. A variable of four categories formed by categorization according to GDS-15 (> 4 vs ≤ 4) or PGCMS (< 13 vs ≥ 13), respectively, as well as group (exercise vs. control), was used as an independent variable in the ANCOVA in addition to age, sex, and the covariates adjusting for differences (p ≤ 0.15) between groups regarding baseline characteristics.

Additional within- and between-group analyses were also performed among participants with dementia. The rationale for these analyses was that it is important to study the effect among people with dementia because they seem to have an increased risk of depression and reduced well-being, and that treatments for depression may be less effective in this group. A variable of four categories formed by categorization according to dementia (yes/no) and group (exercise vs. control), was used as an independent variable in the ANCOVA in addition to age, sex and covariates adjusting for differences (p ≤ 0.15) between groups regarding baseline characteristics. The analyses were tested for interactions between allocation to group and presence of dementia.

Analyses were performed using SPSS software, version 16.0 (SPSS Inc., Chicago, IL), and Stata Software version 10.0 (StataCorp, College Station, Texas) for the cluster adjustments. All statistical analyses were 2-tailed, and a p-value of < 0.05 was considered to indicate statistical significance.

Paper IV

Difference in the target variables was calculated as the 3-month follow-up value minus the baseline value. A negative difference in GDS-15 scores indicates reduction in depressive symptoms, and a positive difference in PGCMS scores indicates increased psychological well-being. A positive difference for the BBS and Barthel ADL Index indicates a higher balance function or higher level of independence at follow-up, respectively.

Multivariate regression was used to investigate associations between differences in BBS and GDS-15 and BBS and PGCMS, respectively. Associations were also investigated between the difference in Barthel ADL Index and GDS-15, and Barthel ADL Index and PGCMS, respectively. Participants with data on difference in GDS-15 or PGCMS and difference in BBS or Barthel ADL Index scores formed the sample for each separate analysis. The dependent variable was either difference in GDS-15 or difference in PGCMS scores. Independent variables were difference in BBS or Barthel ADL Index scores. The multivariate regression was adjusted (by adding independent variables) for age, sex, and baseline characteristics (Table 9) with univariate associations to the dependent variable (p ≤ 0.15), which were evaluated in each sample using linear regression. Baseline characteristics associated with difference in GDS-15 were: diagnosis of depression, previous stroke, diabetes mellitus, angina pectoris and osteoporosis. Baseline characteristics
METHODS

associated with difference in PGCMS were: previous stroke, heart failure, malignancy in last five years, and independent gait. In addition, heart failure was associated with difference in GDS-15 in the sample analysing association between BBS and GDS-15, and was included as an independent variable in the multivariate regression. Further, independent gait was not included in the multivariate regression when analysing the association between Barthel ADL Index and PGCMS scores because it is a part of the Barthel ADL Index scale.

Additional interaction analyses were performed to investigate moderating effects of the subgroups dementia, sex, and activity (exercise, control activity or usual care). The multivariate analyses were tested for interaction by including the subgroup, and the product of the subgroup and the difference in BBS or Barthel, respectively, as independent variables in each multivariate model. The rationale for investigating the interaction effects of activity was that it may be important for the association to mental health, whether improved physical capacity or level of independence results from the effects of physical exercise or e.g. recovery from a disease.

Analyses were performed using SPSS software version 19.0 (SPSS Inc., Chicago, IL) and \( p \)-values of < 0.05 were considered to indicate statistical significance.
RESULTS

PAPER I

A description of the characteristics of the 45 participants is presented in Table 2. Four participants declined in cognitive function to a MMSE < 10 since the inclusion six months earlier but were still included in the analyses. Thirty-six participants (80%) had one day in between the two BBS testing occasions, 8 participants (18%) had two days in between tests, and one participant (2%) had three days in between tests. The difference in the time of day when the test started between Berg A and Berg B ranged from 0 to 60 minutes. For Berg A, mean ± SD (range) in BBS score was 30.1 ± 15.9 (3-53) points and for Berg B, 30.6 ± 15.6 (4-54) points.

The distribution of the participants’ differences in BBS score between the two test occasions is shown in Figure 5. The absolute differences in the BBS scores ranged from 0 to 11 (Table 3). Eight participants (18%) showed no difference at all between the test occasions, 18 participants (40%) had a difference of 1 BBS point or fewer and 25 participants (56%) had a difference of 2 points or fewer. The mean ± SD of the absolute difference was 2.8 ± 2.7 (range 0-11) points and the median was 2 points. The absolute differences for the four participants with an MMSE <10 were 1, 3, 4 and 8 BBS points, respectively.

Absolute reliability
No heteroscedasticity was found, either graphically or statistically (p = 0.905). The variation analysis according to Bland and Altman produced a residual mean square of 7.6278. The equation of repeatability gives $2.77 \times \sqrt{7.6278} = 7.7$ for a 95% confidence level. This implies that a change of 7.7 BBS points must occur in order to reveal a genuine change in function for a participant. Corresponding figures for 90 and 80% confidence levels were 6.4 and 5.0 BBS points, respectively. When performing the analyses excluding the participants who had declined in cognitive function to below the initial inclusion criterion (MMSE score <10), the results for the absolute reliability were 7.4 (95%), 6.2 (90%), and 4.8 BBS points (80%).

Relative reliability
Both the ICC (3,1) and the ICC (1,1) were calculated to 0.97.

Additional analyses
Regarding absolute difference in score between Berg A and Berg B, participants with severe cognitive impairment (MMSE ≤ 17) had a mean ± SD difference of 3.2 ± 3.0 BBS points compared with 2.6 ± 2.4 for participants without cognitive impairment (p = 0.498). There was no significant association between the MMSE
RESULTS

score and absolute difference in BBS score between tests ($p = 0.882$). In addition, the absolute difference was not significantly associated with the participant’s age ($p = 0.286$).

The physiotherapists assessed 28 participants and the physiotherapy students assessed 17. The absolute differences in BBS score between tests were: mean ± SD 2.5 ± 2.2 and 3.5 ± 3.4 BBS points, respectively ($p = 0.233$).

### Table 2. Characteristics of the participants in Paper I (n = 45).

<table>
<thead>
<tr>
<th>Characteristic</th>
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<tbody>
<tr>
<td>Age, mean ± SD</td>
<td>82.3 ± 6.6</td>
</tr>
<tr>
<td>Female sex, n (%)</td>
<td>36 (80)</td>
</tr>
<tr>
<td><strong>Diagnoses, medical conditions, and drugs for regular use</strong></td>
<td></td>
</tr>
<tr>
<td>Depression, n (%)</td>
<td>29 (64)</td>
</tr>
<tr>
<td>Dementia, n (%)</td>
<td>30 (67)</td>
</tr>
<tr>
<td>Previous stroke, n (%)</td>
<td>10 (22)</td>
</tr>
<tr>
<td>Heart failure, n (%)</td>
<td>14 (31)</td>
</tr>
<tr>
<td>Previous fracture, during the last five years, n (%)</td>
<td>13 (29)</td>
</tr>
<tr>
<td>Delirium episode (in the last month), n (%)</td>
<td>12 (27)</td>
</tr>
<tr>
<td>Urinary tract infection (in the last year), n (%)</td>
<td>20 (44)</td>
</tr>
<tr>
<td>Analgesics, n (%)</td>
<td>20 (44)</td>
</tr>
<tr>
<td>No. of prescribed drugs, mean ± SD</td>
<td>9.6 ± 3.5</td>
</tr>
</tbody>
</table>

**Functional assessments**

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<table>
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<tbody>
<tr>
<td>Barthel ADL Index, mean ± SD</td>
<td>13.7 ± 5.0</td>
</tr>
<tr>
<td>Independent gait indoors (with or without walking aid)*, n (%)</td>
<td>33 (73)</td>
</tr>
<tr>
<td>Mini-Mental State Examination, mean ± SD, n=44</td>
<td>17.5 ± 6.3</td>
</tr>
<tr>
<td>Geriatric Depression Scale-15, mean ± SD, n=38</td>
<td>3.8 ± 3.2</td>
</tr>
<tr>
<td>Mini Nutritional Assessment, mean ± SD, n=41</td>
<td>20.9 ± 3.7</td>
</tr>
</tbody>
</table>

**Note:** For all assessment scales, except Geriatric Depression Scale-15, a higher score indicates better function or mental health. Functional assessments were made in connection with the assessment of the Berg Balance Scale. All other characteristics were collected six months earlier. Numbers after a characteristic indicate missing assessments.

* Assessed using the Barthel ADL Index.
RESULTS

**Table 3.** Absolute difference in total score on the Berg Balance Scale between the two test occasions.

<table>
<thead>
<tr>
<th>Differences in BBS points</th>
<th>No. of participants n=45</th>
<th>Percent</th>
<th>Cumulative percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>8</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>22</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>16</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>13</td>
<td>69</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>9</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>7</td>
<td>84</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
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<tr>
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<td>8</td>
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<td>9</td>
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<td>2</td>
<td>98</td>
</tr>
<tr>
<td>11</td>
<td>1</td>
<td>2</td>
<td>100</td>
</tr>
</tbody>
</table>

**Note:** BBS = Berg Balance Scale.

**Figure 5.** Results of the Berg Balance Scale for each participant (n=45), mean values and differences for the two test occasions.
RESULTS

PAPER II

The characteristics of the 834 participants are presented in groups according to cognitive function (Table 4). The mean score on the MMSE for the whole sample was 19.8 (SD = 8.0, range 0–30). Mean age was 90.2 years, 584 participants (70%) were women and 344 (41%) lived in residential care facilities. Six hundred and six participants (73%) lived in Sweden, 578 (69%) lived in urban areas, and 682 (82%) lived alone. Three hundred and twenty-eight participants (39%) had a dementia disorder, 293 (35%) a diagnosis of depression, 180 (22%) had previous stroke, and the mean number of drugs in regular use was 6.9 (range 0 – 29).

Feasibility

In total, 650 (78%) of the 834 participants completed the GDS-15 (Table 4) and the mean score was 3.7 (SD = 2.7, range 0–14). Of the remaining 184 participants’ 143 declined or were unable to answer the questions, and 41 answered fewer than 14 questions of the GDS-15. Those who declined or were unable to answer the GDS-15 (n = 143) were older (mean age 91.5 vs. 89.9, \( p < 0.001 \)), more likely to be women (82% vs. 67%, \( p < 0.001 \)), and had lower cognitive function (MMSE mean score 8.2 vs. 22.2, \( p < 0.001 \)), than those who answered it (n = 693).

The number of people who completed the GDS-15 interviews declined with increasing cognitive impairment (Figure 6), odds ratio = 1.22 (confidence interval = 1.19-1.26, \( p < 0.001 \)). For the two MMSE groups with scores of < 10, the proportion who completed GDS-15 was 1% and 42%, respectively, compared to 64–95% in the MMSE groups with scores of \( \geq 10 \) (Table 5). Of the 650 participants who completed the GDS-15, 572 (88.0%) answered all 15 questions and 78 (12.0%) answered 14 (Figure 2). Among those participants who completed 14 questions, 25 (32%) did not answer question 10 “more problems with memory than most”, 13 (18%) question 15 “most people better off”, eight (10%) question 11 “wonderful to be alive”, and seven (9%) did not answer question 9 “prefer to stay in”.

Construct validity

The correlations between the GDS-15 and the PGCMS scores were statistically significant among groups of people with MMSE scores of five or more and the coefficients ranged from -0.583 (MMSE 28–30) to -0.717 (MMSE 10–14) (Table 5, Figure 7). The correlations between the GDS-15 and PGCMS scores did not differ between the groups of people with MMSE scores of 5-9, 10-14, 15-19, 20-24, or 25-27 compared to the group of people with MMSE scores of 28–30 (data not shown).
RESULTS

Additional analyses
There were no differences in correlation levels between the age groups, or between males and females (data not shown).
Table 4. Characteristics of the participants in Per II (n = 834).

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of people, n</td>
<td>67</td>
<td>36</td>
<td>84</td>
<td>128</td>
<td>223</td>
<td>173</td>
<td>123</td>
<td>834</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>59 (88.1)</td>
<td>32 (88.9)</td>
<td>63 (75.0)</td>
<td>93 (72.7)</td>
<td>143 (64.1)</td>
<td>119 (68.8)</td>
<td>75 (61.0)</td>
<td>584 (70.0)</td>
</tr>
<tr>
<td>Age, mean ± SD</td>
<td>92.7 ± 4.6</td>
<td>93.1 ± 5.5</td>
<td>91.6 ± 4.8</td>
<td>90.8 ± 4.5</td>
<td>90.2 ± 4.2</td>
<td>88.8 ± 4.0</td>
<td>88.2 ± 3.9</td>
<td>90.2 ± 4.5</td>
</tr>
<tr>
<td>Living in institutional care, n (%)</td>
<td>63 (94.0)</td>
<td>32 (88.9)</td>
<td>63 (75.0)</td>
<td>68 (53.1)</td>
<td>70 (31.4)</td>
<td>33 (19.1)</td>
<td>15 (12.2)</td>
<td>344 (41.1)</td>
</tr>
<tr>
<td>Barthel ADL index, mean ± SD</td>
<td>4.4 ± 4.7</td>
<td>8.6 ± 6.2</td>
<td>10.3 ± 6.1</td>
<td>15.0 ± 5.5</td>
<td>17.5 ± 3.7</td>
<td>18.8 ± 2.4</td>
<td>19.4 ± 1.7</td>
<td>15.5 ± 6.1</td>
</tr>
<tr>
<td>GDS-15, n (%)</td>
<td>1 (1.5)</td>
<td>15 (41.7)</td>
<td>54 (64.3)</td>
<td>98 (76.6)</td>
<td>203 (91.0)</td>
<td>162 (93.6)</td>
<td>117 (95.1)</td>
<td>650 (77.9)</td>
</tr>
<tr>
<td>GDS-15, mean ± SD</td>
<td>4.0</td>
<td>4.5 ± 3.5</td>
<td>4.6 ± 2.9</td>
<td>4.6 ± 3.0</td>
<td>3.8 ± 2.7</td>
<td>3.4 ± 2.3</td>
<td>2.6 ± 2.1</td>
<td>3.7 ± 2.7</td>
</tr>
</tbody>
</table>

Note: MMSE = Mini-Mental State Examination, GDS-15 = Geriatric Depression Scale 15-item version. For all assessment scales, except Geriatric Depression Scale-15, a higher score indicates better function or mental health.

* n is the number of people who completed the scale, i.e. answered at least 14/15 questions.

---

Table 5. Correlation between the Geriatric Depression Scale 15-item version and the Philadelphia Geriatric Center Morale Scale among people with differing levels of cognitive impairment.

<table>
<thead>
<tr>
<th></th>
<th>0-4</th>
<th>5-9</th>
<th>10-14</th>
<th>15-19</th>
<th>20-24</th>
<th>25-27</th>
<th>28-30</th>
<th>0-30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Both GDS-15 and PGCMS performed, n* (%)</td>
<td>1 (1.5)</td>
<td>14 (38.9)</td>
<td>47 (56.0)</td>
<td>86 (67.2)</td>
<td>186 (83.4)</td>
<td>151 (87.3)</td>
<td>114 (92.7)</td>
<td>599 (71.8)</td>
</tr>
<tr>
<td>Correlation between GDS-15 and PGCMS, r</td>
<td>-</td>
<td>-0.709</td>
<td>-0.717</td>
<td>-0.633</td>
<td>-0.680</td>
<td>-0.649</td>
<td>-0.583</td>
<td>-0.667</td>
</tr>
<tr>
<td>p-value</td>
<td>0.005</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Note: MMSE = Mini-Mental State Examination, GDS-15 = Geriatric Depression Scale 15-item version, PGCMS = Philadelphia Geriatric Center Morale Scale. Correlation between variables calculated using two-tailed Pearson’s correlation, presented with correlation coefficient (r) and p-value. For all assessment scales, except Geriatric Depression Scale-15, a higher score indicates better function or mental health.

* n includes assessments where GDS-15 and PGCMS were completed, i.e. at least 14/15 and 16/17 questions, respectively, were answered.
Figure 6. Proportion of people who completed the Geriatric Depression Scale 15-item version, in relation to level of cognitive function, measured using the Mini-Mental State Examination (MMSE).

Figure 7. Correlation between the Geriatric Depression Scale 15-item version (GDS-15) and the Philadelphia Geriatric Center Morale Scale (PGCMS) among people with differing levels of cognitive function, measured using the Mini-Mental State Examination (MMSE). Correlations that were significant (see Table 5) are presented. Bars represent 95% confidence intervals for r.
PAPER III

The baseline characteristics of the participants (n = 191) are shown in Table 6. The prevalence of the diagnosis of depression was 61% and 49% used antidepressants. There were no significant differences between the groups regarding use of antidepressants at baseline, 3- or 6-month follow-ups (data not shown for 3- and 6-month follow-ups). The number of drugs in regular use for each participant ranged from 0 to 27, and the mean was 9.1. Thirty-seven percent of the participants were able to rise independently from a chair with armrests and 63% were able to walk independently indoors with or without a walking aid. The mean ± SD for the MMSE score was 17.8 ± 5.1 and ranged from 10 to 30. The MNA scores for the participants ranged from 5.5 to 27.5, with a mean ± SD score of 20.5 ± 3.7. The proportion of participants considered at risk of malnutrition or malnourished was 81% (77% and 85% in the exercise and control groups, respectively).

At baseline, the mean ± SD for GDS was 4.4 ± 3.2 with a range of 0-14, and 11.0 ± 3.5 with a range of 2-17 for the PGCMS. Thirty-seven percent had a GDS-15 score of > 4, and 63% had a PGCMS score of < 13. Of those participants diagnosed with depression and being treated with antidepressants (n = 86), 40 (47%) still had a GDS-15 score of > 4 at baseline.

Outcome analyses

When all the participants were evaluated, the within-group and the between-group analyses showed no significant changes in outcome variables at the 3- and 6-month follow-ups (Tables 7 and 8).

Additional outcome analyses

There was a significant within-group increase in the PGCMS score at the 3-month follow-up in the exercise group among those with PGCMS scores of <13, 1.0 ± 2.3 (mean ± SD), \( p = 0.01 \) (Table 7). The corresponding between-group difference was 0.85 (-0.10 to 1.80), mean (95% CI), \( p = 0.08 \) in favour of the exercise group (Table 8). No significant changes were found in the other within-group or between-group analyses among participants with GDS-15 scores of > 4 or PGCMS scores of < 13, respectively.

Among people with dementia, there was a significant between-group difference in PGCMS scores at the 3-month follow-up in favour of the exercise group. The between-group difference was 1.12 (0.09 to 2.16), mean (95% CI), \( p = 0.03 \) (Table 8). No other significant changes were found in the within-group or between-group analyses among people with dementia. In addition, no significant changes were found among people without dementia and no significant interaction effects were seen between allocation to group and presence of dementia (data not shown).
## Results

Table 6. Baseline characteristics of the participants in Paper III.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total n = 191</th>
<th>Exercise n = 91</th>
<th>Control n = 100</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, mean ± SD</strong></td>
<td>84.7 ± 6.5</td>
<td>85.3 ± 6.1</td>
<td>84.2 ± 6.8</td>
</tr>
<tr>
<td><strong>Female sex, n (%)</strong></td>
<td>139 (73)</td>
<td>67 (74)</td>
<td>72 (72)</td>
</tr>
<tr>
<td><strong>Diagnoses and medical conditions, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>116 (61)</td>
<td>55 (60)</td>
<td>61 (61)</td>
</tr>
<tr>
<td>Dementia disorder</td>
<td>100 (52)</td>
<td>47 (52)</td>
<td>53 (53)</td>
</tr>
<tr>
<td>Delirium episodes, in the last month</td>
<td>50 (26)</td>
<td>21 (23)</td>
<td>29 (29)</td>
</tr>
<tr>
<td>Previous stroke</td>
<td>54 (28)</td>
<td>26 (29)</td>
<td>28 (28)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>37 (19)</td>
<td>14 (15)</td>
<td>23 (23)</td>
</tr>
<tr>
<td>Heart failure</td>
<td>52 (27)</td>
<td>25 (28)</td>
<td>27 (27)</td>
</tr>
<tr>
<td>Angina pectoris</td>
<td>53 (28)</td>
<td>27 (30)</td>
<td>26 (26)</td>
</tr>
<tr>
<td>Fracture, in the last five years</td>
<td>66 (35)</td>
<td>31 (34)</td>
<td>35 (35)</td>
</tr>
<tr>
<td>Malignancy, in the last five years</td>
<td>24 (13)</td>
<td>10 (11)</td>
<td>14 (14)</td>
</tr>
<tr>
<td><strong>Drugs prescribed for regular use, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diuretics</td>
<td>94 (49)</td>
<td>45 (50)</td>
<td>49 (49)</td>
</tr>
<tr>
<td>Analgesics</td>
<td>111 (58)</td>
<td>56 (62)</td>
<td>55 (55)</td>
</tr>
<tr>
<td>Benzodiazepines</td>
<td>76 (40)</td>
<td>35 (39)</td>
<td>41 (41)</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>94 (49)</td>
<td>46 (51)</td>
<td>48 (48)</td>
</tr>
<tr>
<td>Neuroleptics</td>
<td>42 (22)</td>
<td>17 (19)</td>
<td>25 (25)</td>
</tr>
<tr>
<td>No. of drugs for regular use, mean ± SD</td>
<td>9.1 ± 4.4</td>
<td>9.2 ± 5.0</td>
<td>9.0 ± 3.9</td>
</tr>
<tr>
<td><strong>Functional assessments</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual impairment, n (%)</td>
<td>56 (29)</td>
<td>32 (35)</td>
<td>24 (24)</td>
</tr>
<tr>
<td>Mini-Mental State Examination (0-30), mean ± SD</td>
<td>17.8 ± 5.1</td>
<td>17.5 ± 5.0</td>
<td>18.0 ± 5.3</td>
</tr>
<tr>
<td>Barthel ADL Index (0-20), mean ± SD</td>
<td>13.1 ± 4.2</td>
<td>12.8 ± 4.5</td>
<td>13.4 ± 3.8</td>
</tr>
<tr>
<td>Mini Nutritional Assessment (0-30), mean ± SD</td>
<td>20.5 ± 3.7</td>
<td>20.4 ± 3.9</td>
<td>20.6 ± 3.6</td>
</tr>
<tr>
<td>Health, self-perceived as better than age peers, n (%)</td>
<td>77 (41)</td>
<td>30 (33)</td>
<td>47 (48)</td>
</tr>
<tr>
<td>(n=189)</td>
<td>(n=97)</td>
<td>(n=98)</td>
<td></td>
</tr>
<tr>
<td><strong>Physical capacity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berg Balance Scale (0-56), mean ± SD</td>
<td>26.6 ± 14.8</td>
<td>26.6 ± 15.3</td>
<td>26.6 ± 14.4</td>
</tr>
<tr>
<td>(n=190)</td>
<td>(n=99)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Able to rise independently from a chair without arm-support†, n (%)</td>
<td>70 (37)</td>
<td>32 (35)</td>
<td>38 (38)</td>
</tr>
<tr>
<td>Independent gait indoors (with or without walking aid)‡, n (%)</td>
<td>121 (63)</td>
<td>56 (62)</td>
<td>65 (65)</td>
</tr>
<tr>
<td><strong>Outcome measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geriatric Depression Scale-15 (0-15), mean ± SD (range)</td>
<td>4.4 ± 3.2 (0-14)</td>
<td>4.6 ± 3.4 (0-14)</td>
<td>4.2 ± 2.9 (0-14)</td>
</tr>
<tr>
<td>(n=180)</td>
<td>(n=85)</td>
<td>(n=95)</td>
<td></td>
</tr>
<tr>
<td>Geriatric Depression Scale-15 &gt; 4, n (%)</td>
<td>67 (37)</td>
<td>32 (35)</td>
<td>35 (35)</td>
</tr>
<tr>
<td>Philadelphia Geriatric Centre Morale Scale (0-17), mean ± SD (range)</td>
<td>11.0 ± 3.5 (2-17)</td>
<td>11.1 ± 3.7 (2-17)</td>
<td>11.0 ± 3.3 (3-17)</td>
</tr>
<tr>
<td>(n=188)</td>
<td>(n=89)</td>
<td>(n=99)</td>
<td></td>
</tr>
<tr>
<td>Philadelphia Geriatric Centre Morale Scale &lt; 13, n (%)</td>
<td>118 (63)</td>
<td>54 (59)</td>
<td>64 (64)</td>
</tr>
</tbody>
</table>

**Note:** For all assessment scales, except Geriatric Depression Scale-15, a higher score indicates better function or mental health.

* Assessed using the Mini Nutritional Assessment scale, item P (no = 0-1, yes = 2)
† Assessed using the Berg Balance Scale.
‡ Assessed using the Barthel ADL Index.
Table 7. Within-group differences between post- and pre-intervention values for the outcome measures according to the intention-to-treat principle, in the total sample and in the additional analyses.*

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Follow-up (in months)</th>
<th>n</th>
<th>Exercise Difference Mean ± SD</th>
<th>p-value</th>
<th>Control Difference Mean ± SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>GDS-15</td>
<td>3</td>
<td>75</td>
<td>0.03 ± 2.3</td>
<td>0.92</td>
<td>90  -0.10 ± 1.9</td>
<td>0.62</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>73</td>
<td>0.12 ± 2.5</td>
<td>0.68</td>
<td>83  -0.20 ± 2.2</td>
<td>0.39</td>
</tr>
<tr>
<td>PGCMS</td>
<td>3</td>
<td>79</td>
<td>0.35 ± 2.7</td>
<td>0.25</td>
<td>91  0.02 ± 2.3</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>76</td>
<td>0.32 ± 2.3</td>
<td>0.23</td>
<td>84  -0.01 ± 2.9</td>
<td>0.97</td>
</tr>
</tbody>
</table>

Additional analyses

Participants with GDS-15 > 4

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Follow-up (in months)</th>
<th>n</th>
<th>Exercise Difference Mean ± SD</th>
<th>p-value</th>
<th>Control Difference Mean ± SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>GDS-15</td>
<td>3</td>
<td>28</td>
<td>-0.92 ± 3.0</td>
<td>0.11</td>
<td>32  -0.34 ± 2.4</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>27</td>
<td>-0.52 ± 3.4</td>
<td>0.43</td>
<td>30  -0.60 ± 2.7</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Participants with PGCMS < 13

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Follow-up (in months)</th>
<th>n</th>
<th>Exercise Difference Mean ± SD</th>
<th>p-value</th>
<th>Control Difference Mean ± SD</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGCMS</td>
<td>3</td>
<td>48</td>
<td>1.0 ± 2.3</td>
<td><strong>0.01</strong></td>
<td>58  0.36 ± 2.5</td>
<td>0.28</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>46</td>
<td>0.70 ± 2.4</td>
<td>0.06</td>
<td>53  0.28 ± 3.3</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Participants with dementia

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Follow-up (in months)</th>
<th>n</th>
<th>Exercise Difference Mean ± SD</th>
<th>p-value</th>
<th>Control Difference Mean ± SD</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDS-15</td>
<td>3</td>
<td>41</td>
<td>0.32 ± 2.6</td>
<td>0.44</td>
<td>49  -0.02 ± 2.1</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>42</td>
<td>-0.07 ± 2.6</td>
<td>0.86</td>
<td>45  0.13 ± 1.9</td>
<td>0.65</td>
</tr>
<tr>
<td>PGCMS</td>
<td>3</td>
<td>42</td>
<td>-0.48 ± 3.1</td>
<td>0.32</td>
<td>49  0.33 ± 2.5</td>
<td>0.37</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>43</td>
<td>-0.53 ± 2.5</td>
<td>0.17</td>
<td>45  -0.20 ± 3.3</td>
<td>0.68</td>
</tr>
</tbody>
</table>

Note: GDS-15 = Geriatric Depression Scale 15-item version, PGCMS = Philadelphia Geriatric Center Morale Scale.

* Within-group differences were analysed using paired samples t-test. A negative mean difference in the GDS-15 indicates reduced symptoms of depression, and a positive mean difference for PGCMS indicates increased psychological wellbeing. Additional analyses were performed among participants with significant symptoms of depression (GDS-15 scores of > 4), participants with reduced morale (PGCMS scores of < 13), and participants with dementia.
RESULTS

Table 8. Between-group differences in outcome variables, according to the intention-to-treat principle, in the total sample and in the additional analyses*

<table>
<thead>
<tr>
<th>Outcome measure</th>
<th>Follow-up (in months)</th>
<th>n</th>
<th>Exercise Mean ± SE</th>
<th>Control Mean ± SE</th>
<th>Difference Mean (95% CI)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDS-15</td>
<td>3</td>
<td>165</td>
<td>4.35 ± 0.24</td>
<td>4.25 ± 0.22</td>
<td>0.09 (-0.55 to 0.74)</td>
<td>0.77</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>156</td>
<td>4.50 ± 0.27</td>
<td>4.25 ± 0.25</td>
<td>0.25 (-0.49 to 0.99)</td>
<td>0.50</td>
</tr>
<tr>
<td>PGCMS</td>
<td>3</td>
<td>170</td>
<td>11.52 ± 0.28</td>
<td>10.95 ± 0.26</td>
<td>0.57 (-0.19 to 1.33)</td>
<td>0.14</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>160</td>
<td>11.56 ± 0.29</td>
<td>10.92 ± 0.28</td>
<td>0.64 (-0.16 to 1.44)</td>
<td>0.12</td>
</tr>
</tbody>
</table>

Additional analyses

| Participants with GDS-15 > 4 | GDS-15 | 3   | 60  | 4.28 ± 0.52 | 4.86 ± 0.47 | -0.59 (-1.66 to 0.48) | 0.28   |
|                            |        | 6   | 57  | 4.47 ± 0.61 | 4.35 ± 0.53 | 0.12 (-1.12 to 1.37)  | 0.85   |
| Participants with PGCMS < 13 | PGCMS | 3   | 106 | 12.06 ± 0.40 | 11.20 ± 0.35 | 0.85 (-0.10 to 1.80)  | 0.08   |
|                            |        | 6   | 99  | 11.69 ± 0.42 | 11.00 ± 0.38 | 0.69 (-0.33 to 1.7)   | 0.18   |
| Participants with dementia | GDS-15 | 3   | 90  | 3.92 ± 0.32 | 4.25 ± 0.30 | -0.33 (-1.20 to 0.55) | 0.46   |
|                            |        | 6   | 87  | 4.35 ± 0.36 | 4.25 ± 0.35 | 0.10 (-0.90 to 1.10)  | 0.84   |
|                            | PGCMS  | 3   | 91  | 11.72 ± 0.38 | 10.60 ± 0.35 | 1.12 (0.09 to 2.16)   | **0.03** |
|                            |        | 6   | 88  | 11.85 ± 0.39 | 11.25 ± 0.38 | 0.60 (-0.47 to 1.68)  | 0.27   |

Note: GDS-15 = Geriatric Depression Scale 15-item version, PGCMS = Philadelphia Geriatric Center Morale Scale.

*All data presented are based on adjusted analyses. Between-group differences were analyzed using analysis of covariance (ANCOVA) where the post-intervention value was the dependent variable. The independent variables were group, pre-intervention value (GDS-15 or PGCMS), age, sex, and covariates adjusting for differences (p ≤ 0.15) between groups regarding baseline characteristics (visual impairment and self-perceived health). Lower GDS-15 values indicate fewer symptoms of depression, and higher values in PGCMS indicate greater psychological wellbeing. Additional analyses were performed among participants with significant symptoms of depression (GDS-15 scores of > 4), participants with reduced morale (PGCMS scores of < 13), and participants with dementia.
PAPER IV
Two hundred and six people were included in the study. A description of the participants’ baseline characteristics is displayed in Table 9. The mean age was 84.3 years, 153 (74%) participants were women, and 122 (59%) had a diagnosis of depression. One hundred and one (49%) participants took antidepressants at baseline. At the 3-month follow-up, four (2%) participants had discontinued their use of antidepressants and five (2.5%) had started to use them. One hundred and fifteen (56%) participants had a diagnosed dementia disorder. The mean score for the MMSE was 18.0 ± 5.2 (10 - 30).

Baseline values for target variables and differences in target variables are shown in Table 10. The mean ± SD (range) at baseline was for BBS 27.9 ± 15.2 (1 - 55), Barthel ADL Index 13.3 ± 4.3 (1 - 19), GDS-15 4.3 ± 3.0 (0 - 14), and PGCMS 11.1 ± 3.5 (2 - 17). The absolute differences in mean ± SD (range) between follow-up and baseline were for BBS 4.7 ± 4.1 (0 - 21), Barthel ADL Index 1.7 ± 1.8 (0 - 12), GDS-15 1.6 ± 1.5 (0 - 7), and PGCMS 1.8 ± 1.8 (0 - 12). The number of participants with an absolute difference of 1 point or more were on BBS 185 (92%), Barthel ADL Index 157 (76%), GDS-15 154 (77%), and PGCMS 157 (76%).

Scatterplots of the distribution of differences in target measures for the whole sample are shown in Figure 8. The multivariate regression analyses revealed no significant association between changes in BBS and GDS-15 or PGCMS scores, or between changes in Barthel ADL Index and GDS-15 or PGCMS scores (Table 11). The additional analyses investigating interaction effects for dementia disorder showed no significant associations (Table 11). In addition, there were no interaction effects for subgroups of sex or activity group (data not shown).
RESULTS

Figure 8. Scatterplots of the differences in scores (follow-up value minus baseline values) for the Berg Balance Scale (BBS) versus Geriatric Depression Scale (GDS-15) and Philadelphia Geriatric Center Morale Scale (PGCMS), respectively, and difference in Barthel ADL Index versus GDS-15 and PGCMS scores, respectively. For all assessment scales, except the GDS-15, a positive difference indicates improved function or mental health from baseline to follow-up.
# Results

Table 9. Baseline characteristics of the participants.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Total n = 206</th>
<th>Dementia n = 115</th>
<th>No dementia n = 91</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean ± SD</td>
<td>84.3 ± 6.6</td>
<td>84.1 ± 5.9</td>
<td>84.6 ± 7.3</td>
</tr>
<tr>
<td>Female sex, n (%)</td>
<td>153 (74)</td>
<td>87 (76)</td>
<td>66 (73)</td>
</tr>
<tr>
<td><strong>Diagnoses and medical conditions, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td>122 (59)</td>
<td>68 (59)</td>
<td>54 (59)</td>
</tr>
<tr>
<td>Previous stroke</td>
<td>51 (25)</td>
<td>16 (14)</td>
<td>35 (39)</td>
</tr>
<tr>
<td>Previous urinary tract infection, last year</td>
<td>82 (40)</td>
<td>43 (37)</td>
<td>39 (43)</td>
</tr>
<tr>
<td>Constipation last month</td>
<td>108 (52)</td>
<td>53 (46)</td>
<td>55 (60)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>34 (17)</td>
<td>18 (16)</td>
<td>16 (18)</td>
</tr>
<tr>
<td>Heart failure</td>
<td>59 (29)</td>
<td>24 (21)</td>
<td>35 (39)</td>
</tr>
<tr>
<td>Angina pectoris</td>
<td>68 (28)</td>
<td>29 (25)</td>
<td>39 (32)</td>
</tr>
<tr>
<td>Hip fracture in the last five years</td>
<td>29 (14)</td>
<td>14 (12)</td>
<td>15 (17)</td>
</tr>
<tr>
<td>Osteoporosis</td>
<td>60 (29)</td>
<td>34 (30)</td>
<td>26 (29)</td>
</tr>
<tr>
<td>Malignancy, in the last five years</td>
<td>23 (11)</td>
<td>8 (7)</td>
<td>15 (17)</td>
</tr>
<tr>
<td>Urinary incontinence*</td>
<td>91 (44)</td>
<td>49 (43)</td>
<td>42 (46)</td>
</tr>
<tr>
<td><strong>Drugs for regular use, n (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diuretics</td>
<td>102 (50)</td>
<td>56 (40)</td>
<td>56 (62)</td>
</tr>
<tr>
<td>Analgesics</td>
<td>119 (58)</td>
<td>63 (55)</td>
<td>56 (62)</td>
</tr>
<tr>
<td>Benzodiazepines</td>
<td>80 (39)</td>
<td>39 (34)</td>
<td>41 (45)</td>
</tr>
<tr>
<td>Antidepressants</td>
<td>101 (49)</td>
<td>58 (50)</td>
<td>43 (47)</td>
</tr>
<tr>
<td>Neuroleptics</td>
<td>52 (25)</td>
<td>31 (27)</td>
<td>21 (23)</td>
</tr>
<tr>
<td>Acetylcholinesterase inhibitors</td>
<td>29 (14)</td>
<td>29 (25)</td>
<td>0</td>
</tr>
<tr>
<td>No. of drugs for regular use, mean ± SD</td>
<td>9.1 ± 4.1</td>
<td>8.2 ± 3.8</td>
<td>10.2 ± 4.1</td>
</tr>
<tr>
<td><strong>Assessments</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual impairment, n (%)</td>
<td>51 (25)</td>
<td>30 (26)</td>
<td>21 (23)</td>
</tr>
<tr>
<td>Hearing impaired, n (%)</td>
<td>31 (15)</td>
<td>16 (14)</td>
<td>15 (17)</td>
</tr>
<tr>
<td>Fall last 6 months, n (%)</td>
<td>79 (42)</td>
<td>39 (38)</td>
<td>40 (49)</td>
</tr>
<tr>
<td>Mini-Mental State Examination, mean ± SD</td>
<td>18.0 ± 5.2</td>
<td>16.1 ± 4.9</td>
<td>20.4 ± 4.5</td>
</tr>
<tr>
<td>Mini Nutritional Assessment, mean ± SD</td>
<td>20.5 ± 3.6</td>
<td>20.8 ± 3.5</td>
<td>20.2 ± 3.8</td>
</tr>
<tr>
<td>Health, self-perceived as better than age peers, n (%)†</td>
<td>86 (42)</td>
<td>53 (46)</td>
<td>33 (36)</td>
</tr>
<tr>
<td>Independent gait indoors (with or without walking aid)*, n (%)</td>
<td>135 (66)</td>
<td>81 (70)</td>
<td>54 (60)</td>
</tr>
</tbody>
</table>

**Note:** Numbers after a characteristic indicate that there are missing assessments. For all assessment scales, except Geriatric Depression Scale-15, a higher score indicates better function or mental health.  
* Assessed using Barthel ADL Index.  
† Assessed using the Mini Nutritional Assessment scale.
Table 10. Baseline values and differences for the target variables: the Berg Balance Scale, Barthel ADL Index, Geriatric Depression Scale-15, and Philadelphia Geriatric Center Morale Scale.

<table>
<thead>
<tr>
<th>Target variable</th>
<th>n</th>
<th>Total Mean ± SD (range)</th>
<th>n</th>
<th>Dementia Mean ± SD (range)</th>
<th>n</th>
<th>No dementia Mean ± SD (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berg Balance Scale</td>
<td>204</td>
<td>27.9 ± 15.2 (1 – 55)</td>
<td>113</td>
<td>32.0 ± 14.3 (2 – 55)</td>
<td>91</td>
<td>22.7 ± 14.6 (1 – 50)</td>
</tr>
<tr>
<td>Barthel ADL Index</td>
<td>206</td>
<td>13.3 ± 4.3 (1 – 19)</td>
<td>115</td>
<td>14.1 ± 3.9 (3 – 19)</td>
<td>91</td>
<td>12.2 ± 4.5 (1 – 18)</td>
</tr>
<tr>
<td>Geriatric Depression Scale-15</td>
<td>203</td>
<td>4.3 ± 3.0 (0 – 14)</td>
<td>114</td>
<td>3.7 ± 2.8 (0 – 14)</td>
<td>89</td>
<td>5.0 ± 3.2 (0 – 14)</td>
</tr>
<tr>
<td>Philadelphia Geriatric Center Morale Scale</td>
<td>206</td>
<td>11.1 ± 3.5 (2 – 17)</td>
<td>115</td>
<td>11.7 ± 3.3 (2 – 17)</td>
<td>91</td>
<td>10.4 ± 3.6 (3 – 17)</td>
</tr>
<tr>
<td>Differences (follow-up – baseline value)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berg Balance Scale</td>
<td>201</td>
<td>1.6 ± 6.0 (-21 – 20)</td>
<td>111</td>
<td>1.2 ± 5.9 (-21 – 14)</td>
<td>90</td>
<td>2.0 ± 6.2 (-17 – 20)</td>
</tr>
<tr>
<td>Barthel ADL Index</td>
<td>206</td>
<td>-0.4 ± 2.4 (-12 – 6)</td>
<td>115</td>
<td>-0.6 ± 2.1 (-7 – 5)</td>
<td>91</td>
<td>-0.2 ± 2.7 (-12 – 6)</td>
</tr>
<tr>
<td>Geriatric Depression Scale-15</td>
<td>201</td>
<td>0.00 ± 2.2 (-6 – 7)</td>
<td>114</td>
<td>-0.04 ± 2.4 (-6 – 6)</td>
<td>87</td>
<td>0.06 ± 1.9  (-6 – 7)</td>
</tr>
<tr>
<td>Philadelphia Geriatric Center Morale Scale</td>
<td>206</td>
<td>0.1 ± 2.6 (-12 – 7)</td>
<td>115</td>
<td>0.03 ± 2.8 (-12 – 7)</td>
<td>91</td>
<td>0.3 ± 2.3  (-7 – 6)</td>
</tr>
<tr>
<td>Absolute values for differences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berg Balance Scale</td>
<td>201</td>
<td>4.7 ± 4.1 (0 – 21)</td>
<td>111</td>
<td>4.5 ± 4.0 (0 – 21)</td>
<td>90</td>
<td>4.8 ± 4.4  (0 – 20)</td>
</tr>
<tr>
<td>Barthel ADL Index</td>
<td>206</td>
<td>1.7 ± 1.8 (0 – 12)</td>
<td>115</td>
<td>1.5 ± 1.6 (0 – 7)</td>
<td>91</td>
<td>1.9 ± 2.0  (0 – 12)</td>
</tr>
<tr>
<td>Geriatric Depression Scale-15</td>
<td>201</td>
<td>1.6 ± 1.5 (0 – 7)</td>
<td>114</td>
<td>1.7 ± 1.7 (0 – 6)</td>
<td>87</td>
<td>1.4 ± 1.3  (0 – 7)</td>
</tr>
<tr>
<td>Philadelphia Geriatric Center Morale Scale</td>
<td>206</td>
<td>1.8 ± 1.8 (0 – 12)</td>
<td>115</td>
<td>2.0 ± 1.9 (0 – 12)</td>
<td>91</td>
<td>1.6 ± 1.6  (0 – 7)</td>
</tr>
</tbody>
</table>

Note: For all assessment scales, except Geriatric Depression Scale-15, a higher score and a positive difference indicates better function or mental health.
Table 11. Multivariate regression models for associations between differences in scores for Berg Balance Scale and Geriatric Depression Scale-15, or Philadelphia Geriatric Center Morale Scale, respectively, as well as between differences in scores for Barthel ADL Index and Geriatric Depression Scale-15, or Philadelphia Geriatric Center Morale Scale, respectively. Each analysis was evaluated for interaction of dementia disorder.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Unstandardized β</th>
<th>95% CI</th>
<th>Standardized β</th>
<th>p-value</th>
<th>Interaction dementia p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Geriatric Depression Scale-15</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berg Balance Scale *</td>
<td>196</td>
<td>0.026</td>
<td>-0.024 – 0.075</td>
<td>0.072</td>
<td>0.31</td>
<td>0.54</td>
</tr>
<tr>
<td>Barthel ADL Index †</td>
<td>201</td>
<td>0.12</td>
<td>-0.004 – 0.25</td>
<td>0.13</td>
<td>0.05</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Philadelphia Geriatric Centre Morale Scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Berg Balance Scale ‡</td>
<td>201</td>
<td>0.045</td>
<td>-0.014 – 0.10</td>
<td>0.11</td>
<td>0.14</td>
<td>0.89</td>
</tr>
<tr>
<td>Barthel ADL Index §</td>
<td>206</td>
<td>-0.013</td>
<td>-0.16 – 0.13</td>
<td>-0.012</td>
<td>0.85</td>
<td>0.21</td>
</tr>
</tbody>
</table>

**Note:** Dependent variables were difference in Geriatric Depression Scale-15 or difference in Philadelphia Geriatric Center Morale Scale scores, respectively. Independent variables were difference in Berg Balance Scale or Barthel ADL Index scores. The multivariate regression was adjusted for age, sex, and baseline characteristics (Table 1) with univariate associations to the dependent variable (p ≤ 0.15), evaluated in each sample using linear regression. Interaction for dementia was tested by including dementia disorder and the product of the difference in Berg Balance Scale or Barthel ADL Index scores and dementia as independent variables in each multivariate model. Participants with sufficient data comprised the sample for each separate analysis.

* Adjusted for age, sex, diagnosis of depression, previous stroke, diabetes mellitus, heart failure, angina pectoris, and osteoporosis.
† Adjusted for age, sex, diagnosis of depression, previous stroke, diabetes mellitus, angina pectoris, and osteoporosis.
‡ Adjusted for age, sex, previous stroke, heart failure, malignancy in last five years, and independent gait indoors.
§ Adjusted for age, sex, previous stroke, heart failure, and malignancy in last five years.
DISCUSSION

MAIN FINDINGS
The absolute reliability indicated large variability on an individual level where a change of 8 BBS points must occur before a change in function can be confirmed, using a 95% confidence level, among older people who are dependent in ADL and living in residential care facilities. In contrast to the absolute value, the relative intrarater reliability for the BBS was high (ICC = 0.97). The variability between the two test occasions was not significantly associated with the participants' cognitive function, age, or whether a physiotherapist or a physiotherapy student performed the assessments.

The results from the population-based study indicate the overall usefulness of the GDS-15 to assess depressive symptoms among very old people with MMSE scores of ten or more. Almost two thirds of the participants with MMSE scores of 10-14 were able to complete the GDS-15 assessment, compared to those with MMSE scores of 0-4 and 5-9 where the proportion that completed GDS-15 were only 1% and 42%, respectively. For participants with MMSE scores of five or more, the correlations between the GDS-15 and the PGCMS did not significantly differ from those participants with the highest cognitive function (MMSE 28–30). The correlations did not significantly differ between women and men, or between the age groups (85, 90 and 95 and over), respectively.

The high-intensity exercise programme showed no significant between-group effects on depressive symptoms or well-being among older people living in residential care facilities when the total sample was analysed. However, in the additional analyses among participants with dementia, there was a significant between-group difference in psychological well-being in favour of the exercise group at the 3-month follow-up.

No significant associations were found between change in physical capacity or dependence in ADL, and change in depressive symptoms or psychological well-being among older people living in residential care facilities. Further, interaction analyses showed no moderating effects for dementia disorder, sex or whether or not an activity was offered during the 3-month follow-up period.

RELIABILITY OF THE BERG BALANCE SCALE
The variability of absolute intrarater reliability was higher than in a study of patients with Parkinson disease\textsuperscript{135}, where the reported absolute reliability was 2.8 BBS points. However, in an absolute interrater reliability study by Stevenson et al\textsuperscript{136} of patients who had had a stroke, the variability was 6.9 BBS points (95% confidence level). Stevenson also calculated an absolute reliability of 6.2 BBS
points (95% confidence level) in data from patients with a recent stroke from an interrater reliability study by Berg et al. Thus, large variability has also been seen in other studies, even though a direct comparison with these two studies is not applicable because they used interrater reliability and the study by Stevenson used the best performance of three attempts at each item. One important reason for the large variability might be difficulties in measuring physical function. However, the main reason for the high variability in the present study might be the population's fluctuating function, which is indicated by a high prevalence of diseases and cognitive and physical impairments. This is supported by the large variability in an instrument that evaluates basic mobility and balance, the Timed "Up & Go" Test, when evaluated in a similar population. In addition, the mean value for the BBS was rather low in the present study, which may indicate that many of the participants performed their maximum physical capacity in a majority of the items. When assessing maximum physical capacity, one may assume that minor day-to-day fluctuations in function can also lead to considerable variation in repeated measurements. Cognitive function was not found to be significantly related to the variability in BBS scores in Paper I. However, the fact that the great majority of the participants were more cognitive impaired than in earlier studies, might have contributed to the large variability found. 

In earlier studies of reliability of BBS scores, the participants seem to have had a higher level of cognitive function than those in Paper I. The high ICC value in Paper I (ICC = 0.97) supports earlier intrarater reliability studies of the BBS where ICCs ranged from 0.87 to 0.99. However, this finding contradicts the interpretation of the result of the absolute reliability calculation. The limitations with ICC, where the ICC value might be an effect of the range of scores among individuals, can also be demonstrated from earlier reliability studies of the BBS. In the study by Berg et al, where there is a wide range among individuals' scores (mean BBS score ± SD was 37.1 ± 17.2), ICC was calculated as 0.98 and absolute reliability was 6.2 points compared with an ICC value of 0.87 and an absolute reliability value of 2.8 points in a study by Lim et al with a lower range of participants' scores (mean BBS score ± SD was 53.8 ± 2.0). Although absolute reliability showed less variability in the study by Lim and colleagues, the ICC value indicated the opposite. Several authors have discussed the limited value of ICCs when interpreting results from reliability studies, and, according to Finch, relative reliability should be used to provide information about whether a scale can discriminate among individual performances. This means that high ICC values show that the individuals tested get different scores along the scale, indicating that the scale can differentiate among individual functions.
USEFULNESS OF THE GERIATRIC DEPRESSION SCALE
The results which indicate the usefulness of the GDS-15 among people with a level of cognitive impairment down to MMSE scores of 10 seem to be in accordance with those Gerritsen et al presented when comparing GDS-30 with a self-rating scale for depression (Depression List) and a scale for psychological well-being (PGCMS) among nursing home residents. Gerritsen et al also found relatively strong correlations between GDS-30 and the self-rating scales among people with MMSE scores of 5 or more. The decline in completion rate with decreasing cognitive function was also found in the study by Gerritsen et al, which showed that 72% of people with MMSE scores of 5–12 completed the GDS-30, compared to 100% of people with MMSE scores of 22–30. The higher completion rate in that study, compared to the present population-based study, might be due to possible sample selection in the low cognition groups because the GDS-30 was not offered to all participants both for practical reasons and the frailty of the residents. The results from the Paper II showed overall stronger correlations than the results presented in a study by Debruyne et al, who compared GDS-30 scores with results from another scale assessing depressive symptoms (Cornell Scale for Depression in Dementia) among older people with varying levels of cognitive function including those with severe cognitive impairment. One explanation for the low correlations in that study may be the administration of the Cornell scale, where the participants were interviewed together with a caregiver. Among people with MMSE scores of five or more, self-reports of depressive symptoms and well-being seems more valid than ratings or observations by staff or family carers.

Two items in particular appeared to be more difficult to answer in the GDS-15. These were items 10 and 15, both of which include a comparison with other people. Sutcliffe et al suggested that GDS-15 could be shortened for people living in residential care facilities because they found increased internal consistency when three items (items 9, 10, and 15) were removed. This was based on difficulties experienced with these specific questions, perhaps because of a reluctance among old people to make assumptions about other people’s life situations (item 10 and 15), or because some people simply never go outside (item 9).

EFFECTS OF EXERCISE ON MENTAL HEALTH AMONG OLDER PEOPLE LIVING IN RESIDENTIAL CARE FACILITIES
The lack of positive effects on depressive symptoms is in accordance with all previous randomised controlled trials evaluating exercise programmes of at least moderate intensity, or progressively increased load or dose, as a single intervention among people in residential care facilities. Regarding well-being, one of these trials reported no and negative effects and one reported positive effects on dimensions that appear similar to well-being. However, the actual between-group effect of the exercise programmes in the latter trial could not be interpreted...
due to the report of analyses adjusted for number of minutes of treatment, which was considerably higher in the control group\textsuperscript{119, 120}.

The aetiology of depression and low well-being among older people living in residential care facilities may contribute to the lack of positive effects in the total sample in Paper III. Older people in residential care facilities often suffer from organic brain disorders, such as stroke or dementia. These are associated with a higher risk of depression and disturbed brain function and might change the prerequisites for benefitting from antidepressants and exercise\textsuperscript{27, 42, 46}. The prevalence of stroke and dementia was 28\% and 53\%, respectively, in Paper III. In addition, baseline data showed that almost half the people receiving ongoing pharmacological antidepressant treatment were still suffering from depressive symptoms. Many participants in Paper III had prescribed drugs which have depression as a known side effect\textsuperscript{174}, or had a poor nutritional status which may have a negative influence on quality of life among people living in residential care facilities\textsuperscript{175}. Furthermore, older people have often suffered many losses e.g. of independence, physical capacity or family and social networks, which are associated with depressive symptoms and reduced well-being\textsuperscript{18, 126, 176}. It may be difficult to influence symptoms caused by such psychosocial circumstances through an exercise programme. Thus, depression and reduced well-being in this group of older people may be caused by a variety of individual factors and may, therefore, require individually targeted multifactorial treatment strategies.

Although depressive symptoms and psychological well-being are often strongly correlated, there may be some differences in the possibility of influencing them through exercise as a single intervention, considering the results from the additional analyses in Paper III. Both the analyses among participants with reduced well-being and participants with dementia indicate effects on psychological well-being but not on depressive symptoms. The analyses among the participants with PGCMS scores of $< 13$ showed a significant within-group increase at 3 months which may indicate a possible effect among those with reduced well-being. The between-group analyses, however, did not reach significance, possibly caused by low power in the analysis. Among the participants with dementia, there was a significant between-group difference in PGCMS scores in favour of the exercise group at the 3-month follow-up. One possible reason for this effect could be that people with dementia are especially physically inactive in their daily lives making them particularly receptive to being affected by an exercise intervention\textsuperscript{79, 80}. However, the results from sub-group analyses should be interpreted with caution\textsuperscript{177}.
PHYSICAL CAPACITY AND DEPENDENCE IN ADL AS MEDIATORS BETWEEN EXERCISE AND MENTAL HEALTH

In contrast to Paper IV, earlier prospective studies among community-dwelling older people have found that changes in physical capacity and dependence in ADL are associated with change in depression\textsuperscript{28, 37}. In addition, community-dwelling older informants in a qualitative study has described the importance of independence in mobility and ADL for life satisfaction\textsuperscript{126}. However, these results may not be applicable to people living in residential care facilities because they are all dependent on assistance in their daily life, and even if they improved their physical capacity or dependence in ADL they would still probably be dependent on assistance and living in the same setting. In addition, in contrast to the population in the prospective studies mentioned above\textsuperscript{28, 37}, many of the participants in Paper IV were severely cognitively impaired which may have influenced their experience of their functional status at the time, in that they believed they had either better or worse function than was actually the case. Consequently, a change in physical capacity or dependence in ADL might not have an impact on mental health. In addition, these associations may not exist among older people in residential care facilities because increased physical capacity and independence in ADL does not lead to increased daily physical activity, which may have an impact on mental health\textsuperscript{39, 40}. Increasing the level of daily physical activity may be challenging in this group\textsuperscript{178} as these people live in an environment that may not stimulate physical activity\textsuperscript{94}, that may offer them more assistance from caregivers than they actually need\textsuperscript{95}, and include a large proportion of people with dementia who could have difficulties initiating activities\textsuperscript{80, 127}. Unfortunately in Paper IV, the daily physical activity level of the participants was not measured.

Physical exercise programmes have shown positive effects on physical capacity and ADL ability among people living in residential care facilities\textsuperscript{111}, including people with dementia\textsuperscript{116}, but not on mental health. Paper IV indicates that a change in physical capacity or dependence in ADL is not associated with change in mental health. Thus, physical capacity and dependence in ADL do not seem to mediate an association between physical exercise and mental health. Subsequently, these results may offer an explanation to why studies of exercise to influence mental health have not shown effects in this group of older people\textsuperscript{95, 117, 118}. However, Paper III revealed a positive effect on well-being in a sub-group of people with dementia compared to a control activity. Considering the results from Paper IV, it is unlikely that the effect in that sub-group was caused by improved physical capacity or independence, but rather by physiological or psychosocial effects of the physical exercise intervention. The other randomised controlled studies among people living in residential care facilities, which did not show any effects on depressive symptoms and well-being, offered physical exercise interventions with similar frequency, but at lower intensity. Thus, since the possible effects of exercise on mental health in this group of older people might depend on physiological or
psychosocial effects of physical activity, rather than being mediated by improved physical capacity or independence, future studies should focus on evaluating the effects of physical exercise interventions offered more frequently and at moderate or high intensity, or evaluating interventions that aim to increase levels of daily physical activity.

FURTHER METHODOLOGICAL CONSIDERATIONS

General methodological considerations regarding GDS-15 and PGCMS
The yes/no format of the questions in the GDS-15 and PGCMS makes the scales suitable for use in this group of older people with varying degree of cognitive function\textsuperscript{142}. In addition, administrating the GDS-15 as an interview facilitates the completion of the questions for people with such impairments as e.g. visual impairment. The instructions for the GDS-15 and the PGCMS call for the symptoms to be rated according to their presence during the preceding week, a task that requires recalling the preceding week. This may be difficult for individuals with severe cognitive impairment both to understand and answer and it is likely that among those in this thesis with cognitive impairment, the answers are mainly based on their feelings at the time of the interview rather than the preceding week.

Paper II indicates the usefulness of the GDS-15 in assessing depressive symptoms among older people with MMSE scores of ten or more. In addition, there is support in the literature that a large proportion of people with cognitive levels down to MMSE scores of ten can answer questions about their quality of life in a valid way\textsuperscript{172, 179, 180}. Unfortunately, the reliability of the GDS-15 and PGCMS has not been well investigated among older people in residential care facilities, but all participants in the studies in this thesis were assessed by a trained investigator following the same procedure. How sensitive these scales are to change over time is also unknown. The scale steps are crude compared to using Lickert scales; however Lickert scales seems less feasible in this group of people due to the presence of cognitive impairments.

Paper I
One limitation in Paper I is that the sample size did not reach the recommended 50 people for using Bland and Altman’s statistical method\textsuperscript{133}. However the 45 people included approaches the recommended number. Even though the interval may have become slightly smaller with a larger sample, the results still indicate a wide variability in balance performance in these individuals. The main result in Paper I is calculated with a 95 \% confidence level, but one could question whether this confidence level is always necessary in the clinical setting when interpreting results from an assessment such as the BBS. Stevenson et al also presented lower levels of confidence, which seems useful as an alternative when clinically evaluating an individual’s function\textsuperscript{136}.
Two people were excluded before the second test because of acute illness. However, a more thorough assessment prior to the test occasions with (e.g. assessment of whether the participant had slept badly or had increased pain) might have provided additional information that may explain some of the variability between the test occasions. The exclusion at baseline of those who were independent in ADL and those with very low physical or cognitive function limits the external validity. Despite this limitation, the participants in Paper I had a wide range of both cognitive and physical performance, making them representative of a large part of the population living in residential care facilities. Inclusion for the REMANU Study was carried out six months before the start of the collection of data used in Paper I, and consequently, four participants had declined in cognitive function to a level below the inclusion criterion. However, exclusion of those four participants in the analysis did not notably affect the results.

The methodological strengths of Paper I are that the testing environment and time of day for administration were standardized, and that adherence was high. It was considered necessary to have at least one day of rest between tests to avoid having a lower result on the retest because of fatigue. A larger number of days in between might have increased the risk of other incidents occurring that could affect the health of these older people. There are many factors that can influence the testing situation and thus the absolute variability: e.g. the clarity of the descriptions for each scale step; the interpretation of the descriptions of the scale steps and assessment of the individual’s performance by the assessor; the health status of the individual and the possibility for individuals with cognitive impairment to understand and participate in the testing sessions. In order to capture mainly variability within the individual we tried to standardize as many aspects as possible in the testing situation, e.g. by giving education to the assessors including performing practice assessments in groups, performing the assessments in the home environment, at the same time of day and with the same assessor.

**Paper II**

The large sample size in the population-based study made it possible to divide the sample into groups according to level of cognitive function and to compare groups with severe cognitive impairments with a group with high cognitive function. The sample comprised very old people with a wide variety of health and living conditions, reflecting the heterogeneity existing in this group. No consensus was found in the literature on how to handle missing answers on the GDS-15; some allow and some do not allow missing answers. One missing answer was allowed in Paper II with regard to the population studied, and it was considered unlikely to have a significant impact on the results, as was confirmed in the analyses.
The PGCMS seems to be an appropriate choice when evaluating the construct validity of the GDS-15 since depressive symptoms are closely related to poor psychological well-being among older people 56, 67, 149, 158. The correlations between GDS-15 and PGCMS in Paper II indicate that answers are not given randomly, which might be expected from people with cognitive impairments or dementia. In order to further investigate the usefulness of the GDS-15, future studies should evaluate the validity of GDS-15 against a depression diagnosis or another scale for depressive symptoms among people with MMSE scores of 10-14. Unfortunately, this was not possible in the present study since the depression diagnosis was partly based on the score from the GDS-15.

**Paper III**

One limitation is that the number of participants included was not based on a power analysis for a between-group analysis using the GDS-15 and the PGCMS as outcome measures 114. Although 191 participants were included, a larger number would have been preferable to increase the power in the analyses. Some limitations in external validity exist because the MMSE score was limited to 10 or more, all participants had to be dependent in ADL, and able to rise from a chair with help from no more than one person. However, the strength of Paper III is that it included people with dementia and cognitive impairment, who make up a large part of those living in residential care facilities. Although not all participants achieved the desired high-intensity exercise level, it was estimated that most participants exercised at high or moderate intensity. Furthermore, the exercise intervention was well controlled with a control activity performed at the same frequency, the attendance was high in both groups, and the assessors in the study were blinded to group allocation and earlier test results.

**Paper IV**

One methodological strength in Paper IV is the use of changes over time to analyse the associations of two variables, instead of analysing the association by using a level of a variable at baseline to predict a level of another variable at follow-up. Neither of these two analytic approaches makes it possible to draw any conclusions about the causal relationship between the variables. However, the analyses in Paper IV provide a better understanding of how physical capacity and dependence in ADL interact with mental health over time among older people living in residential care facilities. Further, the assessments at follow-up were performed by assessors blinded to earlier test results and the rating scales that were used are well established for use in older people. For the studied population which included people with cognitive impairment, the choice of performing the Barthel ADL Index interview with the nurse’s aide who knew the participant well probably increased the accuracy of data on ADL.
The GDS-15, PGCMS and Barthel ADL Index are recommended for use among older people, but it is not known how sensitive the scales are to register change over time, especially not over a period of a few months. In Paper IV, three out of four participants changed at least one point in each of these scales during the 3-month follow-up period. It is also important to consider the absolute reliability of the rating scales when investigating associations between two measurement scales. In the studied population, it is likely that the health status of many individuals fluctuated due to a high prevalence of diseases and physical and cognitive impairments. This may contribute to variability in measurements and make it more difficult to reveal associations between rating scales. In Paper I, the BBS was investigated for absolute reliability in this population of older people and to our knowledge, absolute reliability has not been investigated for the other rating scales used in Paper IV. The scatterplots (Figure 8) show that some individuals had a difference in BBS scores of eight or more. There is no visible association between differences in BBS scores with differences in GDS-15 or PGCMS scores, respectively, among these individuals. This lack of association strengthens the conclusion that there is no association between physical capacity or dependence in ADL and mental health in this group of older people. Further, the association between the target variables closest to significance (GDS-15 and Barthel ADL Index $p = 0.06$, see Table 11) was in opposite direction of the hypothesis.

**CLINICAL IMPLICATIONS**

**Paper I**
Despite a large variability at an individual level, the mean for the group was rather consistent between the two test occasions, indicating that the scale is suitable for use in evaluating groups over time. In addition, the BBS is a functional way of measuring an individual's balance and can provide valuable information for clinicians designing individual exercise programmes. It is also easy to administer since it does not require much time or equipment. However, it seems important that clinicians should be careful when using assessments of the BBS to draw conclusions concerning change in balance function among older people living in residential care facilities.

**Paper II**
The GDS-15 seems to have an overall usefulness in assessing depressive symptoms among very old people with low levels of cognitive function, down to MMSE scores of ten, as almost two thirds of the participants with MMSE scores of 10-14 were able to complete the scale and the level of agreement with PGCMS did not differ from that for people with higher cognitive function. In older people with lower MMSE scores than ten, and those over ten unable to complete the GDS-15, there is a need to develop and validate other measurements to assess depressive symptoms.
Papers III and IV

Influencing depressive symptoms and well-being among older people living in residential care facilities through physical exercise seems to be a challenge. Possible exercise effects on mental health in this group of older people might depend on physiological or psychosocial effects of physical activity, rather than be mediated by improved physical capacity or dependence. It may be that exercise interventions offered more frequently than 2-3 times per week and with moderate or high intensity, or exercise interventions aimed at increasing levels of daily physical activity would be more effective in influencing depressive symptoms and well-being in this group of older people. In addition, exercise alone may not be the optimal treatment. Perhaps this issue requires reasoning similar to that applied to fall prevention, i.e. that older people living in the community can experience preventive effects from exercise as a single intervention while people living in residential care facilities need individually targeted, multifactorial strategies. Pharmacological treatment, review of pharmacological treatment and the withdrawal of inappropriate substances, treatment of associated diseases, improved nutritional status, cognitive psychotherapy, social stimulation and participation in an exercise programme, are examples of possible components in a multifactorial intervention.

Ethical considerations

When carrying out research among older people it is important to include also people with cognitive impairments, and those with dementia disorders. However, inclusion of these people may cause an ethical dilemma as it can be difficult to ascertain their understanding of the participation, but at the same time it is important to include them in research in order to gain knowledge regarding the diseases and health-related issues concerning them. In the three data collections involved in this thesis, all participants were given oral and written information about the study before giving consent to participate. For those with impaired cognitive function or dementia, the staff were consulted and next of kin were also informed and asked for their consent when appropriate. All participants were guaranteed that they would not be individually identifiable in the presentation of the results. They were also informed that it was possible to withdraw from participating in the study without stating a reason, and with no detriment to their care situation.

The testing and intervention sessions could be demanding for the participants. All participants were informed that they could stop the testing and intervention sessions whenever they wanted to without stating any reasons. All the investigators had medical education and experience of working with older people with physical and cognitive impairments. Concerns and emotions evoked in the participants during the testing or intervention sessions were addressed respectfully, and sessions were paused if the participant wanted or needed a break.
DISCUSSION

The REMANU and the FOPANU studies had the inclusion criterion of an MMSE score of ten or more for participation. This limits the external validity and unfortunately excludes some individuals who need to be investigated. However, the MMSE limit was based on clinical experience that these people could follow simple instructions and thus participate in testing and activity sessions as well as express willingness or unwillingness to participate.

When performing an exercise intervention it is important to consider the safety of the participants. For the FOPANU Study all residents had the approval of their responsible physician. In addition, the intensity of the exercise was gradually increased during the first two weeks. The responsible physiotherapists were experienced in working with the rehabilitation of older people with multiple diseases and physical or cognitive impairments. The participants were encouraged to exercise at high intensity, however the actual intensity was self-paced and exercises were individually adjusted progressively. In the case of any type of adverse event during activity sessions, these were documented according to a specific protocol. The physiotherapists and the occupational therapists were in close contact with staff and contacted the registered nurse or physician when needed.

IMPLICATIONS FOR FUTURE RESEARCH

The high-intensity exercise programme shows no effects in the total sample on depressive symptoms or psychological well-being among older people living in residential care facilities, and physical capacity and independence in ADL do not seem to mediate the association between exercise and mental health. However, sub-group analysis among people with dementia shows positive effects on well-being. In addition, during interviews informants described experiences of increased well-being\textsuperscript{15}. Based on these results, there are many interesting aspects to explore in future research. Firstly, it is important to confirm the effects among people with dementia by replicating the study among people with dementia only. Also, an intervention using high-intensity exercise in older people offered more frequency (i.e. more often than 2-3 sessions/week), or an intervention aimed at increasing the level of daily physical activity would be interesting for future research to evaluate. Depressive symptoms and well-being may have different aetiologies among older people in residential care facilities, and there may be a need for multifactorial strategies if all individuals are to be reached. Therefore, future studies could also evaluate programmes including individualised multifactorial interventions.

It is important to investigate whether there are individuals who are responders to the exercise programme regarding depressive symptoms and psychological well-being, and if so what would the characteristics of such responders be. The absolute reliability of the assessment instruments GDS-15, PGCMS and the Barthel ADL
DISCUSSION

Index among older people living in residential care facilities is not known and needs to be evaluated in future studies. This would facilitate the interpretation of change in scores between assessments which is important to know in the clinical setting but also in research to further explore for example the presence of responders. In addition, the sensitivity-to-change of these scales is another interesting aspect which, combined with information regarding absolute reliability, can strengthen the usefulness of the scales as outcome measures in the clinical setting and in research.

The GDS-15 and the PGCMS probably capture different dimensions of mental health, and these differences are indicated by the positive effects on well-being but not on depressive symptoms among people with dementia. Even though the GDS-15 and the PGCMS are associated in cross-sectional studies, it is not known whether a change over time in one scale is reflected by a change in the other scale, and it would also be interesting to investigate this.

Regarding the use of GDS-15 among very old people with MMSE scores of 10-14, there is a need to further investigate the validity by evaluating the GDS-15 against a depression diagnosis or another scale of depressive symptoms. It seems that two items on the GDS-15 were more difficult to answer than the others. These items could maybe be rephrased to better suit the population of very old people, including people living in residential care facilities, or shorter versions of the GDS-15 might be more useful. This is an area for future research. In addition, many people with MMSE scores of less than 14, especially those below ten, had difficulties to answer the questions on the GDS-15. For those people it may be necessary in future research to develop, or to further evaluate, other instruments for assessing depressive symptoms.

The absolute reliability of the BBS indicates a quite large individual variability, which could be caused either by the individual or by measurement error. The use of the mean of repeated measurements to increase the accuracy of assessments of walking ability, has increased the reliability for tests of walking ability183. It would also be interesting to evaluate this with reference to the BBS.
CONCLUSIONS

Despite a high ICC value, the result of the absolute reliability indicates that a change of 8 BBS points is required to reveal a genuine change in function between 2 assessments using a 95% confidence level among older people who are dependent in ADL and living in residential care facilities. This knowledge is important in the clinical setting when evaluating an individual's change in balance function over time in this group of older people.

The results indicate that the Geriatric Depression Scale-15 has an overall usefulness for assessing depressive symptoms for clinical and research purposes, among very old people with an MMSE score of ten or more. More studies are needed to strengthen the validity of GDS-15 among older people with MMSE scores of 10-14, by evaluating GDS-15 against a depression diagnosis or another scale for depressive symptoms. In older people with MMSE scores lower than ten and those over ten unable to complete the GDS-15, there is a need to develop and validate other measurements to assess depressive symptoms.

A high-intensity functional weight-bearing exercise programme over a period of three months seems generally not to influence depressive symptoms or well-being among older people living in residential care facilities, including people with severe cognitive or physical impairments. A change in physical capacity or dependence in ADL does not appear to be associated with a change in depressive symptoms or psychological well-being among older people living in residential care facilities, including people with dementia disorders. This lack of association may explain why studies of the use of physical exercise to influence mental health have generally not shown any effects in this group of older people. However, an exercise programme as a single intervention may have short-term effects on well-being among people with dementia, but further research is needed to confirm this finding.
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