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Tele-rehabilitation in a geriatric population: Feasibility and potential barriers

PhD dissertation

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List of abbreviations

ADL	Activities of Daily Living
AUH	Aarhus University Hospital
COPD	Chronic obstructive pulmonary disease
DEMMI	De Mortons Mobility Index
ED	Emergency Department
EHR	Electronic Health Record
eHLA	electronic Health Literacy Assessment
FES-I	Falls Efficacy Scale-International
FRS	Functional Recovery Score
GP	General practitioner
IADL	Instrumental Activities of Daily Living
ICF	International Classification of Functioning
ICT	Information and Communication Technology
IQR	Interquartile Range
IT	Information Technology
MPI	The Multidimensional Prognostic Index
OEP	Otago Exercise Program
OR	Odds Ratio
RCT	Randomised Controlled Trial
SPMSQ	Short Portable Mental Status Questionnaire
TR	Tele rehabilitation
WHO	World Health Organization

Introduction

This PhD study investigates the feasibility and potential barriers of offering tele-rehabilitation (TR) to geriatric patients after an acute admission to hospital and the prevalence of computer and internet use and digital literacy amongst patients admitted to the Department of Geriatrics, Aarhus University Hospital, Aarhus, Denmark.

TR is used in many specialties but is seldom used in geriatrics (1-3). This is despite the fact that older patients often experience a decrease in their functional capacity in connection with illness and hospitalisation (4, 5). In these patients, offering TR immediately after discharge seems attractive for several reasons. Older people often prefer to exercise at home (6), and TR can save the older person from backbreaking transportation and waiting time both before and after a training intervention in a community centre for older people (7). TR might result in greater adherence to a training programme compared to the usual training offers such as balance and muscle strength exercises (8). However, we do not know whether the prerequisites for using TR amongst frail geriatric patients after an acute admission are present.

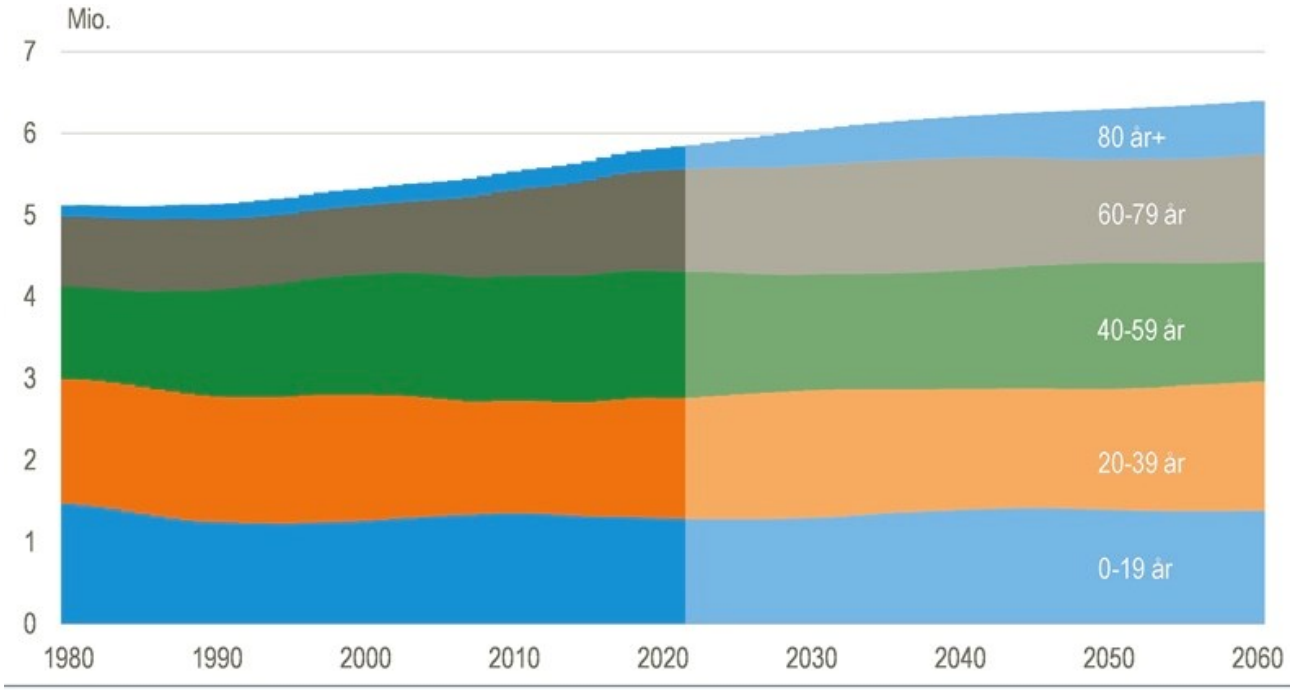
Background

Ageing society

Life expectancy has improved in all countries globally. However, there is a 32-year difference in life expectancy between people living in the Central African Republic, who have an average life expectancy of 53 years, compared to almost 85 years for the Japanese population (9, 10). Switzerland tops the European list, with a life expectancy of 84 years as of 2020. It is expected to rise to 88 years in 2050 (11).

In 2019, almost 5.8 million people lived in Denmark. Of these, 1,136,000 people had reached the age of 65, 872,000 were between 65 and 74 years old, and 264,000 were 80 years and older (12). In 2060, the Danish population is expected to number 6.3 million inhabitants, including 616,156 persons aged 80 years and older (Fig. 1) (12).

Figure 1. Life expectancy in Denmark



Statistics Denmark, 2021 (12)

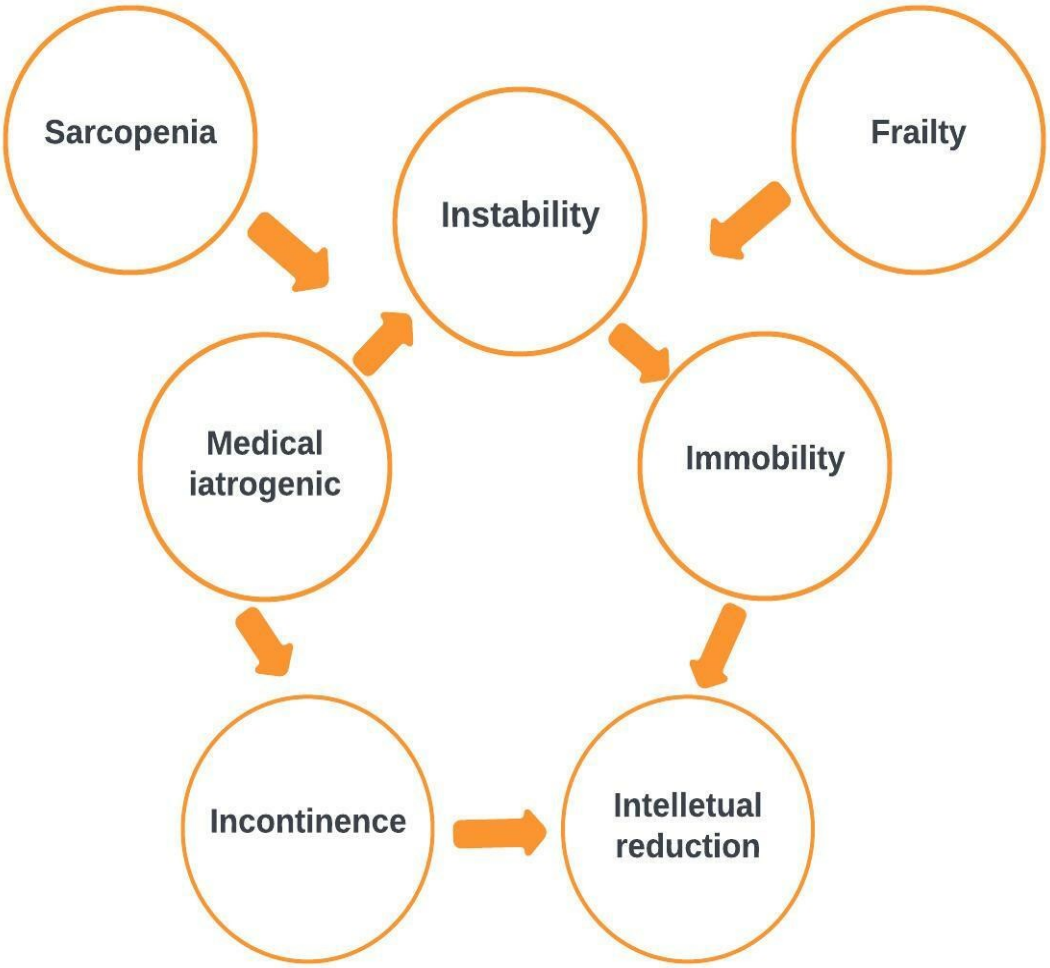
Research shows that significantly fewer children are being born than expected, resulting in a world with many retired people and few people of working age to take care of older generations (13). A longer life is not always accompanied by good health. Getting older is often followed by multimorbidity because of chronic and degenerative disorders (14). In Denmark, for example, a decrease of about 2 years in healthy life years was found between 2010 and 2019 (10).
The World Health Organisation (WHO) aims to raise awareness of the connection between global health and ageing, and expressed the need for action based on evidence-based policies to close this gap (15).

Geriatric patients

Most geriatric patients are no longer characterised by age, but most are aged 70 years or older (16) and suffer from comorbidities. The most common geriatric syndromes comprise one or more of the following: immobility, instability, cognitive decline, including dementia, depression and delirium, incontinence, and iatrogenic disease (17). Recent research has added sarcopenia and frailty (Fig. 2)

(18, 19). All geriatric syndromes are interactions between disease and age that affect multiple systems and are contributory causes to why geriatric patients are admitted to hospital.

Figure 2. The geriatric syndromes



Although older medical patients are usually hospitalised for short stays; acute hospitalisation can be stressful due to, for example, immobilisation (20), sleep disorders (21), and decreased dietary intake (22). These are all factors that may affect homeostasis and, thus, start a negative spiral in older patients' functional capacity, which is not necessarily regained without further action (23, 24).

Immobilisation

Immobilisation partly explains why some older patients experience a reduction in their physical functional capacity both during hospitalisation and after discharge. This can influence their risk of falling and contribute to their decline in health (5, 23). Prolonged immobilisation time can influence skeletal muscle protein synthesis, lean tissue mass, and lower extremity strength (25). More of these adverse effects of immobilisation contribute to the development of sarcopenia (24).

Sarcopenia

From the age of 50, there is a natural loss of leg muscle mass of 1%–2% per year and, by extension, a loss in muscle function of 1.5%–5% per year, eventually leading to primary sarcopenia (26). A study of the natural losses of appendicular lean muscle mass, muscle strength, and physical function in a cohort of healthy individual volunteers from the age of 20–93 years was conducted to create normative reference values that can be used, for instance, to diagnose sarcopenia (27).

The development of sarcopenia is complex, and the underlying pathophysiological mechanisms are still being investigated. Nevertheless, sarcopenia is an ageing-related health problem (28) that is defined by Cruz-Jentoft et al. as "a progressive and generalised skeletal muscle disorder that is associated with increased likelihood of adverse outcomes including falls, fractures, physical disability, and mortality"(19) . Sarcopenia can be divided into primary and secondary sarcopenia (24).

Primary sarcopenia is related to age alone (24), and leads to reductions in appendicular lean muscle mass, muscle strength, and physical function, all below the mean scores of a healthy reference group's normative values (27). Secondary sarcopenia is triggered by diseases other than ageing, such as diabetes (29), cancer (30), heart disease (31), kidney disease (32), chronic obstructive pulmonary disease (COPD) (33), stroke (34), and malnutrition (35). When sarcopenia is triggered by disease, the above-mentioned processes accelerate.

An Italian study that examined sarcopenia incidence amongst patients admitted to a geriatric ward found that 35% were diagnosed with sarcopenia. At discharge, a further 15% had developed sarcopenia, resulting in 50% with sarcopenia (36). The last 15% might be explained by illness and immobilisation during hospitalisation: one study found that older medical patients spent 17 hours in bed per day even though they had gait function (37). Also, 1 year after hospitalisation, a decline in functional capacity has been observed (38). It has proved difficult to estimate the prevalence of

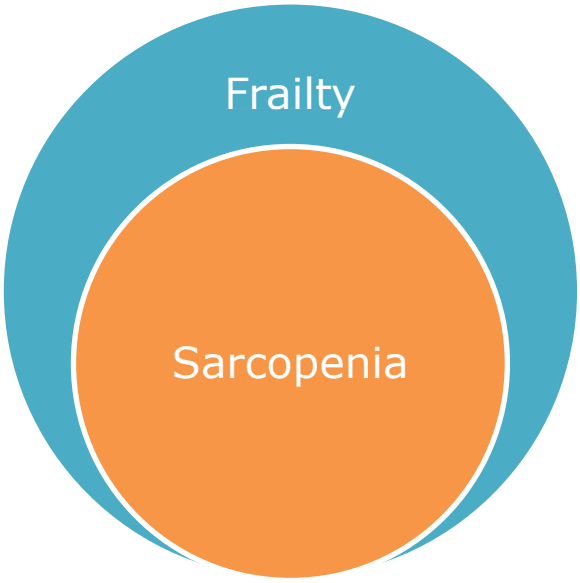
sarcopenia, as it depends on the definition used: Mayhew et al. found a variation in prevalence between 9.9% and 40.4% (39).

Sarcopenia and frailty

Sarcopenia and frailty are two syndromes that partly overlap (40). Frailty is a complex disorder that includes more inter-related physiological systems primarily related to advanced age and is clinically expressed as weakness, fatigue, weight loss, and slowness (40). Both sarcopenia and frailty can be measured by hand grip strength and walking speed (40), and malnutrition plays an important role in both syndromes. Following low food intake and, by extension, a loss in body weight, the body reacts by catabolising fat and muscle mass to provide energy (41). In particular, protein intake is significant for maintaining muscle mass or attenuating the loss of lean muscle mass in older persons (42).

Sarcopenia most often precedes frailty but also helps to accelerate frailty (Fig 3) (40). These age-related physical syndromes can be reversed or attenuated by interventions in which physical activity programmes, including resistance-based training, are primary treatment (43, 44).

Figure 3. Sarcopenia and frailty



Benefits of physical activity and exercises in older people

Physical activity is one of the components of healthy and active ageing and might also reduce the risk of impaired cognition in older people with comorbidities (45). Physical exercises, for instance, supplemented with protein intake in older men and women, have been found to have positive effects on adipose tissue, cardiorespiratory endurance (46), muscle quality, and functional capacity (47). Resistance training conducted at high intensity is needed to counteract age-related muscle wasting (48, 49). Such exercises promote, amongst other benefits, muscle protein synthesis, which is part of the process that occurs when muscle tissue is rebuilt, and contribute to improving not only muscle mass but also muscle function, thereby preventing sarcopenia (43, 50).

Although geriatric patients are rarely able to participate in high-intensity resistance exercises during and immediately after hospitalisation (51), it is important to start training as soon as possible in order not to lose functional capacity (52). Exercise at home is highly valued by community-dwelling older people (6), whereas transportation to a training centre several times a week may be resource-demanding (53). Therefore, TR could cover the gap between hospitalisation and starting at a training centre, and be a solution for people unable to leave home immediately after an acute illness. It could also be a solution for people who need to socially distance to avoid transmission of infections by person-to-person contact (1, 54).

Rehabilitation

Meyer et al. called in 2021 for a common definition of the concept of rehabilitation that could be used internationally (e.g., in a research context) (55). The authors problematised the large differences that exist in the definition of rehabilitation between countries, which are often based on "local regulations and traditions" (55).

The WHO has defined rehabilitation as "a set of interventions designed to optimise functioning and reduce disability in individuals with health conditions in interaction with their environment" (56). The concept of rehabilitation was also defined in a Danish context in 2004 (57). Work is underway on an updated rehabilitation definition and is expected to be completed in 2022 (Personal communication with Rehabiliteringsforum.dk).

Rehabilitation services in the Danish healthcare system

In Denmark, a rehabilitation reform was introduced in 2007. The main part of rehabilitation was moved from the counties to the 98 municipalities. If hospitalised patients experience a decrease in

their functional capacity, a rehabilitation plan must be prepared at the time of discharge. The rehabilitation plan is based on the framework of the WHO's International Classification of Functioning (ICF), in which functioning collectively refers to "health conditions, activity, participation, and contextual factors that affect people's ability to perform activities of daily living and take part in community life" (58).
The rehabilitation plan must be made in collaboration between the patient and the health professional. The plan must state a deadline for starting rehabilitation after discharge from the hospital if there is a health professional-justified need for this. This is the case if significant potential will otherwise be lost in relation to achieving full or the best possible functional capacity (59). However, the municipalities have not always been able to fulfil this aim due to lack of resources (53). Therefore, new ways of practising rehabilitation are urgently needed. Here, TR may hold promise.

Telemedicine

The WHO defines telemedicine as "the delivery of health care services, where distance is a critical factor, by all health care professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment and prevention of disease and injuries, research and evaluation, and for the continuing education of health care providers, all in the interests of advancing the health of individuals and their communities" (60). Telemedicine had its tentative beginnings in 19th century, when an article in *The Lancet* explained that it was possible to diagnose a cough in an infant by telephone (61). In 1920, Norway provided clinical medical support for ships at sea. This radio-established support also made it possible to conduct urgent surgical operations (61). Tele-monitoring, using different kinds of sensors, such as pedometers, blood glucose or oxygen saturation meters, are examples of modern telemedicine interventions (62).
In Denmark, positive effects have been found in patients with COPD using telemedicine. The patients are monitored for their weight, blood pressure, oxygen saturation, and spirometry. The study revealed that the number of readmissions fell by half, and the patients felt more secure because health professionals took care of them all the time (63).

Tele-rehabilitation

TR is part of the telemedicine concept and is defined by Russel et al. as "the provision of rehabilitation services at a distance using telecommunications technology as the delivery medium"

(64). TR is used in situations where physical presence is challenging and for different purposes, such as physical assessment and treatment (1, 65). These different purposes require different technical applications, and therefore TR is provided in various ways, such as online videos where patients follow pre-recorded videotaped exercises, also called asynchronous e-visits (66) or two-way real-time videoconferencing. The latter is a kind of face-to-face solution, where, for instance, physical exercises are guided by a physiotherapist in front of a camera. This real-time TR makes it possible to both see and communicate with the patients involved. The technology has been shown to be both feasible and effective as group exercises for COPD patients and patients with heart failure and has been found to be effective in reducing sarcopenia, increasing physical function, endurance and self-efficacy, and reducing pain (67-71).

Literature review of the use of tele-rehabilitation

A systematic literature search was conducted several times in the study period and the last time was in January 2022. The purpose was to identify literature that deals with tele-rehabilitation or telemedicine involving a physical exercise training intervention conducted via screens on televisions, computers, laptops, or smart phones, and offered to older people and hereby to answer the research question: *"Which TR methods involving physical exercise training interventions are feasible to implement among community-dwelling older people and what effects have been found when TR is implemented in this target group"?*

The systematic literature search was performed in the databases PubMed, Embase, Cinahl, and Pedro according to the PICO framework but restricted to (P) Population and (I) Intervention only. With the purpose to find as many citations as possible, we did not include terms for Comparator (C) or Outcome (O) in our search string.

The following MeSH terms were used: Aged, Sex, Geriatrics, Older people, Elderly, Frail elderly, and Tele-rehabilitation, Telemedicine, Virtual rehabilitation, Remote rehabilitation, Computer-based exercises, Computer-generated exercises combined with Physio therapy, Physiotherapy, Physical therapy, Physical therapy modalities.

We accepted studies where the participants had a mean or median age of ≥70 years, and a standard deviation in which the youngest participants being ≥65 years of age.

Limits: Last 20 years, humans, feasibility and pilot studies, clinical trials, controlled clinical trials, meta-analysis, multicentre study, randomised controlled trials, non-randomised trials, feasibility studies, pilot studies, abstracts [text].

The table includes various study designs, but RCTs (randomized controlled trials) performed in the patient's own home and in patients with the highest mean/ median age are prioritized first.

Table 1 Literature review of tele rehabilitation in older people

Study		Population	Sample size (N)	Diagnosis	Setting	Tele-rehabilitation intervention	Results
Author, year, Country, Title	Design Mean age or Medium age years (±SD)	Recruited from				Description	
Hong et al. 2017, South Korea *Effects of home-based tele-exercise on sarcopenia among community-dwelling elderly adults: Body composition and functional fitness*	A randomised controlled trial Mean age 82.2 (±5.6)	Home-dwelling older people over age 65 years were voluntarily recruited from a Senior Citizen Centre	23	Patients with motor malfunctions, unstable cardiovas-cular diseases, diabetes mellitus, mental illness were excluded	Home	The intervention group received exercises via real-time videoconferencing "all in one" touch screen computers 3 times a week for 12 weeks. The control group did not receive any intervention, but every 2nd week their physical activity and nutrient level were noted.	Compared to the control group, the intervention group showed changes in body composition before and after applying the tele-exercise. Also, a significant effect was found in functional fitness
Hong et al. 2018 South Korea *Web-Based Telepresence Exercise Program for Community-Dwelling Elderly Women with a High Risk of Falling*	Double-blind, parallel-group, randomised controlled trial. Mean age 82.2 (±5.6)	Same study as above, but different outcome	23		Home	The study did not score the participants' computer literacy before study start. A certain level of computer literacy was not a requirement. The participants received TR via real-time voice calling, video chat, and text messaging.	After 12 weeks of exercising, the study found a significantly better score in the intervention group in Berg Balance Test and Fear of Falling compared to the control group.

Bernocchi et al. 2018, Italy *Feasibility and Clinical Efficacy of a Multidisciplinary Home-Telehealth Program to Prevent Falls in Older Adults*	Randomised controlled feasibility and efficacy trial Mean age 79 (±6.6)	Older people discharged home after in-hospital rehabilitation.	283	Patients were recruited after in-hospital rehab if they had one or more chronic disease, had a fall, or were in risk of falling	Home	The TR intervention: Otago exercises via paper instruction sheets. Twice monthly the adherence to the training programme was facilitated by a physiotherapist through real-time videoconference by following the participants in conducting the exercise sessions. Every second week the physiotherapist called the patients and they also followed up on patients by phone calls if necessary. Caregivers supported the participants, e.g., in using the video conferencing system when possible. The control group received usual care by GP and recommended balance and strength exercises.	A total of 38 patients dropped out – 19 in each group. Ten patients refused to follow the TR programme, 9 patients were hospitalised, and 7 patients died. Eleven patients refused to come to the final visit. Significantly more patients in the control group had a fall in the 6 months after discharge. Functional status and balance-related problems also improved significantly more in the intervention group. Adherence to the exercises for both groups was 82% (±43%.) Adherence to the sessions not supervised via videoconference was 76% (±30%).
Ortiz-Piña et al., 2021 *Effects of Tele-Rehabilitation Compared with Home-Based in-Person Rehabilitation for Older Adult's Function after Hip Fracture*	A choice-based single-blinded, non-randomised clinical trial Mean age Interv. group 75.9 (±5.8) Control group 80.4 (±5.5)	Home dwellings Only patients with a caregiver were included. Recruited from hospital	62	Patients who had undergone surgery after a 1.hip fracture	Home	The patients and their caregivers could choose between: 1) usual care and home rehab (control group) 2) usual care and (intervention group) a 12-week multidisciplinary TR programme using pre-recorded instructional videos and written instructions according to the patient's functional status. The sessions were supervised by the informal caregiver, who could request weekly videoconferences with the physio- and occupational therapist. Usual care was an educational workshop.	Both the intervention and the control group improved in their functional capacity, but the TR group was superior in gait velocity and in the level of assistance to perform the activities of daily living
Smaerup M. Archives of Physical Medicine and Rehabilitation. 2015 *Computer-assisted training as a complement in*	Randomised controlled trial Mean age Interv. group 76.7 (±7.6) Control group 78.7 (±6.6)	Geriatric outpatients referred to a fall clinic	60	Chronic dizziness due 2.to vestibular dysfunction	Hos-pital and Home	Both groups received vestibular rehabilitation twice a week at the hospital during 16 weeks. Alongside the hospital training, a TR intervention was compared with home-exercising following printed exercises. The TR methods was home-based video-taped exercises revealed on a computer screen.	Both groups improved significantly during 16 weeks of rehabilitation. The study found no significant differences between the 2 groups. Compliance to the TR intervention was 57%.

rehabilitation of patients with chronic vestibular dizziness							
An et al., 2021, Switzerland *Effects of Preoperative Telerehabilitation on Muscle Strength, Range of Motion, and Functional Outcomes in Candidates for Total Knee Arthroplasty*	A Single-Blind Randomised Controlled Trial Mean age 75 (± 6)	Randomised into 3 groups: 1) TR intervention group 2) Patient education group 3) Control group Recruited preoperative	53 women	*Prior to a Total Knee Arthroplasty 3*	Home	The intervention took place in the patients' homes prior to a total knee arthroplasty (TKA), 30 min per session, 2 times/day, 5 days/week for 3 weeks: TR intervention group received tele-rehabilitation exercises at home via a real-time videoconferencing system with visual feedback from a therapist on devises using smart phones or tablets Patient education group received non-supervised home safety exercises and the same exercises as the TR group. The control group received usual care.	The study found a positive effect on muscle strength, range of motion, and physical functional outcomes after TKA in the TR intervention group compared to the education and usual care groups
Tsai et al. 2016, Australia *Home-based tele-rehabilitation via real-time videoconferencing improves endurance exercise capacity in patients with COPD*	Randomised controlled study Mean age 74 (±8)	Community dwellings Recruited from a tertiary hospital pulmonary rehabilitation programme	36	COPD 3	Home	Supervised group TR exercising three times a week for 8 weeks. The hospital-based physiotherapist supervised remotely using real-time videoconferencing system. Brochure and face-to-face sessions in equipment use. The control group received usual medical care.	The intervention group improved significantly better in endurance exercises and self-efficacy compared to the control group. The study found a trend towards improved health-related quality of life in the intervention group compared to the usual medical care.
8) Piqueras et al. 2013, Spain	Single-blind, randomised, controlled	Patients recruited after planned total	181	Total knee arthroplasty	Acute -care hos-	The interactive virtual (ITV) TR intervention used a 3D avatar by reproducing the avatars movements.	The IVT group achieved a greater increase in muscle strength.

Effectiveness of an Interactive Virtual Telerehabilitation System in Patients after Total Knee Arthroplasty	non-inferiority trial. Mean age 73.3 (± 6.5)	knee arthroplasty			pital rehab unit and in the pa-tients ho-mes	Daily remotely therapist supervision (not real-time contact) contact via telephone if necessary. This intervention was compared with usual care consisting of conventional out-patient physical therapy.	Timed Get-Up-and-Go test: similar in both groups There were no problems in using the portal, which was found to be intuitive and easy to understand.
9) Laver et al. 2012, Australia *Use of an interactive video gaming program compared with conventional physiotherapy for hospitalised older adults: a feasibility trial*	A single centre, parallel, randomised controlled pilot study Mean age 85 (±4.5)	Patients recruited from a geriatric rehabilitation ward.	44	Patients were included if: no severe cognitive impairments, sufficient communi-cation skills, weighing < 150 kg, independent sit-to stand transfers, prior to admission ambulating independently, sufficient vision	Hos-pital	Intervention group: physiotherapist supervised balance, strength, or aerobic exercises via wireless pointer and balance board. The system represented the participant on a screen, e.g., as a penguin. The control group received the traditional physiotherapy.	The intervention group improved more on the Timed Up and Go test than the control group. No serious adverse events were registered, and it was possible to achieve high levels of adherence in both groups. It was only possible to recruit a few of the eligible patients to the study.
10) Van den Berg et al. 2015, Australia *Video and computer-based interactive exercises are safe and*	A randomised trial Mean age 80 (±12)	Geriatric and neurological patients Recruited from a Rehabilitation centre	88	Mobility and balance limitations 4	Re-habili tation centre	The intervention group received usual rehabilitation supplied by physiotherapist-prescribed, video/computer-based interactive exercises. The control group received standard rehabilitation-unit care alone. This study used functionally relevant devices and games which also gave feedback about task performance.	Only performance on the maximal balance range test was significantly better in the intervention than in the control group. Compared to the control group, the study found a trend towards better walking speed and self-rated health status in the intervention group.

improve task-specific balance in geriatric and neurological rehabilitation							
11) Li et al., 2020, Hong Kong *Effects of a home-based occupational therapy tele-rehabilitation via smartphone for outpatients after hip fracture surgery*	A feasibility randomised controlled trial Mean age: Interv. group (76.5) (±8.6) Control group 82.1 (±9.7)	Recruited from a geriatric day hospital	31	1. Patients with surgery after a hip fracture	Day hospital rehabilitation	The intervention group received home-based video-taped exercises via smartphone or tablet apps. The patients were able to film own performance and send it to the therapist who could up-date the home programme according to the film sessions if needed. The control group received the training programme on written sheets of paper.	No significant differences were found between the two groups at pre-test, post-test, and follow up in gait velocity, balance test, pain, activities of daily living, and fear of falling.
12) Oesch et al., 2017, Switzerland *Exergames versus self-regulated exercises with instruction leaflets to improve adherence during geriatric rehabilitation*	Single-centre randomised controlled clinical trial Median age (IQR): Interv. group 73.8 (67.9–79.1) Control group: 74.3 (66.1–79.3)	Geriatric in-patients	54	Multiple diagnosis 5	Rehabilitation clinic	The intervention group performed exergames for balance, leg strength, and flexibility according to the older person's balance skills. The control group used a printed instruction sheet with conventional exercises for balance, strength, and mobility performed in sitting, standing, or walking, depending on the patient's balance ability. The study ran for 10 days.	No difference was found regarding adherence to the training programme. Results with regard to time and frequency of exercise sessions were in favour of the conventional exercises.
13) Crotty et al. 2014, Australia *Tele-rehabilitation for older people using*	Feasibility study Home dwellings: Mean age 73.0 (±10.1)	Home-dwellings and nursing home residents.	61 Home-dwellings 43 Nursing home	Stroke, fractures, or prolonged hospital admission 6	Home and Nursing home	Tablet videoconferencing sessions in, e.g., physiotherapy, and medical reviews telehealth consultations. Familiarity with technology and computer self-efficacy was assessed prior to commencing the project.	All the 61 home-dwellings undertook the TR programme but only 17 of the nursing home residents. Seventy-four percent entered the TR programme directly after discharge.

off-the-shelf applications: acceptability and feasibility	Nursing home residents: Mean age 83 (±7.9)		re-sidents			Applications and tools were assisted with patient and carer engagement. No log-in or passwords were used. Patients were trained to use the computer.	
14) Chan et al., 2012 Hong Kong *Interactive virtual reality Wii in geriatric day hospital: A study to assess its feasibility, acceptability and efficacy*	A clinical trial with matched historic controls Mean age 80.1 (±7.1)	Geriatric patients Those who could understand the procedure of using Wii-IVR and were suitable to carry out the movements involved in the study were recruited as participants.	30	Geriatric patients with multiple diagnosis. 5	Day hos-pital	Eight sessions using a Wii controller to carry out arm movements, while the arm movements were reproduced on a television screen. Two participants were able to play together. The game took about 10 min. This intervention was combined with the conventional rehabilitation at the geriatric day hospital.	Interactive virtual reality Wii under supervision was feasible and well accepted. Participants achieved a similar percent maximum heart rate reserve in Wii and simulated rehabilitation tool (arm ergometer), and they participated without excessive fatigue. There were no serious adverse events. , Improvement in functional assessment was also found compared with historic controls.
15) Albiol-Perez, 2017, Spain *The effect of balance training on postural control in patients with Parkinson disease using a virtual rehabilitation system*	Feasibility study Mean age 79.6 (±5.80).	Older hospital in-patients	10	Parkinson 6	Hos-pital	Both traditional and virtual rehabilitation. The exercises were performed in front of a 47" Television screen consisting of different seated balance tasks displayed on the screen. In this sitting position, the study tested and stored spatial postural control by using a Nintendo Wii Balance Board.	The study found a trend in improvements in the sitting position for central-left and right spatial postural control.

Summary of literature review of tele-rehabilitation

The search produced a total of 850 hits, and additional references were applied through hand search of relevant papers including the reference lists of reviews and systematic reviews.

As seen in Table 1, the TR literature review identified a total of 15 studies conducted in different populations with various diagnoses, age groups, settings, TR devices, and methods.

Age groups and diagnosis

The 15 studies are naturally distributed as follows: four in those aged 70–74 years, six studies among those 75–79 years, and five in those 80–85 years.

The studies represented different diagnoses: stroke: 1, hip fracture/other fractures: 3, total knee arthroplasty: 2, Chronic Obstructive Pulmonary Disease (COPD): 1, Parkinson disease 1, vestibular dysfunctions: 1, geriatric patients with multiple diagnosis: 2, fall risk/ balance and gait impairments: 2, Sarcopenia: 1, others: 1.

Effects

Based on the randomised controlled trials, TR interventions are as good as conventional training offers when it comes to improving functional status, fall risk, gait velocity, balance, endurance, and self-efficacy.

TR in geriatric patients according to settings and time of recruitment

The six studies involving geriatric patients (66, 72-76) of these five were performed in a hospital or rehabilitation setting (72-76) and one performed in a combination of both at the hospital and at home (66). Apart from the study by Chan et al. (72) the other four studies were RCT studies, two of which were a pilot RCT study (76) and a feasibility RCT study (74). The study by Oesch et al. ran for ten days (73) .

The RCT by Laver et al. found a significantly better gait speed in favour of the TR intervention group (76). The RCT by Van den Berg et al. found a significantly better performance on the Maximal Balance Range test in the TR intervention group (75). The study by Smaerup et al. found no significant difference between the intervention and the control group according to dynamic gait balance and the number of sit to stand (66). None of the five studies included TR undertaken immediately after an acute admission.

Seven of the 15 studies were conducted in the participant's own home (66, 69, 71, 77-80). The two studies by Hong et al. were done in the same population (71, 81). This is the only study found where TR was conducted in the patient's own home and the patients had a mean age between 80 to 85 years, reflecting the age of geriatric patients in Denmark (82).
Participants in the other studies that carry out TR in the participants' own homes are either younger or have a caregiver to supervise the TR intervention (66).
Based on this literature review, none of the studies investigated TR in geriatric patients after discharge from an acute short hospitalisation. We therefore planned a RCT of TR in such a population.

The Randomised Controlled Study

The Geriatric Department at Aarhus University Hospital consists of a fall clinic, two wards with 32 beds where frail older acutely ill patients with complex medical diseases are treated and a "hospital at home" geriatric team visiting patients from just after and until a couple of weeks after discharge. The average length of hospital stay is 6.4 days. The "hospital at home team" saw the need for early rehabilitation after discharge and suggested that a study be conducted to determine whether TR be offered to these patients.
The original aim of this PhD study was to conduct a randomised controlled trial with the purpose to investigate the use of TR in geriatric patients aged 75 years or older, just discharged after acute hospitalisation. The TR intervention was planned to be provided as real-time videoconferencing both as group and individual interventions.
We hypothesised that physiotherapist-supervised TR in *groups* was superior to physiotherapist-supervised *individual* TR, which again was superior to the *traditional* exercise programmes in relation to physical functional capacity, degree of loneliness, quality of life, and fear of falling.
Patients were planned to be recruited from the Department of Geriatrics at Aarhus University Hospital. Unfortunately, even after changing *the age limit* to 65+ years and including geriatric *patients who had undergone surgery after a hip fracture,* we were unable to recruit patients for the study. We tried to test use of the same TR system in fall patients who were not acutely ill and citizens discharged from the Geriatric Department to a rehabilitation centre in the municipality of Aarhus (See Appendix 1). We had to acknowledge that it was impossible to recruit participants for TR in a RCT design and decided to examine the reasons why it was not feasible.

Feasibility and potential barriers when offering tele-rehabilitation to geriatric patients

(Study 1 and Study 2)

Our main aim in this PhD study was now to examine the feasibility and identification of barriers for geriatric patients to join TR. We conducted interviews of patients selected for the planned RCT, both those who in the first place agreed to participate and later dropped out and those who denied to participate in the first place (Study 1).

Furthermore, we decided to conduct a TR case report involving four patients (Study 2). Two were recruited from the Fall Clinic at the Department of Geriatrics, Aarhus University Hospital and two from the Rehabilitation Centre, Vikærgården. This TR intervention used both the Otago exercise programme and the real-time video conferencing technology as originally planned for the RCT (see Appendix 1 and Appendix 2).

The results from Study 1 and Study 2 led us to Study 3 and Study 4 for the purpose of investigating factors influencing participation in a TR intervention among a broad population of geriatric inpatients and outpatients.

Prevalence of computer users, computer skills, and digital literacy for the potential use of tele-rehabilitation in geriatric patients

(Study 3 and Study 4)

First, we saw a need to study the prevalence of computer users in a geriatric population and to highlight factors that influenced the use of computers among both in- and outpatients, which resulted in Study 3. Next, to examine computer habits and the association between digital literacy, stress levels, and frequency of internet use in the geriatric population (Study 4). The background for investigating these issues will be described in the next section.

Use of Information and Communication Technologies and technical support

Much progress has been made in recent years to use Information and Communication Technologies (ICT). In Denmark, in 2020, 97 out of 100 families had internet access in their homes (83), and devices such as smart phones and tablets make it possible to access the internet outside one's home (84). Likewise, IT (information technology) platforms have been developed, for instance, the Danish KMD VIVA, Skype, and Microsoft Teams, all platforms that can be accessed via apps, e.g., on static computers, tablets, or smart phones, and some of them are also used in a TR set-up (85, 86).

Even though the older members of the population feel challenged when confronted with ICT solutions, a continued growth in internet access is being found in the oldest age group (84, 87).

The digital divide

Prensky et al. describe the digital divide between generations: people born before 1970 are digital immigrants because they first learned to use a computer after they became adults (88). Prensky explains that due to the human brain's plasticity, the brain develops differently in those who grew up using computers, called digital natives, compared to the digital immigrants (88).

When some older people are confronted with new technological solutions, they feel insecure and experience a higher degree of stress and anxiety than do younger generations (89, 90). This might contribute to the explanation why less than 10% of people 65 years or older were online worldwide in 2020 (91).

Digital solutions and eHealth literacy

It may also stress people described as digital immigrants (88) that more and more countries focus on e-Governance solutions in the service of citizens (92). Today in Denmark, it is possible to access medical data through the national health information portal, Sundhed.dk, and it is mandatory for Danes to use digital solutions, e.g., a digital mailbox in connection with written inquiries to the public authorities. However, citizens who cannot use the digital self-service solutions are still allowed to receive post by surface mail (93). The largest proportion who deselect these ICT solutions are found among the oldest citizens, 30% in the age range between 75 to 84 years and 62% of those aged 85 years and up (94).

Older people are not only confronted with e-Governance solutions, but the concept eHealth solutions is also gaining more and more ground. WHO defines eHealth as “the use of information and communication technologies for health and health related fields" (95). As a spin-off of eHealth solutions, the concept eHealth literacy has emerged and is defined by Norman and Skinner as "the ability to seek, find, understand, and appraise health information from electronic sources and apply the knowledge gained to addressing or solving a health problem" (96). Norman and Skinner state that if people are to benefit from using eHealth solutions, it is necessary to reduce the gap between the solutions offered and the digital preconditions people have for using them. (96).

Digital literacy

Digital or technological literacy are included as a prerequisite for optimal eHealth literacy, and Karnoe et al. describe the term as referring to the degree to which users of solutions involving computers feel familiar and confident in the use of the devices, and furthermore, the degree of their incentive for engaging with computer use (97). Karnoe et al. have developed a tool that is capable of measuring digital literacy and can therefore be used to screen for eligibility in eHealth projects (97). Such projects could, for instance, be a TR intervention.

Some older computer users are in need of technology support to establish which technologies are currently on the market and how to use the technology devices. This support could be a professional IT supporter, a friend, a family member, or a caregiver, who may also provide help with ongoing computer problems (98, 99).

Survey on computer prevalence and digital literacy among geriatric in- and outpatients

We chose to conduct a questionnaire survey in a cross-sectional study design. We included consecutively all patients referred to a Danish geriatric speciality including both inpatients and outpatients. The outpatients were referred to a geriatric fall clinic. We selected both patient groups for the purpose of increasing the generalisability of the study. First, we investigated the prevalence of computer users and whether computer use was associated with age, sex, level of education, functional capacity, and frailty. Next, we examined digital literacy of geriatric computer users and the association between digital literacy and the frequency of internet use and stress levels. Examination of digital literacy among computer users was based on the results from our feasibility study because several computer users expressed that they declined to participate in the TR intervention because they felt insufficiently digitally literate. First, a literature search was done.

Literature review of digital skills

Another systematic literature search was performed in January 2022 in the databases PubMed, Embase, and Cinahl to answer the research question "Do personal characteristics such as age, sex, educational level, and living status impact digital literacy". Since there is a constant development in the proportion who use computers and more are expected to become more familiar with computer use, we chose to limit the search to articles published within the last 10 years.

The following MeSH terms were used: Aged, Sex, Geriatrics, Older people, Elderly, Frail Elderly, and Computer use, Internet use, Digital literacy, Digital literacy older, Digital literacy elderly, Digital literacy assessment, Computer skills, Computer literacy, Technological literacy, Internet literacy, Digital inclusion.

As in the first literature search, we accepted studies of participants with a mean- or median age of 70 years or more and a standard deviation in which the youngest participants were no less than 65 years of age.

Limits: last 10 years, humans, feasibility and pilot studies, clinical trials, controlled clinical trials, meta-analysis, multicentre study, randomised controlled trials, non-randomised trials, feasibility studies, pilot studies, abstracts [text].

The studies in the literature review are arranged by year, with the most recent studies first.

Table 2 literature review of digital skills

Study		**Population**		**Sample size** (N)	**Description**	**Results**
Author, year, Country, Title	Design, year of data collection	Mean age or Medium age years (±SD)	Recruited from			
Lee et al., 2021 USA *Understanding the Uptake of Digital Technologies for Health-Related Purposes in Frail Older Adults*	Survey Data collected in 2014–15	From 65 to 90 years	"Kaiser Permanente Northern California health plan"	Frail (*n* = 647), non-frail (*n* = 3,904).	Internet technologies and preferred modalities were examined among frail and non-frail older adults to obtain health information and advice for future health initiatives according to virtual care.	Frail older adults were less likely to have technology devises and use online health resources.
Arcury TA, et al. 2020 *Older Adult Internet Use and eHealth Literacy Questionnaire*	Survey Data collected in 2014–16	55 years and older 15% were 70 years or older	Patients at clinics serving low-income populations	200	Examine internet use and personal characteristics associated with internet use, eHealth literacy levels, and associated factors.	Fifty-three percent used the internet. Those less than age 65 years used the internet more. 75.9% experienced stress when using a computer. Those higher educated and those who were married were more likely internet users. Internet use did not differ by sex.
Alam et al., 2019, Australia *Determinants of access to eHealth services in regional Australia*	Survey Data collected in 2016	Sixteen percent of the participants were 65 years or older	Participants from remote, rural and regional areas	390	Access to eHealth services was examined in relation to, among other factors, sex, age, educational level, digital literacy, and computer and internet access hours spent on computer and internet.	Only 10% had internet access among those aged ≥ 65 years. Factors influencing eHealth services were medium-sized households, socioeconomically disadvantaged households, broadband access, adequate digital literacy, but these factors were not assessed by age groups.
Estacio et al., 2019, England *The digital divide: Examining socio-demographic factors associated*	Survey	Age groups: 27% aged18–34 years, 46% aged 35–64 years, and 27% aged ≥65years	Community dwelling adults	1046	The study examined: "the relationship between health literacy and the use of the internet to seek health information"? And "the socio-demographic characteristics of people who use the internet to seek health information"?	Among those 65 years or older, only 15% had internet access and only 11% used the internet for health information

with health literacy, access and use of internet to seek health information	Data collected in 2013					
Lesauskaite et al. 2019, Lithuania *Older Adults-Potential Users of Technologies*	Survey Data collected in 2017	Geriatric in-patients mean age 78.2 (±9.3) Community dwellers mean age 69.6 (±5.6)	Geriatric inpatients community-dwelling persons "attending Third Age University"	375 123 in-patient 278 commu-nity-dwellers	Examine the use of technologies that help older people to stay longer at home and whether they are capable of using them. Data from the geriatric inpatients were compared with data from citizens living in the community Education was divided into university level or less than university level	Community dwellers used, cell phones, computers, and the internet more often than geriatric in-patients, and they were more prone to use the new technologies than geriatric in-patients. In contrast to community dwellers, education level and sex did not influence computer use among geriatric inpatients.
Houwelingen et al., 2018, The Netherlands *Understanding Older People's Readiness for Receiving Telehealth: Mixed-Method Study*	Mixed-Method Study 1) a cross-sectional survey 2) Qualitative observations Data collected in 2012	Median age, 70	Community dwelling older people	256	The survey investigated the "intention to use videoconferencing" and the responders' capacities for using digital technology in daily life.	Fourteen percent had experiences with using videoconferencing. The intent to use videoconferencing depends on expectations of usefulness of the application, if it is easy to use, and confidence concerning privacy and security Digital literacy and self-efficacy dominated the use of technology and to overcome barriers.
Kärenen et al. 2017, Finland *Use of Information and Communication Technologies Among Older People With and Without Frailty*	Survey Data collected in 2015	Aged 65 or older	Older people with and without frailty	794	Compared the frail, prefrail, and nonfrail senior citizens regarding use of internet or smartphones and tablet computers and attitudes towards the use of advanced mobile devices.	The frailer a person was, the less likely they were to have an internet connection.

Berner et al. 2015, Sweden *Factors influencing Internet usage in older adults (65 years and above) living in rural and urban Sweden*	A cross-sectional sample Data collected from 2001–04	Mean age: 73 years	Older persons living in large to midsize cities and rural Sweden	7181	Investigated differences between country and city dwellers in internet use according to age, education, sex, household economy, cognition, living alone/or with someone.	Country dwellers used the internet less than city dweller. For city dwellers, higher education level, living with someone, and good cognitive function were factors that influenced their internet use.
Levy et al, 2014, USA *Health Literacy and the Digital Divide Among Older Americans*	A survey Data collected from 2009–10	Three age groups: 65–69.9 70-74.9 ≥ 75	General population of community dwelling adults.	Total = 2408 General population (n = 824) Internet users (*n* = 1,584)	Compared users and non-users of the internet and for what?	Those aged 75 years or older, education lower than high school, and those with impaired cognition were less likely to use the internet. Among users, the study found that those with low health literacy used the internet less for health information.
Choi & Di Nitto, 2013, USA *The Digital Divide Among Low-Income Homebound Older Adults*	A survey Data collected from 2012–13	78% were 60+ years Mean age (±SD) 76.6 (9.8) The data were collected in 2009 and 2010	Home-bound, low-income, and disabled recipients of home-delivered meals.	980	eHealth literacy, internet use patterns, and attitudes towards computer/internet were compared between people < 60 years and people ≥ 60 years. The survey was targeted current users, previous users, and never users.	Sixty percent of the total responders had never used the internet. Twenty percent had previously used the internet, and 20% used it currently. Thirty-four percent of those <60 years and 17% of those ≥60 years used the internet, Cost and disability were some of the reasons for discontinuing. Those of higher age had lower perceived eHealth self-efficacy.
Berner et al. 2013, Sweden *Factors associated with change in Internet usage of Swedish older adults*	A longitudinal study, interviews, medical examinations and supplementary questionnaires Data collected from 2004–10	There were 10 age cohorts from the age of 60 to 96 years, mean age 75 years. Follow-up every 6 years	Older people in Sweden.	1402 Participants	Investigated who started to use the internet over a period of 6 years. Cognition, extraversion, openness, functional disability, household economy, sex, age, and education were investigated in relation to starting to use the internet	Factors such as higher cognition, being male, and between the ages of 60 and 80 years were determining factors in starting to use the internet. The results indicate that the oldest adults (81–96 years) are slow to adapt to internet use and more attention should be paid to how to support this group.

Summary of literature review of digital skills

The search produced a total of 409 hits, and additional references were applied through a hand search in relevant papers including the reference lists of reviews and systematic reviews. Eleven studies fulfilled the criteria for the review. The studies were a combination of self-reported questionnaires and face-to-face or telephone surveys. All studies were published within the last ten years but more studies used data from before 2010.

The purposes of the studies were different, for example, internet habits (100), choice of electronic devices (100), eHealth literacy (90, 101, 102), and factors that influenced access to eHealth services (103). One study examined the intention to use videoconferencing (104) and one study compared the use of technologies among geriatric inpatients and community dwellers (100).

The studies revealed that those of higher age had lower perceived eHealth self-efficacy. Among computer/internet users, low health literacy and higher frailty level predicted significantly less use of the internet for medical or health information (98, 105). One study found that more than two-thirds experienced stress when using a computer (90).

The intent to use videoconferencing depended on expectations of usefulness of the application and how easy it was to use (104).

Self-efficacy and digital literacy appeared to be the most important themes that played a role in their use of technology and overcoming barriers. No studies investigated digital literacy among geriatric in- and outpatients.

Summary of background

Immobilisation in connection with illness and hospitalisation may lead to sarcopenia and frailty and hence loss of functional capacity. Physical exercises can prevent these negative outcomes. Transportation to and from the training centre can be resource-demanding for the patients and the society. Thus, TR may be an opportunity to achieve qualified training at home.

RCTs have found positive effects on functional status, fall risk, and self-efficacy. Only few experimental TR studies are conducted among persons 70 years or older, and no studies including frail geriatric inpatients discharged after a short hospitalisation were found. However, it proved impossible to recruit geriatric patients for a TR study. In preparation for future TR interventions, we therefore changed the study plan to focus on feasibility, barriers, and computer skills among geriatric patients.

The literature review indicates which factors might influence older peoples' digital literacy and how this affects their use of eHealth services, but no studies investigate specifically digital literacy among geriatric patients.

Aims and hypothesis

The overall aim of this PhD study was first of all to investigate the effect of TR in geriatric patients with reduced functioning just after an acute admission and short hospital stay. A total of 333 patients were screened for eligibility. Only 33 fulfilled the inclusion criteria and only 2 of them consented to participate. This negative result led to a revision of our overall aim and instead to study the feasibility and potential barriers for participating in TR offered to geriatric patients.

Objective - Study 1

To examine the feasibility of providing TR as home exercises in a population of geriatric patients after acute hospitalisation.

Hypothesis: It is feasible to conduct TR in groups as home exercises to geriatric patients after acute hospitalisation

Objective - Study 2

To examine whether it is at all possible to do TR as home exercise in geriatric patients and at the same time describe the digital literacy, the TR intervention, and the pedagogical initiative in a small non-randomised sample of TR users.

Objective - Study 3

To examine the prevalence of computer users in a population of geriatric patients and to study whether there are any associations with age, sex, level of education, living status, state of frailty, and dwelling status.

Hypothesis: The prevalence of computer and internet use is associated with younger age, male sex, lower state of frailty, higher level of education, living with someone, and living outside an institution

Objective - Study 4

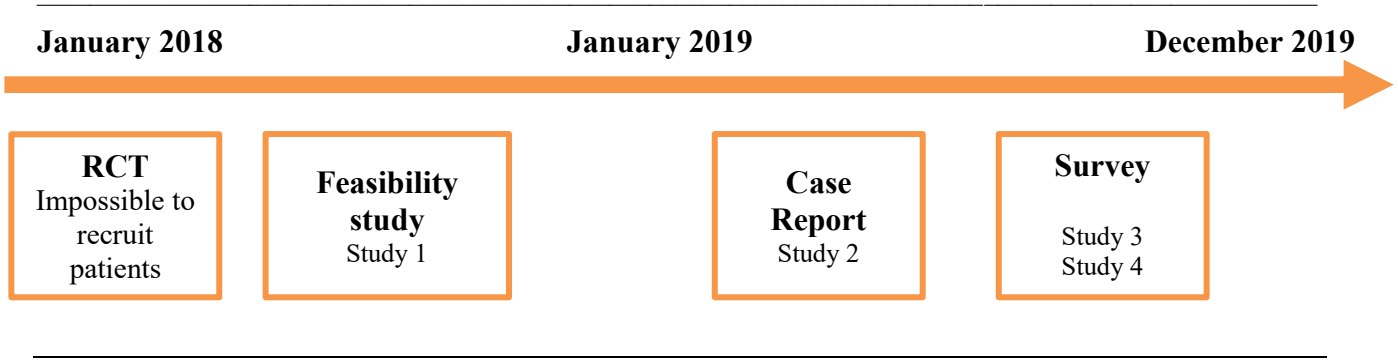
To examine geriatric in- and outpatient's computer habits and digital literacy, and to study whether there are any associations between digital literacy and frequency of internet use and level of stress

Hypothesis: Geriatric in- and outpatients' digital literacy is associated with level of stress and frequency of internet use.

Methods

This chapter is structured by reviewing the four studies separately. The figure 5 shows the four studies time line for recruitment and inclusion.

Figure 5. Time table of the periods of recruitment and inclusion of patients for the PhD study



Study 1

A group-based real-time videoconferencing tele-rehabilitation programme in recently discharged geriatric patients (51)

During our attempts to recruit acutely admitted medical and surgical geriatric patients for the RCT, we counted the number of eligible patients, those who agreed to participate and those who declined. In addition, we took the opportunity to interview eligible patients to examine why they refused to participate in the TR intervention. Both the quantitative and the qualitative part were used in the feasibility study, Study 1.

Design

The design was a feasibility study describing the flow of patients and reasons for exclusions. A part of the study included a qualitative study design using a structured interview method. This design was based on the methods described by Brinkmann and Kvale, and Kumar (106, 107).

Patients

The study was divided into two periods. The first period ran from 15 March to 16 May 2018. During this period only acutely admitted medical patients were included. A second period ran from 1 September to 8 November 2018 in which also hip-fracture patients were included in order to reach a higher number of patients. The in- and exclusion criteria were similar in the two periods.

Inclusion criteria

65+ years, living in the municipality of Aarhus, users of all kinds of walking aids at discharge, and computer users before hospitalisation. Furthermore, it should be possible to achieve a stable internet connection in the patient's home.

Exclusion criteria

Terminal illness, unable to speak and understand Danish, a diagnosis of dementia or a score in Short Portable Mental Status Questionnaire (SPMSQ) (108) above 4, a great fall risk when completing the Otago Exercise Programme, and suffering from acute stroke.

Data collection

During the two inclusion periods, we counted the total number of patients screened for eligibility. Hereafter, we counted eligible patients and patients that did not meet the inclusion criteria. Reasons for exclusion according to the exclusion criteria were noted. Among those who were eligible, we interviewed 17 patients out of a total number of 33. In order to avoid a low response rate among this population, we chose a structured interview form by posing the responders one identical preliminary question: "whether the patients would like to describe 'the challenges and/or barriers to participate in this TR project'". Hereafter they were asked for an example or if they could elaborate the answers.

The interviewer's task was to facilitate the interview while being as neutral to questions and answers as possible. All the answers were written down on a laptop. We first analysed the answers, next they were condensed, and finally they were separated into three themes. When answer saturation was reached, we assumed that there was a sufficient number of responders in the study.

The Department of Geriatrics has two wards. All patients stay in single rooms, and it was here the interviews were conducted. If the patients were discharged, the interviews were conducted in the patients' own homes or by telephone. In total, nine patients had an interview at the hospital, three in their own homes, and five via telephone.

Outcome measures

Primary outcome

- number of patients eligible to participate in a TR intervention and reasons for exclusion

Secondary outcome

- challenges and/or barriers to participation in the TR intervention

We described the patients according to age, sex, level of education, living status, functional capacity, and frailty.

Education level was categorised using a combination of the Danish educational system before 1958[1] (109) and those who had a vocational education, e.g., carpenter, mechanic, baker, or butcher. This was done in order to nuance education levels. We therefore divided education into Level 1: Patients who finished 7th grade. Level 2: Patients who finished 8th to 10th grade. Level 3: Patients, professionally trained, and Level 4: Patients who finished high school or had a higher education.
Living status was categorised into living alone or living with someone (spouse, partner, next of kin).
Dwelling status was categorised into living in own home, in sheltered home, or living in an institution.
Functional capacity: We assessed that the Functional Recovery Score (FRS) (see Appendix 2) was the measurement tool that came closest to cover ICF's domains in relation to our target group (110). ICF describes two domains "*These domains are classified from body, individual and societal perspectives by means of two lists: a list of body functions and structure, and a list of domains of activity and participation"* (58).
For measuring *State of frailty*, we chose the Multidimensional Prognostic Index (MPI) (Appendix 2) (111).

Ethical considerations

In accordance with the Committees on Health Research Ethics, Health Science Questionnaire surveys and interview surveys, written informed consent was not required (112). The patients gave oral informed consent. The feasibility study was approved by the Danish Data Protection Agency (1-16-02-201-17).

Statistical methods

Power calculations

By default, we made a power calculation for the originally planned RCT which resulted in a total of 129 participants needed. For the subsequently feasibility study, we used the data from the planned RCT study to describe the population. Therefore, we did not make any specific power calculation in Study 1. Regarded the qualitative part of Study 1, sufficient power was reached by obtaining

[1] "During the 1960s, it became common for classes to remain undivided after 5th grade, and for students to continue schooling beyond the compulsory education" 109.Holm-Larsen SR, Uffe; Skovgaard-Petersen, Vagn,. Dansk skolehistorie: Den Store Danske på lex.dk; 2016 [updated 05-12-2016. Available from: https://denstoredanske.lex.dk/dansk_skolehistorie#-P%C3%A5_vej_mod_en_enhedsskole_(1903-58)..

theoretical saturation. Saturation was achieved when answers were already stated by former respondents.

Statistical analysis

A descriptive analysis of all 33 eligible patients and the 17 interviewed patients was made separately to summarise patients' characteristics expressed as means and standard deviations (SD) or numbers and percentages. These data were normally distributed.

Study 2

Tele-rehabilitation in community-dwelling older people with reduced functional capacity- a four-person case report

Design

The design was a case report study

Patients

For the case report, we recruited a non-randomised sample of four patients. Two patients from a geriatric fall clinic at Aarhus University hospital and two from a rehabilitation centre for older people in the municipality of Aarhus, Denmark. These four patients were not recruited from the planned RCT, but all received a geriatric medical intervention.

Inclusion criteria

Affiliated with a geriatric subspecialty, were computer users, had a physical functional decline within the last year, and scored less than 4 errors in the SPMSQ.

Exclusion Criteria

Terminal illness, unable to speak and understand Danish, fall risk when completing the Otago Exercise Programme.

Data Collection

All four patients' personal characteristics were described individually according to age and sex, living status, diagnoses, education level, and place of recruitment.

Before start-up of the TR intervention, all four participants had their digital literacy measured by using the electronic Health Literacy Assessment (eHLA) questionnaire. The eHLA is suitable for screening purposes in projects involving telehealth solutions; of note, the eHLA consists of four health-related tools and a digital part consisting of three tools. By contacting the authors, we were told that all or parts of the seven scales of the eHLA could be used (97). We chose to use the digital part of eHLA only, which covered the questions we wanted answered according to computer and tablet usage (Appendix II).

Both before and after the 8-week training period, the participants' functional capacity was measured by using the FRS (110, 113) and the De Morton Mobility Index (DEMMI) (114) and fear of falling was measured by the Falls Efficacy Scale-International (FES-I) (115). All four patients were scored both before start of the intervention and again after the 8-week training intervention. For detailed

descriptions of the measurements, see Appendix 2. These measurements were assessed by two trained therapists.

We measured the number of home visits and adherence to the intervention according to attendance during the TR sessions, as registered in the Electronic Health Record (EHR). The EHR also recorded whether the patients participated in a group or individual training session, as well as the number of falls during the intervention period.

TR intervention

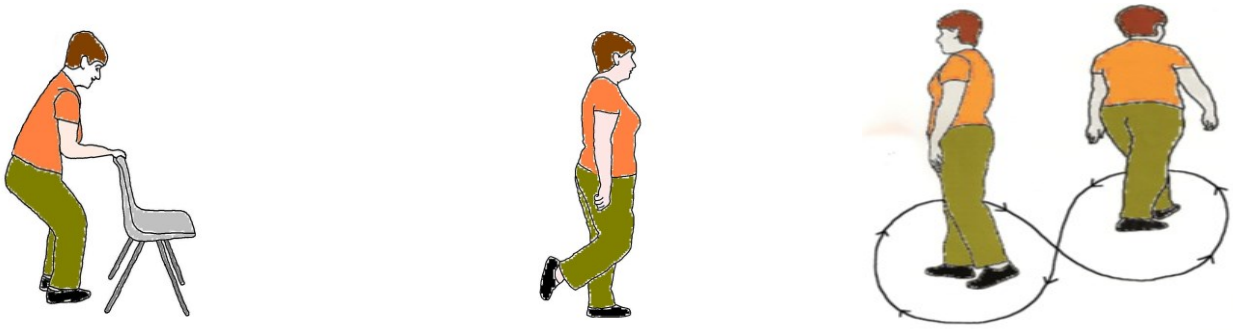
The patients had installed a computer with a 21 inches' computer screen, an extern camera, and extern microphone/ loudspeaker (Fig 6). The TR itself was conducted via an internet-based, real-time video conference system (85). The system used was the same TR system as was originally planned for the RCT study. For a more detailed description, see Appendix 2.

Figure 6. Electronic equipment used in the TR intervention

The physiotherapist used the same equipment as that installed in the patients' homes

We strived to conduct the group exercises with three people but also accepted pairs of two. We used the Otago exercise Programme – a home-based balance and strength exercise programme (Fig 7). (Appendix 2 for a more detailed description) (116).

Figure 7. Examples of the Otago exercises used in the TR intervention



Outcome measures

- Computer users who are able to participate in a TR intervention
- Level of digital literacy
- The pedagogical initiative needed
- Number of home visits, individual and group sessions, and adherence to the TR intervention
- Change in physical functional capacity and fear of falling after cessation of the TR intervention

Ethical considerations

The case report was approved by the Central Denmark Region Committees on Health Research Ethics (1-10-72-394-17) and by the Danish Data Protection Agency (1-16-02-201-17). Participants that gave written informed consent were informed that they could withdraw at any time. The communication that took place during the TR intervention between patients and therapist was carried out over the internet using a secure system.

Statistical methods

Power calculation

No power calculation was made in this case report.

Statistical analysis

The four patients' personal characteristics were described individually in the text. They were scored in FRS, DEMMI, and FES-I before the intervention, and these measurements were repeated after the 8-week TR intervention and presented separately. An individual and overall mean score in the eHLA questionnaire was found by first adding the scores within each item and then dividing the number of questions within each item. Numbers of home visits, individual and group training sessions, and number of falls during the intervention period were counted and presented for each participant as registered in the EHR.

Study 3

Prevalence of computer users among geriatric in- and out patients

Design

A survey conducted in a cross-sectional study design.

Patients

Patients were consecutively included from a geriatric outpatient fall clinic and from the two geriatric wards at Aarhus University Hospital. The study period ran from 1 October to 1 December 2019.

Inclusion criteria

Cognitive well-functioning in- and outpatients referred to two wards and a fall clinic at the Department of Geriatric, Aarhus University Hospital.

Exclusion criteria

The patients were excluded if they had a score of 4 or more errors in the SPMSQ, indicating impaired cognitive function. Patients who already had a diagnosis of dementia stated in their hospital journal were excluded from the study without being scored according to the SPMSQ.

Data collection

To ensure high validity, the questionnaire survey was conducted by two trained interviewers. Based on experiences from other studies (89, 105, 117) and our own RCT (51), we were worried about a low response rate especially among the frailest patients. Therefore, we chose to read aloud all questions for the patient and fill in the answers from the patient in the questionnaire.

The interviewers reviewed the first respondents together to address any doubts or anything else that could affect the answers. It took about 20 minutes to complete each interview. All hospitalised patients stayed in single rooms, where the interview took place. For the patients in the fall clinic, only the patient and the surveyor were present in the room. Patients visiting only the ED (emergency department) were contacted the first week after discharge and asked if they were willing to participate in the survey. Hereafter an appointment was made. These interviews were made by telephone.

Patient characteristics and the choice of outcome measures were chosen beforehand based on characteristics of the geriatric patient according to the literature. Information about age, sex, education level, living status, dwelling status, functional status, cognitive impairment, frailty level, prescribed medication, home help, and use of a walking aid was retrieved from the EHR. Education level, living status, dwelling status, functional capacity, and state of frailty were described as in Study 1.

Information about computer and internet use was collected from the patients by asking: “Do you occasionally use a computer?” and “Do you occasionally use the internet?”
Although we chose to ask for "computer use" first and then "internet use", we used the total number of 124 computer users in the analyses and not just the 120 who were internet users. We made that choice even though most comparative studies are described based on the use of the internet. Our aim was to investigate how many geriatric patients were potentially to be included in a TR intervention, and we assessed that the responders were able to use a computer even though they were not internet users.
We categorised the number of individual devices as desktop and/or laptop computers, tablets, fixed net phone, mobile phone, and smart phone, with a yes/no answer possible. *Cognitive impairment* was measured by the SPMSQ as described in Study 1 (118).

Outcome measures

Primary outcome

- The prevalence of computer users in geriatric in- and outpatients

Secondary outcome

- Associations between computer use and age, sex, education level, living status, state of frailty, and dwelling status

Ethical considerations

The survey questionnaire was approved by the Danish Data Protection (1-16-02-201-17). The patients gave oral consent and were informed that they could decline to respond to the questionnaire at any time. The study was a quality development project for which background data were already collected in connection with another project in the department (111).

Statistical Methods

Power calculations

A power analysis was performed to calculate the sample size for the survey based on data from Statistics Denmark; 92% of people aged 65–74 and 71% of people aged 75–89 years used the internet occasionally in 2019. This analysis resulted in a sample needed of 158 respondents. To achieve a valid sample size for a two-sample comparison and to obtain a sufficient number for the adjusted analysis, another 10% were added per variable, resulting in a total of 248 patients for a significance level of 0.05 and a power of 90% (119).

Statistical Analysis

To summarise the respondents' characteristics, a descriptive analysis was performed, expressed as means and SDs or numbers and percentages. For normally distributed data, the differences between users and non-users of computer/internet were analysed by using Student's *t*-test for normally distributed data, expressed as means and SDs, and the Wilcoxon rank-sum test for non-normally distributed data, expressed as medians and interquartile ranges (IQRs). A chi-square test was used to analyse categorical variables, including dichotomous variables expressed as both numbers and percentages.

By using a logistic regression model, we evaluate associations between baseline characteristics and participants' use of computer/internet. Hereafter, we mutually adjusted for explanatory variables that were considered confounders: age, sex, level of education, living status, frailty, and dwelling status. The model was checked for interactions between the variables, and no interactions were found. The results were presented as odds ratios (ORs) with 95% confidence intervals (95% CIs). Hosmer–Lemeshow test was used to assess the logistic regression model's goodness of fit. All tests were two-sided and performed at a significance level of 0.05 and a power of 0.90. We stored all data in RedCap(120) and for the statistical analysis we used Stata version 17.

Study 4

Computer habits and digital literacy in geriatric patients- a survey

Design

Study 4 is a survey conducted in a cross-sectional study design – a part of the Study 3 questionnaire survey.

Patients

Patients were restricted to only computer users found in Study 3.

Inclusion criteria

The inclusion criteria are as described in Study 3.

Exclusion criteria

The exclusion criteria are as described in Study 3.

Data collection

Baseline characteristics as described in Study 3.

To gather information about digital literacy, we used the digital part of the eHLA questionnaire (Appendix 2) (97). (Copy from Paper 4):

Stress level when using a computer and the internet. Stress was measured following Arcury et al. (90) and divided into five levels ranging from no stress to very high stress.

Internet use frequency was categorised following Arcury et al. (90) into three groups: never, less than once a day, and at least once a day.

Number of computers, tablets, landline phones, feature phones, and smartphones.

Computer help was categorised into no help and help from a spouse/cohabitant, children/grandchildren, friends/acquaintances, or professional IT staff.

Searching the internet, for example, for news, health information, YouTube, search engines (e.g., Google or Bing), games, and recipes. All items were in the form of yes/no questions.

Digital services, e.g., internet banking or patients' digital mailbox (e-boks), a Danish national email service. All items were in the form of yes/no questions.

Social networking, e.g., Facebook, Instagram, Skype, and Face time. All items were in the form of yes/no questions.

Outcome measures

Primary outcome

- Computer habits and digital literacy and the association between digital literacy and level of stress and frequency of internet use

Secondary outcome

- Association between digital literacy and frequency of internet use and stress levels

Ethical considerations

See ethical considerations in Study 3

Statistical methods

Power Calculation

The number of responders in Study 4 was based on the number of computer users found in Study 3, resulting in a total of 124 responders.

Statistical analysis

We described the respondents' personal characteristics, computer and internet habits, computer assistance, and use of electronic devices as means and as SDs for continuous variables and frequencies and percentages for categorical variables. The three digital questions in the eHLA questionnaire were presented as described in Study 2 by "first as means, adding the scores within the single item and then dividing the total score by the number of questions used in the single item". We used a linear regression analysis to investigate associations between technology familiarity, technology confidence, and incentives for engaging with technology and levels of stress and internet use frequency stratified by sex. The analysis was mutually adjusted for age, sex, frailty, education, living status, and dwelling status, and hereafter we examined the model for confounding and effect modification. All data were stored in REDCap (120), and analyses were made in Stata version 17.

Results

We found that inclusion of geriatric patients in a TR study is difficult. We, therefore, examined the feasibility and barriers for this in four studies.

Study 1

A group-based real-time videoconferencing tele-rehabilitation programme in recently discharged geriatric patients (51)

Only two patients out of 33 who fulfilled the inclusion criteria consented to participate. The most important barriers in this feasibility study (51) we uncovered were exhaustion after discharge from an acute hospitalisation and lack of computer skills.

Ninety percent were excluded on the basis of the chosen exclusion criteria, with reduced cognitive function as the dominating factor. We found that 42 patients (14%) did not use a computer (Fig. 8), but patients excluded for other reasons were not subsequently investigated regarding whether they had a computer at home. The prevalence of computer users was further examined in Study 3.

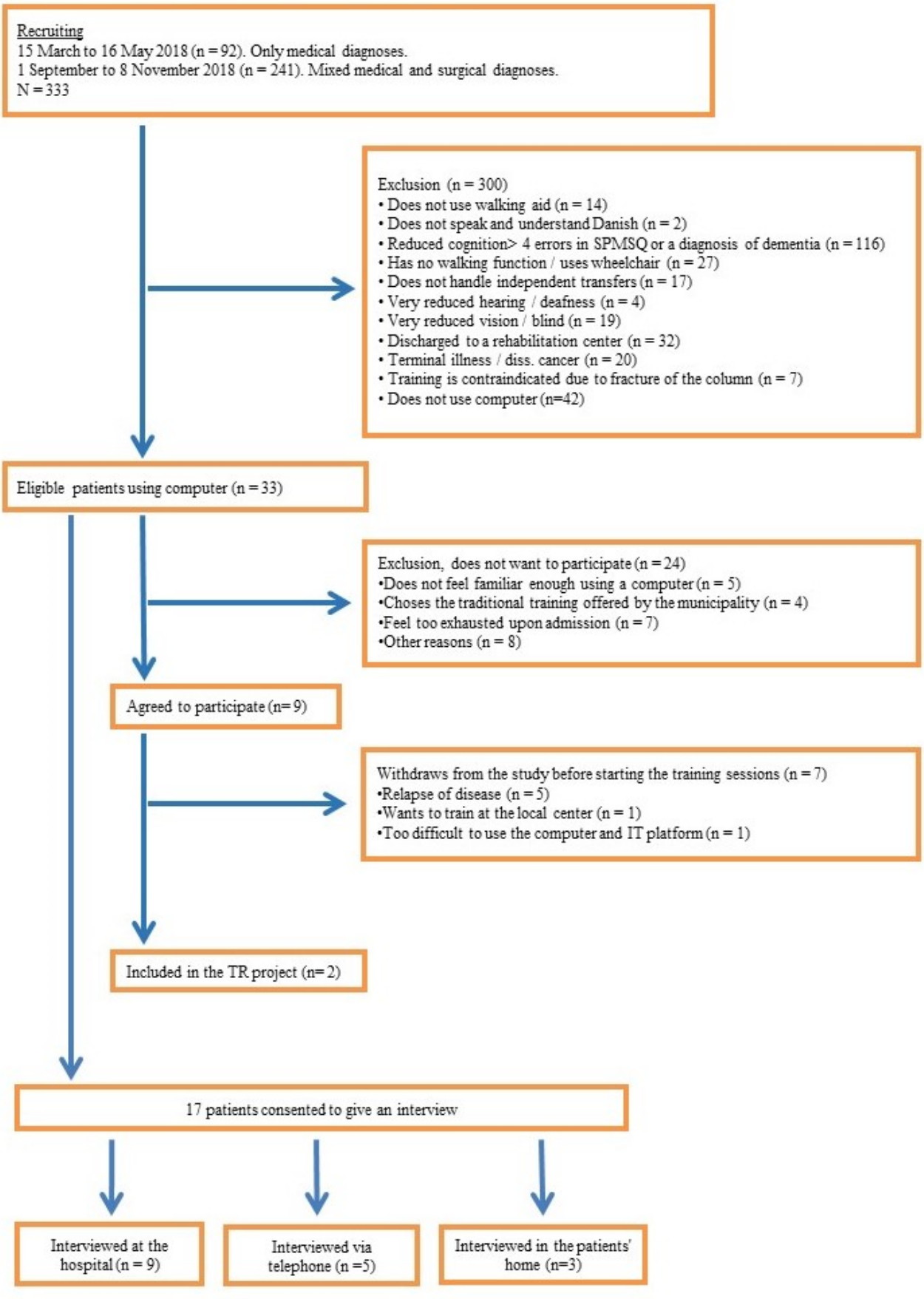
Three specific terms describing barriers for not participating in a TR intervention

After having analysed, condensed, and separated the 17 interviews of the 33 patients, we ended up with three specific terms as reasons for not participating in the TR intervention. Apart from exhaustion after an acute hospitalisation, the next most used explanation was that even though they were computer users, they did not feel that their digital literacy was sufficient to use the computer applications. The third most expressed reason was that some chose the traditional training offer. Other explanations were that one found his apartment too small for exercising, another found it difficult to exercise at scheduled times (51) .

Thus, exhaustion and digital literacy were statements that became crucial to the choices we made as a next step to study in this PhD study.

Digital familiarity was further examined in Study 4

Figure 8. Flowchart of patient selection for the feasibility study 1



As seen in Table 3 even though the 9 patients who in the first place consented to participate seemed to be older, less frail, living with someone, and had an education level of high school or higher they did not differ significantly from the whole group of the 33 eligible patients and the 24 patients who declined to participate.

Table 3. Patient characteristics of 33 eligible patients from the feasibility study

Characteristics	***Patients total N=33***	***Declined to participate n=24***	***Consented to participate n=9***	***P-values***
Age mean (±SD)	82.3 (±7.8)	81.3 (±7.6)	85.1 (±8.0)	0.21
Female	25 (76)	20 (83)	5 (56)	0.10
Living with someone	16 (49)	10 (42)	6 (67)	0.41
FRS mean (±SD)	58.5 (18)	57.4 (16)	61.2 (25)	0.61
Education level, n=32				
Finish seven grade	16 (49)	13 (54)	3 (33)	
Finish 8 to 10 grade	10 (30)	6 (26)	4 (44)	
Trained workers	2 (6)	2 (8)	0	
High school/ higher education	4 (12)	2 (8)	2 (22)	0.37
Frailty level, n=32				
Non frail	10 (30)	5 (21)	5 (56)	
Moderately frail	20 (61)	16 (67)	4 (44)	
Severely frail	2 (6)	2 (8)	0 (0)	0.15

FRS= Functional Recovery Score, (max 100 points)

Seventeen patients were interviewed, and a data saturation was achieved corresponding 55% of the total number of 33 patients (Table 4). The interviewed 17 patients were younger than the total population of 33 patients (Table 4).

Table 4. Patient characteristics of interviewed patients in the feasibility study

Characteristics	***Patients total*** **n=17**
Age, mean (SD)	78.3 (6.2)
Female, n (%)	14 (82)
Living with someone, n (%)	6 (40)
FRS, mean (SD)	55.3 (15.0)
Education n(%), n=15	
Finish seven grade	8 (47)
Finish 8 to 10 grade	4 (23)
Trained workers	1 (6)
High school further-higher education	2 (12)
Frailty n(%), n=15	
Non frail	3 (17)
Moderately frail	11 (65)
Severely frail	1 (6)

FRS= Functional Recovery Score (max 100 points)

Study 2

Tele-rehabilitation in community-dwelling older people with reduced functional capacity – a 4-patient Case Report

With this case report, we wanted to describe a TR intervention in geriatric patients supervised by a physiotherapist using a real-time video conferencing system. Four older patients were recruited from either a geriatric fall clinic or a rehabilitation centre for older people and received TR conducted both as individual training sessions and in groups during an 8-week period. We found it was possible to conduct TR in this small non-randomised group of geriatric patients. The four patients were familiar with computer use, when supported with written material, and the study achieved a high adherence by a flexible approach to the training schedule.

Description of the four patients

Patient 1 was an 80-year-old woman. She had a trained worker education and was living alone but referred to the Fall Clinic due to benign paroxysmal positional vertigo (BPPV) and was recruited from the fall clinic. She also suffered from COPD and social anxiety with the consequence that she never joined training sessions at the local community centre for older people. Patient 1 did not use any assistive devices. She first started individual TR training and later joined TR group training.

Patient 2 was an 85-year-old woman. She had a 7th grade education and was cohabiting and had declined functional capacity after a hospital stay. She also suffered from COPD and was on permanent oxygen. Patient 2 used a walker. She was recruited to the present study by the geriatric team from the rehabilitation centre for older people and started individual TR training there. After discharge, Patient 2 continued TR training at her home, first individually and then in a group.

Patient 3 was a 75-year-old woman. She had a higher education level, lived alone, and had undergone surgery for a hip fracture when she was recruited by the geriatric team at the rehabilitation centre for older people. She used a walking frame to get around inside, while outside she used an electric handicap scooter. Shortly after participating in group exercises, Patient 3 went on holiday in Sweden. She brought her tablet, on which she had installed the TR app for this study. Unfortunately, there was no network available where she stayed, so she had to give up TR for a

period of about 2 weeks but continued TR both individually and in groups after returning back home.

Patient 4 was an 80-year-old woman. She had a higher education level and was living alone and referred to the Fall Clinic due to BPPV and was recruited from the fall clinic. She also had a hip fracture the year before the TR intervention. Because of the hip fracture and dizziness, Patient 4 got around using a walker. She was able to drive her car but very afraid of falling. She stopped the training sessions 2 weeks earlier than the planned 8 weeks because of a family event.

Functional assessment, digital literacy and adherence to the training sessions

Due to the low number of participants, it was not possible to make general conclusions about their scores in the selected tests that described their functional capacity. Patient 1 also suffered from BPPV and still received treatment in the Fall Clinic during the 8 weeks that the TR intervention took place. Therefore, dizziness and unsteadiness might explain her lower DEMMI score, both affected by BPPV (Table 5).

Table 5. Baseline and follow-up scores of *FRS, DEMMI, FES-I, **eHLA (Copy from Paper 2)

Patient Number	***FRS baseline***	***FRS follow-up***	***DEMMI baseline***	***DEMMI follow-up***	***FES-I baseline***	***FES-I Follow-up***	***eHLA Technology familiarity (max. 24 p)***	***eHLA Technology confident (max. 16 p)***	***eHLA Incentive for engaging with technology (max. 16 p)***
Patient 1	75	92	85	67	23	29	3.5	3.8	3.8
Patient 2	30	79	49	53	49	23	2.5	3.3	3.3
Patient 3	66	91	53	62	29	19	3.5	4	4
Patient 4	91	91	41	67	25	25	4	3.8	4
Mean							3.4	3.7	3.8

* FRS: Functional Recovery Score (max. 100 points), DEMMI: The De Morton Mobility Index (max. 100 p), FES-I: Falls Efficacy Scale-International. **eHLA: digital literacy assessment toolkit was measured before start of the TR intervention. eHLA was only measured at baseline. eHLA is described in Appendix II.

Adherence to the training sessions

In general, there was a high degree of participation among the four patients, which alternated between individual and group exercises (Table 7). We found it important to retain the participants for the TR intervention. Therefore, if there were days when the patients did not have the opportunity to participate in group exercises at the set times, they were offered individual TR instead (Table 6).

Table 6. Number of home visits by the test therapist, and the distribution of individual and group training sessions

Patient number	***Home visits (n)***	***Individual training sessions (n)***	***Group training sessions (n)***
Patient 1	4	2	14
Patient 2	4	3	11
Patient 3	3	4	10
Patient 4	3	7	9

Information about home visits and individual or group training sessions were retrieved from the HER

Therapeutic intervention and pedagogical initiatives

The physiotherapist first visited two patients in their homes and two at the rehabilitation centre. The two patients at the rehabilitation centre started exercising at the training centre, where the computer devices were installed in their own rooms. They continued training after they were discharged home. In the patients' homes, a computer was installed in a location where the patient and the physiotherapist decided the exercises should take place; for patient number 3, who a few weeks earlier had had hip fracture surgery, the computer was installed in her kitchen, where it was possible to make a sort of parallel bars using two tables. The patients were instructed in the computer's use and were also handed a computer guide containing detailed image illustrations. This written guide was optimised several times based on the patients' feedback.

Changes in therapeutic intervention

Initially, we planned online supervision by a physiotherapist for the first 4 weeks via video conferencing. The last 4 weeks were planned to take place without online supervision and instead run video sessions posted on the IT platform as self-training. It was planned that the patients still met online in their training groups. Unfortunately, we encountered technical problems that prevented sufficient sound levels, so we abandoned the self-training video sessions. Instead, we decided to continue the supervised online training for the last 4 weeks, resulting in a total training duration of 8 weeks and a total of 16 training interventions possible.

Also, we quickly learned that it was difficult to retain patients at pre-planned times in the TR intervention. As described earlier patients had to cancel the TR appointment due to, for instance,

private arrangements, or examination and treatment appointments at the hospital. Therefore, we chose a more flexible approach with both individual and group TR interventions. This case report seems to indicate that it is possible to complete TR in geriatric patients not discharged after an acute hospitalisation and with a certain degree of digital familiarity and by offering flexible training sessions.

Study 3

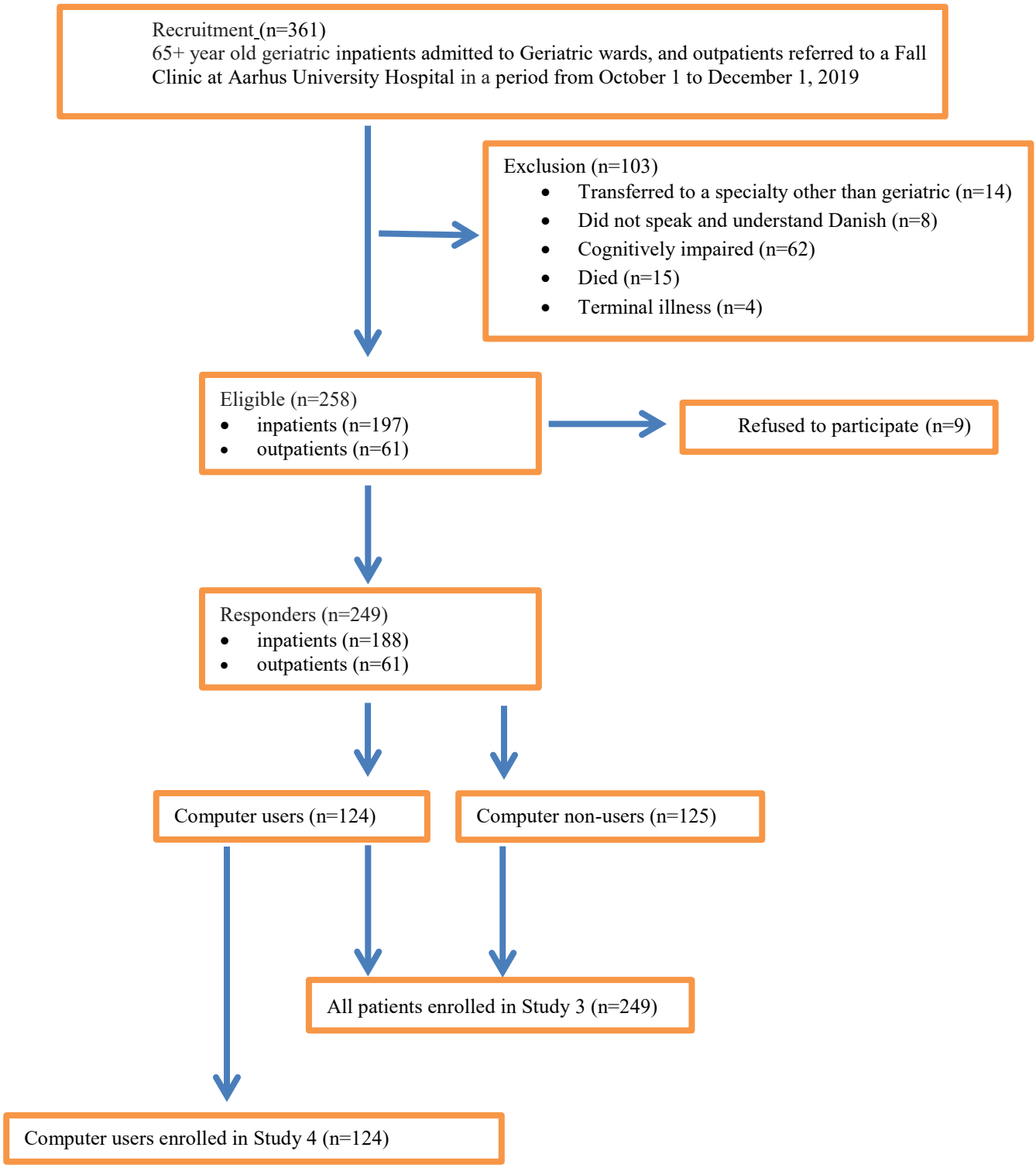
Prevalence of computer users among geriatric in- and outpatients

We found that only half of the geriatric patients were computer users and that computer use was associated with younger age, higher level of education, lower state of frailty, living outside an institution, and higher functional capacity.

Flow of participants

For Study 3, we chose to include all cognitive well-functioning patients referred to the Department of Geriatrics in a questionnaire survey. Therefore, both patients referred to the Geriatric Fall Clinic and acutely ill patients referred to the two Geriatric wards were included. We did that in order to raise the generalisability. We wanted to find the prevalence of computer users and furthermore to determine whether there were any association between computer use and relevant variables.

Figure 9. Flow of questionnaire survey



Influencing factors in computer use

We found that half of the responders, corresponding to 124 patients, were computer users (Fig. 9). The mean age for the whole population of responders was 83.2 (±8.0) years. Computer users were statistically significantly younger than non-users, users having a mean age of 80.5 (±7.5) and non-users a mean age of 85.8 (±7.2) years (Table 7).

The youngest age group was represented by 75% computer users followed by 59% in those aged 75 to 84 years and 33% in the oldest age group. In a logistic regression analysis, we found a reduction in computer use for every year the responders got older after adjustment for sex, education level, dwelling status, living alone/living with someone, and frailty level OR = 0.9 (95% CI: 0.87–0.94; $p < 0.001$).

As seen in Table 7, the study revealed significantly fewer computer users in the age group 85 years or older. No significant difference in computer use was found between the two youngest age groups. For the lowest educated groups, significantly fewer used a computer compared to those with high school or a higher education level. We found no significant difference in computer use between the moderately frail and non-frail groups (Table 7).

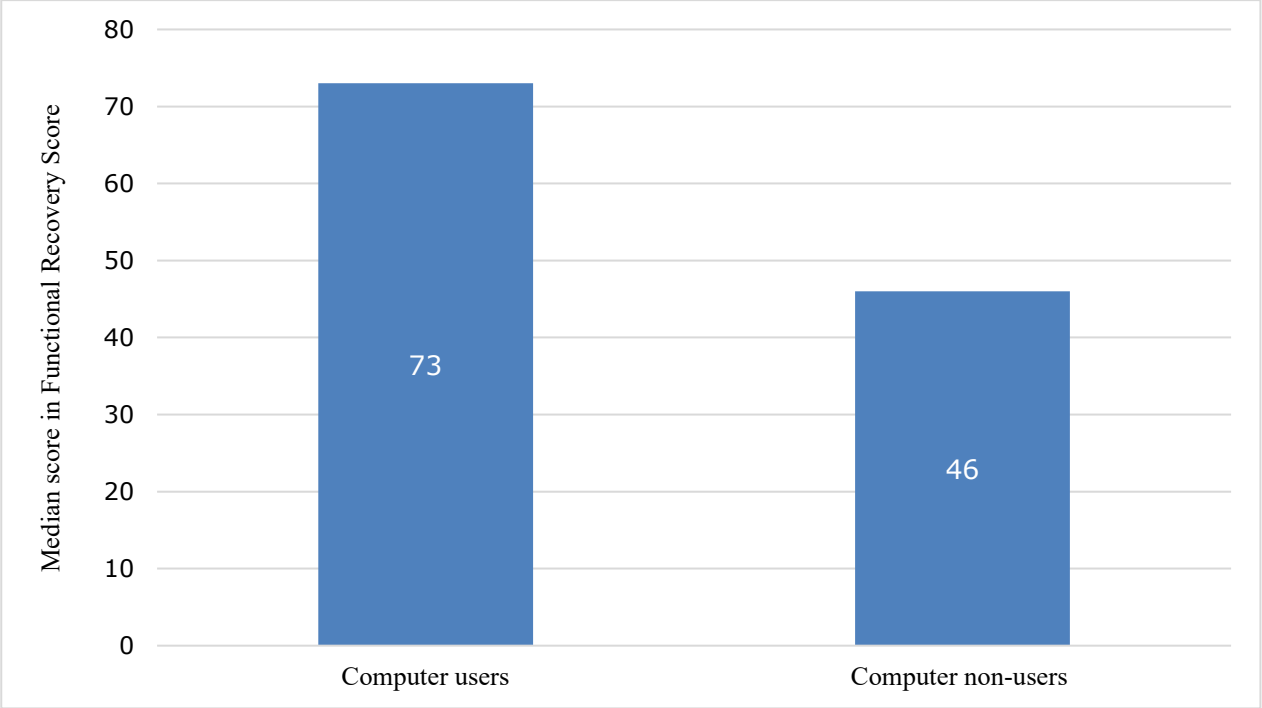
Table 7. Patient characteristics and associations between computer use and state of frailty, age, sex, educational level, and living status (N = 249), (copy from Paper 3) (121)

	Computer use **n (%)**		***Crude OR*** ***95% (CI)***	***p-value***	***Adjusted OR**** ***95% (CI)***	***p-value***
	Users n=124	***Non-users n=125***				
Age groups						
65-74	30 (24)	10 (8)	1.00 (ref)		1.00 (ref)	
75-84	57 (46)	39 (31)	0.49 (0.21-1.11)	.09	0.48 (0.19-1.26)	.14
≥85	37 (30)	76 (61)	0.16 (0.07-0.37)	.001	0.17 (0.07-0.43)	.001
Sex						
Male	52 (42)	50 (40)	1.00 (ref)		1.00 (ref)	
Female	72 (58)	75 (60)	0.92 (0.56-1.53)	.76	1.10 (0.58-2.10)	.76
Level of education, n=247						
High school further-higher education	48 (39)	20 (16)	1.00 (ref)		1.00 (ref)	
Trained worker	30 (24)	18 (15)	0.69 (0.32-1.52)	.36	0.69 (0.28-1.70)	.42
Finished 8 to 10 grade	24 (19)	24 (19)	0.42 (0.19-0.90)	.03	0.34 (0.14-0.86)	.02
Finish seven grade	22 (18)	61 (50)	0.15 (0.07-0.31)	.001	0.14 (0.06-0.32)	.001
Living status						
Living with	51 (41)	34 (27)	1.00 (ref)		1.00 (ref)	
partner/relatives	73 (59)	91 (73)	0.53 (0.31-0.91)	.02	0.98 (0.49-1.90)	.96
Living alone						
State of frailty, n=246						
Non-frail	47 (38)	18 (15)	1.00 (ref)		1.00 (ref)	
Moderately frail	60 (49)	60 (49)	0.38 (0.20-0.73)	.004	0.53 (0.25-1.12)	.10
Severely frail	16 (13)	45 (36)	0.14 (0.06-0.30)	.001	0.19 (0.08-0.49)	.001
Dwelling status						
Own home	113 (91)	94 (75)	1.00 (ref)		1.00 (ref)	
Sheltered home	10 (8)	18 (15)	0.46 (0.2-1.05)	.07	0.79 (0.30-2.06)	.63
Institution	1 (1)	13 (10)	0.06 (0.008-0.50)	.009	0.09 (0.01-0.81)	.03

* adjustments are made for age, sex, level of education, living status, frailty, and dwelling status

As seen in Figure 10, functional capacity measured by the FRS was significantly higher in computer users.

Figure 10. Functional capacity among users and non-users of computer (Copy from Paper 3)



The figure shows that computer users had a median score in FRS of 73 points and non-users had a median score of 46 points in FRS. Functional capacity was significantly higher among computer users than among non-users, $p = 0.001$.

Computer use and functional capacity

We found computer users had a significantly higher functional capacity than the non-users. The mean FRSs of the users and non-users were 69.59 and 51.39, respectively.

To summarize the findings in this prevalence study, half of the geriatric patients were computer users. Computer-users compared to non-users were younger, had a higher functional capacity, were less frail, higher educated, and were living in their own home or in sheltered home.

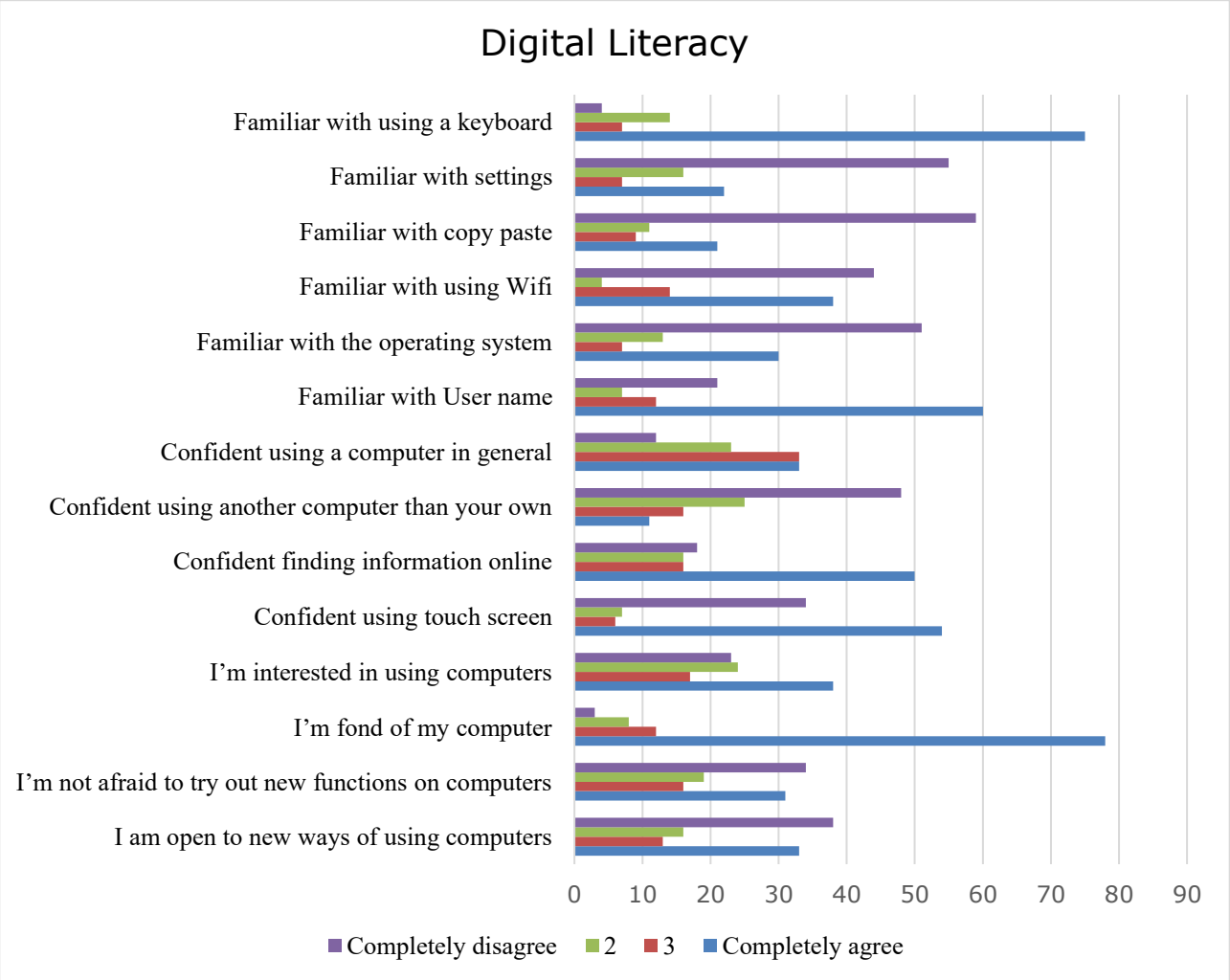
Study 4

Computer habits and digital literacy in geriatric patients

We found that computer users often get help from their children and grandchildren. Furthermore, digital literacy was found to be associated with frequency of internet use, and only men answered that they experienced being stressed when incentives reach a level where they are unable to engage with computer technology.

Figure 11 shows that the responders were most familiar with *using a keyboard* (77%), whereas, they found the *Copy Paste* function less familiar (59%). Only 12% were confident in using another computer than their own, and a little more than a third were *interested in using computers*.

Figure 11. The digital part of the eHLA tool kit rated on a 4-point Likert scale (Copy from Paper 4)



The figure shows the 14 questions in the digital part of the eHLA questionnaire and the responders answers. The answers are provided in percentages.

Higher levels of digital literacy were associated with frequency of internet use

More than half (60%) did not experience any stress when using a computer (Table 9). Twenty-five percent experienced stress levels ranging from moderately- (12%) to very high stress levels (3%). Table 8 reveals that technology familiarity and technology confidence were not associated with stress when adjusting for age, sex, state of frailty, and education level. We found an association between stress and *"incentive to engage with technology"* after adjustment for the above-mentioned variables. However, when stratifying for sex, this was significant for only males. Strong associations were found between frequency of computer use and technology familiarity, technology confidence, and incentive to engage with technology (Table 8).

Table 8. Associations between digital literacy and stress levels and frequency of internet use in 122 patients (Copy from Paper 4)

	Technology Familiarity				*Technology Confidence*				*Technology Incentive*			
n=118	Coef.	P-value	Adj.	P-value	Coef.	P-value	Adj.	P-value	Coef.	P-value	Adj.	P-value
Level of stress	-0.2	0.6	-0.1	0.8	-0.40	0.2	-0.4	0.2	-0.7	0.01	-0.7	0.01
Level of stress, male	-1.2	0.2	-1.1	0.2	-0.7	0.3	-0.4	0.5	-1.1	0.06	-1.2	0.05
Level of stress, female	-0.21	0.7	0.3	0.5	-0.3	0.4	-0.2	0.5	-0.59	0.09	-0.5	0.14
Frequency of internet use	4.3	0.001	3.2	0.001	2.8	0.001	2.5	0.001	3.3	0.001	2.7	0.001
Frequency of internet: male	3.7	0.001	3.9	0.002	3.0	0.001	2.9	0.001	3.5	0.001	3.3	0.001
Frequency of internet: female	4.0	0.001	3.1	0.002	2.6	0.001	2.2	0.001	3.1	0.001	2.5	0.001

Adj=adjusted for age, sex, state of frailty, level of education. Tecnology familiarity, Technology confidence, and Technology incentive are components in the digital part of the eHLA questionnaire

Computer support

Four computer users never used the internet, 42 used the net less than once a day, and 79 used it at least once a day, corresponding to 63% (see Table 9). Only seven persons (6%) did not get any computer support. Most of the responders (65%) got help from children and grandchildren when their computer and internet use was challenged. Less were in need for support when using the digital self-service solution ″e-boks″ compared to computer use in general (Table 9).
Internet banking topped the list as the most used self-service solution. Sending and receiving mails was the next most used internet service (see Table 9).

Table 9. Internet habits in geriatric patients, n (%), (copy from Paper ***4)***

Computer Users	*N=124*
Stress when using computer	
No stress	72 (61)
Low stress level	22 (14)
Moderate stress level	14 (12)
High stress level	7 (6)
Very high stress level	4 (3)
Missing	5 (4)
Computer support*	
No help	7 (6)
Help from spouse	16 (13)
Help from children/ grandchildren	80 (65)
Help from friends	21 (17)
Help from prof IT employee	12 (10)
Help when using e-boks*	
No help	77 (62)
Help from spouse	12 (10)
Help from children/ grandchildren	16 (13)
Help from friends	0 (0)
Do not use e-box	19 (15)
Frequency of internet use	
Never	4 (3)
Less than once a day	40 (34)
At least once a day	75 (63)
Missing	5 (3)
Search the internet*	
Facebook/ Instagram	47 (38)
Skype/ FaceTime	27 (22)
Health information	58 (47)
Search engine (Google/ Bing)	26 (21)
Online news	65 (52)
Internet banking/ e-boks	98 (79)
Mail	90 (73)
YouTube	3 (2)
Online games	29 (23)
Recipes	5 (4)
Others	15 (12)

* more answers can be chosen

This study found that almost all geriatric patients received computer support and most often from children and grandchildren. Their digital literacy was associated with how often they were online. Sixty percent experienced no computer stress, but stress was seen in men when they were asked about their incentive to engage with technological solutions.

Discussion

In this PhD study, we investigated the feasibility of conducting TR in geriatric inpatients and described a TR intervention in a small sample of non-randomised geriatric patients. With the purpose to understand why some geriatric patients have difficulties in using computer technologies or why they choose not to use them, we studied the prevalence of computer users in geriatric patients and in continuation hereof investigated the digital literacy in geriatric computer users. In the following, the results from Studies 1 and 2 are discussed together, whereas Studies 3 and 4 are discussed separately.

Target group for tele-rehabilitation in geriatric patients

We found that when geriatric patients are recruited for a TR intervention conducted in their own homes, it is important to be aware of the time of recruitment meaning that the TR intervention is not offered in immediate continuation of their acute illness. In addition, their digital skills must be assessed, and individual instruction regarding the computer and IT platform supplemented with written material must be considered. It must also be considered whether it is possible to make the time for training sessions more flexible.

The four patients in the case report might represent the target group in which TR is possible to realise. This group was not recruited after an acute admission. Some were daily computer users, and others used their computer several times a week. Therefore, for those four patients we assumed that using a computer in connection with a TR intervention did not require extra energy. On the contrary, we may expect they would save energy because they did not have to leave home for exercising.

The challenges of implementing a TR intervention in older people is complex and can be a combination of several factors such as high age and setting. Ortiz-Piña et al. succeeded to recruit patients for a TR intervention conducted in the patient's own home immediately after hip fracture surgery (78). However, the intervention group in that study had a mean age of 75.9 (±5.8) years, i.e. younger than our patients. In addition, a requirement in the study was that only patients with the possibility to involve a caregiver were included (78). Similar Li et al. recruited patients right after acute hip fracture surgery (74). However, this TR intervention took place in a day hospital rehabilitation unit and the patients' mean age was (76.5) (±8.6).

Hospital or rehabilitation settings might explain why more studies managed to conduct TR in older people after an acute hospitalisation (73, 75, 76, 122). In these settings we might anticipate that

technological support combined with a high motivation for TR amongst the staff are present. The study by Laver et al. who conducted a pilot TR study in a hospital setting included patients with a mean age of 85 years support this hypothesis (123).

Conducting TR in the patient's own home may be more challenging because support is not always available. The participants in a study by Tsai et al. (69) used almost the same methods and equipment as were planned to be used in our RCT (Appendix 1). An explanation for Tsai et al.'s success might be explained by the approximately 8-year younger target group, who were presumably more digital literate and the fact that they were recruited from a tertiary hospital pulmonary rehabilitation programme.

Hong et al. succeeded in recruitment of participants 80 years or older for a TR intervention conducted in the patient's own home (44). These patients were recruited from a senior citizen centre where lack of energy was stated as a reason for not participating (51). Also, Smaerup et al. succeeded in recruiting patients from a geriatric fall clinic for a TR intervention conducted in their own homes. These patients were suffering from vestibular diseases and were outpatients, younger, and most of them were recruited through advertisements in newspapers. One can expect that people who sign up via an advertisement would have more energy and motivation to participate (66).

When the TR intervention is moved to another setting such as a hospital or rehabilitation centre some of the benefits of use of TR solutions disappear, such as reduced transportation time or social distancing. Therefore, we still find an advantage in implementing TR in the patients' own homes if possible.

How to support a TR intervention*?*

In the current case report, we continuously prepared more detailed descriptions regarding how to handle the computer, here based on feedback from the patients involved. We are not sure whether these ongoing optimisations of the written material or whether the flexible approach to the TR sessions by switching between individual and group exercising had an impact on the high degree of adherence we achieved in the case study. Exercising on scheduled times was one of the barriers for not participating in a TR intervention in our feasibility study (51).

Bernocchi et al. conducted TR in stroke patients with a mean age of 79 years (±6.6) and found significant improvement in, e.g., functional capacity (8). The intervention was exercises described on a sheet of paper and conducted in the participants' homes after discharge from a rehabilitation unit. The therapist used a videoconferencing system to watch the participants exercise twice

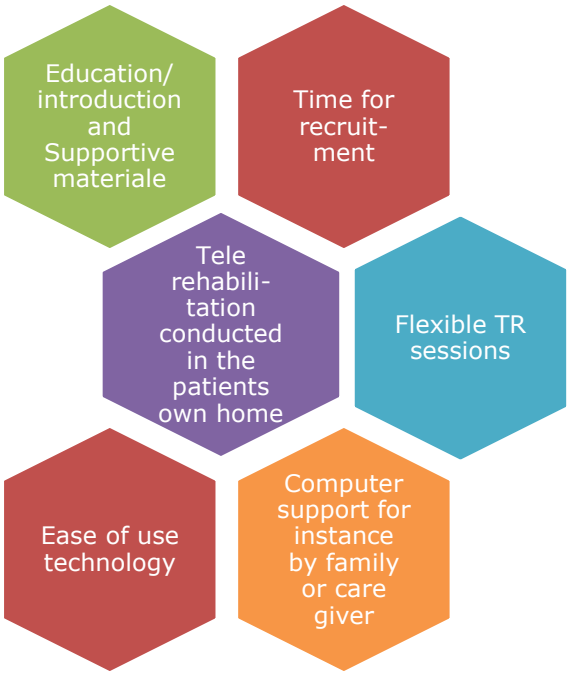
monthly to secure adherence to the programme. The caregivers were also instructed in the videoconferencing system in order to support the participants. Furthermore, a total compliance of 82% for the supervised TR sessions was found. This TR method required fewer TR sessions supervised by the physiotherapist, and still a high compliance was achieved. Whether this high compliance is due to the two monthly supervised TR sessions, involvement of a caregiver, or something else, is not known. However, involving caregivers may be a solution for those who are challenged by low digital literacy (8).

In our feasibility study, we concluded that the computer devices must be as easy to use as turning on the television. Crotty et al. also succeeded by conducting videoconferencing TR by involving carers in both community dwellings (mean age 73 years ± 10.1) and nursing home residences (mean age 83 years ± 7.9) (80). The TR was conducted in the patients' own homes, and for those living in a nursing home, the intervention took place there. No log-in was used to avoid problems with remembering passwords. They were trained individually by therapists to use the devices, and all were supplied with written material. The study found positive effects on, e.g., participants' satisfaction, reduced home visits, and travel time. In this study, age was not an obstacle to technology use, but still it was more difficult to recruit the oldest patients (80).

Similar, Hong et al. recruited older patients with a mean age of 83 years to a home videoconferencing TR. The participants were provided with a computer manual and a 15-inch touch screen computer (81). In both the studies by Crotty et al. and those by Hong et al., "ease of use" technologies were used and pedagogical initiatives taken to ensure a high participation (80, 81).

In conclusion, time for recruitment, ease of use of technologies, supportive material or available computer support, and flexible TR sessions need to be tested further because these factors may be important in retaining older (geriatric) patients in a TR programme conducted in their own homes (Figure 11).

Figure 11. Factors influencing a TR intervention



Low prevalence of computer users in geriatric in-and outpatients

About half of the geriatric patients in study 3 were computer users. They differed from non-users by being younger, less frail, more often highly educated, living outside an institution, and having a higher functional capacity, whereas sex or living with someone did not have any influence.

Factors that influence computer use

Age

We found a decrease in computer use with each passing year the geriatric patients got older. The same association was found by Lesauskaitė et al. (2019) among geriatric inpatients in Lithuania (100). When we divided age into three groups, fewer computer users were found among the oldest age group 85 years or older compared to the youngest age group. What surprised us was that we found no significant difference in computer use between the two youngest age groups. Our findings might explain why we did not succeed in including participants in the RCT by changing the age limit from 75 to 65 years. One explanation may be frailty amongst the younger geriatric patients.

Frailty and functional capacity

About three-quarters of the respondents in our study were scored to be moderately or severely frail. Only the group of severely frail patients was associated with reduced computer use. Few studies have compared computer use to frailty level. However, Keränen et al. investigated the association between frailty level (divided into frail, prefrail, and nonfrail) and internet connections at home among home-dwelling senior citizens; they categorised 7% as frail, finding that fewer of these had an internet connection (105). It is difficult to completely compare the two studies because the target groups are different, and the prevalence of frailty in the study by Keränen et al. was lower. Keränen et al. questioned whether the prevalence of frailty in their study was lower because fewer frail citizens responded to the questionnaire.

In study 3 we compared the functional capacity in the two groups of users and non-users and found computer users having a median FRS of 73 points and non-users a median FRS of 46 points. Zuchermann et al. found that a median score between 80 and 100 reflects high functional capacity, a score between 60 and 79 points reflects a functional capacity of medium level and a score below 60 points reflects those with the lowest functional capacity (124). In our study both groups had reduced functional capacity and therefore in need of exercising. Again, it is important to pay attention to the group of non-users with the lowest functional capacity making them able to access a TR intervention when physical presence is a challenge.

Sex

In our feasibility study, one patient explained that she found her digital literacy too low: "it is more my husband who uses the computer". Our prevalence study (Study 3) did not find any sex differences concerning computer usage, which contrasts with the studies by van Deursen and Helsper from 2015 (125) and Berner et al. from 2013 (126). Both studies found women less likely to use computers. However, when Berner et al. delimited the younger age group to between 60 and 80 years, this association was no longer present (126).

Education level

The diluted difference in computer use between sexes in our study 3 might be explained by the fact that there has been a change in education level over the years between sexes in Denmark. Nowadays, unlike in the 1960s and 1970s, more women have a middle range and higher education level than men (127). Around a third of the respondents in the current prevalence study had a

primary school education, and 18% of those were computer users, whereas among the 28% of those with a higher education level, more than twice as many (39%) were computer users.
Other studies found computer use among older people influenced by education level (90, 128). Van Deursen and Helsper suggested that internet use requires a certain degree of traditional literacy and cognitive skills because the internet is primarily text based (125). In addition, Berner et al. implied that persons with a higher education level have the "curiosity to pick up new skills" (128). However, this association was not found by Lesauskaitė et al. among geriatric inpatients; they divided education into two levels only: "university and below university" (100). The four education levels we used in our study may provide a more nuanced description of the relationship between education and computer use.
The connection between computer use and level of education supports the need for TR solutions that would avoid leaving out the least educated.

Living- and dwelling status

We did not find any association between computer use and living with someone. This is in contrast to Arcury et al. and Berner et al. (90, 128). Berner et al. stated that the association between living with someone and internet use found in their study may be explained by the possibility of receiving computer support from other persons living in the same accommodation (128). Our results might be explained by our respondents being older than those participating in the studies by Arcury et al. (90) and Berner et al. (128). If we assume that our respondents' spouse, partner, and next of kin were around the same age as the respondents themselves, there may be less support because their digital literacy was at the same level.
In this study, we wanted to determine how many of the geriatric patients were possible candidates to join a TR intervention. Therefore, we chose to exclude the cognitive impaired geriatric patients as verified by a score of 4 or more errors in the SPMSQ. We found cognitive impaired older people more suitable for a face to face training intervention. This might explain why only 14 respondents were institutionalised, and among these only one used a computer. Nursing home residents are not challenged by, e.g., the long transportation time but instead by cognitive impairments and therefore might be better suited to another training offer than TR. Crotty et el. examined the feasibility of offering TR in nursing home residents with a mean age of 83 years (±7.9) and experienced a dropout rate of 40%. Furthermore, as mentioned earlier, use of the applications was assisted by

patient and carer engagement, which might explain why it was possible to conduct TR in this population. (80).

Digital skills and challenges in geriatric computer users

In Study 4 we found that 94% of geriatric computer users received computer support. This support came most often from family members. Furthermore, we found computer users' level of digital literacy to be associated with internet use frequency, and in men, stress levels.

In Study 3, we did not find any significant difference in computer use among the two youngest age groups. However, focusing on computer users only in Study 4, we found in a logistic regression analysis that the youngest age group was significantly more digital literate than people in the age range between 75 to 84 years and those 85 years and older.

These findings could indicate that the number of computer users that can be recruited for a TR intervention among the youngest geriatric patients is not necessarily higher than it is in those between 75 to 84 years. However, among computer users, the youngest age group may need less support in connection with a TR intervention because they might be more digitally literate than the older age groups.

Social ties such as children and grandchildren are the most used computer supporters among geriatric patients

We found that almost all our geriatric computer users received computer help. The need for computer support is also described by Hayat et al., who examined how crucial the availability of help from social ties is for people with low eHealth literacy to enable them to access online health information (129). Information that may result in improved health outcomes (129). As mentioned above, Berner et al. suggested that living with someone enables computer users to seek help from partners (128). In our study we found that about two-thirds of the respondents living alone sought help from children or grandchildren. However, some of those living with someone sought computer support both from their partner and from their family, which might support our findings in Study 3 that living with someone was not associated with computer use. This finding may indicate that telehealth solutions such as TR are only possible to implement if computer supporters are present. However, social ties such as family or friends are not always present when the TR is undertaken. For those who do not have social ties, TR interventions involving a caregiver might be a more viable solution. Caregivers may more likely be present in the older persons' everyday life (8, 78).

This support may be necessary only in the start-up phase. Involvement of caregivers could possibly also entail participation of non-users in a TR intervention.

Digital literacy, internet frequency, and computer stress

Holt et al. investigated digital literacy among outpatients with a mean age of 57 years (117). They used the eHLA questionnaire and found a score about 1 point higher than that in the responders in our study 4 (117). This difference in the eHLA score could be explained by age differences. However, when measuring digital literacy in the four patients described in the case report, we found their digital literacy in line with the responders in the study by Holt et al. There were too few participants involved in our case report to draw any conclusions.

Adoption of computer technology is complex. Older people might also be challenged by cognitive impairments and low digital literacy in combination with growing expectations regarding the use of technologies in everyday life (89, 130, 131). Some older people do not feel they know all the new words that are used in connection with ICT solutions and sometimes even forget which computer button to press (132). For some, this may be stressful and associated with less use of the internet and lower eHealth literacy, as found in the study by Arcury et al. (90). Therefore, we also asked the respondents whether they experienced any stress when using their computer. These answers gave us the opportunity to study the association between digital literacy and stress levels.

However, most of the respondents in our Study 4 did not experience high stress levels, and the study did not find stress levels associated with technology familiarity and technology confidence. Yagill et al. (133) investigated associations between stress levels and low self-efficacy among older persons when they use everyday technologies. They did not find any association either. Yagill et al. suggested that in persons with high self-efficacy regarding use of everyday technologies might make them feel responsible for at least try to use these technology solutions (133). Those who have a low self-efficacy do not feel this inner responsibility to use the technology. The suggestions Yagill et al. made may also be an explanation for the low stress level among those respondents with low digital literacy levels in our study. Furthermore, our findings might be explained by the possibility to ask for help, for instance, from family members. Another explanation may be that these people drop the technology and seek other, more conservative solutions instead. This might contribute to the explanation why computer stress in our study was significantly associated with “incentives to engage with technology” in the male sex only, the reason being that men are more satisfied with their IT skills than women (134), hence feel a higher responsibility to use the computer, which then result in stress.

Tele-rehabilitation during and after covid-19

The corona pandemic has resulted in creative IT solutions aimed at promoting social distancing to avoid disease transmission (135). Bettger and Resnik call for further research within TR conducted both during and after the pandemic (54). There is a need for identifying patient groups that can or cannot benefit from TR. Bettger and Resnik state that if TR proves to be both as cost-effective and training effective in line with the usual training offers, TR should also be offered after the pandemic is over (54).

This PhD study had its tentative beginning 2 years before the Covid-19 pandemic. We did not succeed in conducting TR in geriatric patients after an acute hospitalisation. However, the corona pandemic has shown that our target group has a great need to access training online. Therefore, simple IT solutions addressing the older populations are still needed.

In Denmark, IT researchers developed an IT solution during the pandemic where older people, for instance, nursing home residences achieve direct online access to their family and/or friends by only turning on their television (135). The person who initiates the contact, for example, to their older institutionalized relatives, uses a computer link. This computer system only requires that both persons involved have a webcam and internet access. Via the same link, it is possible to set up a face-to-face videoconferencing system and could be a suggestion for a user-friendly TR solution which requires very few computer skills (135).

The fact that older people are forced to stay at home might have changed their attitude to telehealth solutions and their motivation to start using them. A study conducted in the US examined the use of telehealth solutions in 3,257 older people and found an increase in the use from 4.6% before the outbreak in 2019 to 21% during 2020 (136). However, there is still a big gap between younger and older generations and to reduce this gab call for new interventions.

Strengths and limitations

Study 1

Few studies have presented an overview of the feasibility of conducting TR in the oldest and frailest group of older patients assessed consecutively. This may be the group in most need of doing TR because they are challenged by transportation time and the necessity of social distancing. The number of patients, which included both medical patients and patients who had undergone surgery after a hip fracture, makes it possible to generalise the results to several geriatric populations.

Study 2

A strength was the description of a TR intervention in not only one but four communitive-dwelling older people recruited from different geriatric subspecialties, which nuanced this case report. The study could have been appropriately followed up by interviewing the participants to obtain their perspectives on the intervention. Furthermore, it could have been investigated whether they felt that they had had the opportunity to get to know the other participants in connection with the group interventions.

The flexible approach in this study to either individual or group sessions might be a way to achieve high adherence to the TR sessions if it is possible for the therapist to fully implement the intervention in a busy everyday life.

A limitation was the absence of men, despite several attempts to recruit them. That being said, in Study 3, we found no sex differences in computer use. Yet we do not know whether other supportive initiatives to retain men in a TR intervention are needed. Therefore, future studies should strive to include both men and women. In addition, the eHLA questionnaire is a relatively new instrument. Therefore, reference values have not yet been developed. Such values may give us an indication of a certain cut-off score to achieve sufficient digital literacy, for instance, to participate in telehealth solutions such as TR.

Study 3

A strength of the prevalence study was that we interviewed all patients consecutively and achieved a high response rate of 97%. Another strength is that we chose to mix inpatients and outpatients and not analyse them as single groups. We expected this mix of patient groups made the population

more comparable with other geriatric patients in Europe, and thereby increased the generalisability of our results. It was also a strength that more data were retrieved from EHRs.
Another limitation was that we did not ask for the responders' vision nor did we ask whether they had used computers at their work place during their working lives. Both these aspects have been found to be important factors in computer use in later life (137). We were careful not to exhaust the patients further by lengthy interviews. Therefore, we also chose to read all the questions aloud, hoping to avoid a low response rate, as seen in other studies (89, 117). This method could have biased the results.

Study 4

A strength of the current study is that the questionnaire was primarily based on validated questionnaires. In addition, as mentioned above part of the data was retrieved from the EHR. Study 4 is derived from Study 3, and the high response rate of 97% strengthens the generalisability. As mentioned in Study 2, a limitation is that the results found based on the eHLA questionnaire were not possible to compare with reference values.

The influence of cognitive impairment on computer usage in older people

However, there are other factors that could pertain to computer use that were not investigated in this study. Older people are challenged by age-related cognitive changes (130). As the average life expectancy increases, there will similarly be an increase in the number of older people with cognitive challenges. Czaja et al. discussed the impact of age-related changes in cognition on the use of computers and other technological solutions (130). We chose to exclude the cognitively weak geriatric patients because we assume they may be further challenged by the use of computer and therefore instead should be offered face-to-face rehabilitation. To screen for cognitive abilities, we used the SPMSQ. However, the SPMSQ is only a screening tool. We did not make an in-depth examination of the responders' cognitive abilities. It is possible that cognitive disorders not captured by the SPMSQ might contribute to the explanation as to why fewer in the oldest age group do not use computers.
Therefore, the fact that computer users are becoming non-users with increasing age due to increasing cognitive impairments will reduce the prevalence of computer users in the oldest age groups.

Future study design

In our feasibility study, many patients were excluded based on the criteria we had set up (51), resulting in very few eligible patients. Ortiz-Piña et al. conducted TR in a non-randomised study in which the participants could choose between usual care and home rehab (control group) or usual care and a 12-week TR programme (intervention group) (78). The authors in the study by Ortiz-Piña et al. were aware of the bias this could cause. However, they argued that this study design paid attention to patient preferences, and furthermore, it showed whether the choice-based intervention was a success for the person who chose it.

Our literature review uncovered few TR studies among older people who match the age of geriatric patients in Denmark. Whether it would be possible to achieve greater participation in TR interventions by using a design that takes greater account of patients' own preferences should be considered in a future study.

Conclusion

In this PhD study, we found it difficult to recruit geriatric patients for a TR intervention conducted in their own homes after acute hospitalisation. Time of recruitment, exhaustion, and low computer literacy are some of the reasons given for not participating. However, it seems possible to conduct TR in a non-randomised group of specially motivated geriatric patients and achieve a high adherence to the TR programme when written material is supplied and a flexible training schedule by shifting between individual and group sessions provided.

Other studies have succeeded in conducting TR in older people, but most often it is because it either did not take place in the participants' own homes and the participants probably had access to computer support or the participants were younger or not just discharged from the hospital, but were instead in the process of rehabilitation.

The prevalence of computer users seems associated with the youngest age groups, lower state of frailty, higher level of education, and living outside an institution. We found no difference in computer use in relation to sex. On the basis of other studies, it seems that in recent years there has been an equalisation regarding computer use in men and women.

For the computer users, we found that most geriatric in- and outpatients are fond of their computer, but few are open for new functions on computers. They receive computer help, often from family members. Their digital literacy may be associated with frequency of internet use. Stress related to computer use has been found in other studies. We found that stress levels were only male sex-specific and related to their incentives for engaging with technology.

Future perspectives

If older people in the future shall overcome barriers to adoption of IT solutions and realise the potential benefits that TR can deliver, certain issues need to be considered.

Development process, user involvement, system design, and usability

It is important to consider which technologies are challenging for older people. User involvement in the earliest stages of the development process may be crucial. As older potential TR users are a very heterogeneous group, it is that critical that there are representatives from different age groups and education levels, and it is especially important that also the least educated are involved.

The more user-friendly and simpler the systems become, the more likely older people will be able to adopt to them. For instance, it should be possible to access telehealth solutions from devices the patients are familiar with, such as tablets or smartphones or devices similar to televisions, a technology most older people are conversant with. Therefore, the aim should be to make the systems intuitive and as easy to operate as a television set.

Learning and education

When older people are to be introduced to a TR intervention, it is important to facilitate their motivation by an in-depth explanation of the benefits derived from exercising and also the benefits from exercising at home. Furthermore, the introduction to the devices used should consist of an oral guide and, if necessary, be supported by written material, preferably with pictures. As digitalisation will increase further in the future, it may be necessary to make more targeted efforts to offer courses in the use of computers and the internet among the older citizens in general to ensure that they are not left behind in a world that continues to be more foreign to them.

Future digital interventions and support

New TR interventions must be tested, depending on the purpose. It may be possible to achieve a high adherence if the sessions are made as flexible as possible and personally individualised. It may not be necessary that all sessions are supervised by a therapist.

We also need to investigate whether it is possible to complete TR in teams, where the exercises are reviewed via video recordings. This could be done in combination with monthly real-time supervision.

The Danish state has an ambition for digital transformation at all levels of government such as public sector institutions and hospitals. Another ambition is to make the exchange of communication and information between the public and citizens as user friendly as possible. To fulfil that purpose, it is important to get solutions that include the oldest and most digitally challenged citizens, both the old population with cognitive impairment no longer fit to use a computer and those who often are challenged by computer problems. A proposal could be to involve digital natives, e.g., the grandchildren, to help the digital immigrants, their grandparents, with TR. Intensive work should be done to use the right tools specifically targeting all groups of older people, because not everyone is happy to have family members/care partners or caregivers assist them with digital solutions of any kind.

Summary/ Dansk resumé

Nedsat fysisk aktivitet og sygdom kan føre til sarcopeni og skrøbelighed hos ældre mennesker. En hospitalsindlæggelse kan påvirke den ældres funktionsevne bl.a. pga. immobilisering. Træningstilbud efter udskrivelsen kan bryde den negative spiral, men kan for svage ældre være udmattende, da der ofte forekommer ventetid både før og efter træningen, hvorfor flere ældre foretrækker at træne i eget hjem. Telerehabilitering (TR) kan være en metode til at understøtte hjemmetræning. Desværre føler flere ældre sig ikke klædt godt nok på til at bruge en computer, selvom de allerede har investeret i en eller også har de pga. aftagende kognitive evner vanskeligere ved at bruge den.

Udgangspunktet med dette PhD studium var at undersøge muligheden for at gennemføre TR til geriatriske patienter netop udskrevet efter en akut indlæggelse. Det viste sig imidlertid ikke muligt at rekruttere deltagere. Det førte til, at denne PhD afhandling inkluderende fire studier i stedet fokuserer på mulige barrierer for den manglende deltagelse af geriatriske patienter i TR med henblik på fremtidige muligheder.

Vi gennemførte først et feasibility studium, hvor 311 indlagte patienter blev vurderet i forhold til, om de var egnede til inklusion. I studiet fandtes 33 egnede, hvoraf 31 ikke ønskede at deltage. For at afdække den manglende deltagelse gennemførte vi derefter interview af 17 ud af de 33 patienter og fandt, at hovedårsagerne var udmattelse og utilstrækkelige IT færdigheder.

Med henblik på at undersøge, om det overhovedet er muligt at gennemføre TR i hjemmet rekrutterede vi fire hjemmeboende patienter med rehabiliteringsbehov til at deltage i en TR intervention, hvor videokonferencesystemet blev anvendt. Resultatet, beskrevet i en case report, viste at TR faktisk var muligt, men krævede stor individuel tilpasning.

I det 3. studium undersøgte vi, i en spørgeskema undersøgelse, prævalensen af computerbrug hos en bred gruppe af geriatriske indlagte og ambulante patienter, hvilket resulterede i 249 respondenter. Heraf var 124 computerbrugere og 125 anvendte ikke computer. Herudover fandt vi at computerbrug var associeret med alder, uddannelsesniveau, skrøbelighed og at bo uden for en institution.

I studie 4 undersøgte vi på baggrund af data fra studie 3 computervaner, computer hjælp, stress relateret til brug af computer og niveauet af digitale færdigheder hos de 124 computerbrugere fundet i studie 3. Vi fandt, at de fleste af disse computerbrugere fik hjælp af børn eller børnebørn og at digitale færdigheder var positivt associeret til hyppigheden af internetbrug. Kun hos mænd fandt

vi, at de kan opleve at blive stresset når de bliver spurgt til deres incitamenter til at engagere sig i computer teknologier.

Konklusion: TR udført i geriatriske patienters eget hjem er ikke muligt i forlængelse af en akut indlæggelse pga. udmattelse og manglende computerfærdigheder. Barrierene for brug af TR ligger især hos de ældste og de dårligst uddannede, som kun i ringe grad anvender computer og hvor de digitale færdigheder er udfordret. Derimod synes TR at være muligt hos hjemmeboende geriatriske patienter med en vis grad af computerfærdigheder, suppleret med skriftligt materiale, og en individuel tilpasset fleksibel træningsplan.

I fremtiden er det vigtigt at designe brugervenlige IT systemer, eventuelt ved at inddrage de ældre i udviklingsprocessen. For at opnå en højere grad af deltagelse også blandt de der ikke anvender computer er det nødvendigt at supplere TR interventionerne med for eksempel computer undervisning, mundtligt og skriftligt materiale og etablere support fra familiemedlemmer eller andre personer, der i dagligdagen er tæt på den ældre.

English Summary

Decreased physical activity and illness can lead to sarcopenia and frailty in older people. Hospitalisation can further affect an individual's functional capacity, for example, because of immobilisation. Training offered after discharge can break this vicious spiral, but for frail older people training can be exhausting because of the waiting time both before and after the training session. This might explain why many older people prefer to exercise at home. Tele-rehabilitation (TR) can be used to facilitate exercising at home. Unfortunately, some older people do not feel well equipped to use a computer, even though they have one at home. Another explanation could be that they have more difficulty using a computer due to declining cognitive abilities.

The fundamental objective of this PhD study was to investigate whether it was feasible to carry out TR in geriatric patients after hospital discharge after an acute illness. However, recruiting participants for the study was impossible. This led to the four studies presented in this PhD thesis. These studies focused on possible barriers to the non-participation of geriatric patients, and the results will be used in the planning of future TR interventions.

We conducted a feasibility study, Study 1, in which 311 inpatients were assessed for eligibility. In total, 33 patients were found eligible, 31 of whom declined to participate. To identify the lack of participation, 17 of the 33 eligible patients were interviewed, and we found exhaustion after hospital discharge and lack of digital literacy as the most stated causes.

To investigate whether it is at all possible to conduct home TR, we recruited four home-dwelling patients in need of rehabilitation for participation in a TR intervention using videoconferencing. The result, described in a case report (Study 2), revealed that it is actually possible, but requires a tailor-made training offer for each patient.

In Study 3, we examined, in a survey, the prevalence of computer users in a broad population of geriatric in- and out patients. This resulted in 249 responders, 124 of whom were computer users and 125 non-users. We found a positive association between computer use and level of education as well as living outside an institution, but a negative association with frailty and age.

On the basis of data collected in Study 3, we examined in Study 4 computer habits, computer help, stress related to computer use, and level of digital literacy of the 124 computer users we found in Study 3. We found that most computer users receive support from their children or grandchildren, and that digital literacy was positively associated with frequency of internet use. Furthermore, there was an association between stress and the incentive to use computer technologies, but only in males.

In conclusion, TR in geriatric patients' own homes immediately after acute hospitalisation is not feasible because of their exhaustion and low digital literacy.

The barriers for TR are found especially among the oldest and lowest educated, who use a computer only to a small extent and are challenged by their lack of digital skills. On the other hand, TR seems to be possible in geriatric patients living at home with a certain degree of digital literacy, supplemented by written material and an individually tailor-made training session with flexible time schedules.

In the future it is important to design user friendly IT systems maybe by involving older people in the development process. To achieve a higher level of participation also among non-users it is necessary to supplement TR interventions with e.g. computer education, oral and written material and establish support from family or caregivers.

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Appendix I

A description of the planned RCT study

The purpose of the RCT study was to investigate the use of TR in geriatric patients aged 75 years or older, living in the municipality of Aarhus, and just discharged after acute hospitalisation.

Participants who agreed to participate were planned to be allocated to three groups, either one of two intervention groups or a control group. Participants in the two intervention groups were planned to receive supervised real-time videoconferencing TR. Intervention group 1 was planned to receive TR conducted in groups of a maximum of four persons. Intervention group 2 was planned to receive individual TR exercises. The control group was planned to receive the usual exercise programmes offered in the community centre for older people.

The exercises in both periods were based on the Otago Exercise Programme. It is a home-based strength and balance programme and has proven successfully to reduce falls and injuries caused by fall.

We chose the real time videoconferencing system because studies have found that communication between the older person and the physiotherapist is important and has positive effects on adherence to the exercise programme and its outcome [1, 2]. Therefore, it was the optimal proxy for a face-to-face exercise intervention.

Both intervention groups were planned to start exercising within the first week after discharge. The first two training sessions were individually adjusted so that it was possible to make the participant feel confident using the computer program, ensuring that everything was technically in order, e.g., to ensure that the participant was able to hear the physiotherapist and see the instructions on the screen.

After the initial training sessions, participants allocated to group TR were planned to be included in intervention group 1. When there was a total of four participants in intervention group 1, we planned to stop including more members in order to achieve the expected benefits of group exercising. A group of three members was acceptable. Participants in intervention group 2 received individual real-time videoconferencing TR.

The real-time videoconferencing TR was conducted for both intervention groups 3 days a week during 4 weeks with at least 1 day of rest between each exercise session (in total: 12 TR sessions). During the following 4 weeks, the participants in both intervention groups were planned to exercise without real-time supervision. Here the exercises were displayed on the computer by pre-recorded physiotherapist-instructed video sessions. During the last 4 weeks, it was also possible for those in

intervention group 1 to exercise and communicate with the other team members at appointed times. Twice a week, the physiotherapists planned to contact the patients via the computer to see if there were any problems regarding the exercise sessions.

The effects were planned to be measured 4 and 8 weeks and 6 months after discharge.

Outcome measures were *Functional Recovery Score* (FRS) [3], *De Morton Mobility Index* (DEMMI) test [4], hand grip strength [5], Fear of Falling by *Falls Efficacy Scale-International* (FES-I) [6], Health-Related Quality of Life assessed by the *EuroQoL 5-Dimension* (EQ-5D) [7], Geriatric Depression Scale (GDS) [8], and loneliness assessed by *UCLA Loneliness Scale* [9]. In addition, the patients' reasons for selection or refusal of TR were noted.

Clinical guidelines recommend that geriatric patients should exercise for more than 8 weeks if clinical benefits are to be expected [10]. The plan was that the participants in the RCT study after 8 weeks of TR should switch to training under municipal auspices if the expected effects had not been reached. FRS, DEMMI, and FES-I are described in Appendix 2.

Ethical considerations The original planned RCT study was approved by the Central Denmark Region Committees on Health Research Ethics (1-10-72-394-17) and by the Danish Data Protection Agency (1-16-02-201-
17). Participants that gave written informed consent were informed that they could withdraw at any time without losing their right to treatment. The communication that took place during the TR intervention between patients and therapist was carried out over the internet using a secure system.

Power calculations

By default, we made a power calculation for the original planned RCT study based on data from an unpublished RCT study [11] investigating TR in a group of patients with COPD (chronic obstructive pulmonary disease) that showed that a total of 129 participants were needed with 43 patients in each of the three groups [11].

Considerations of preparations in relation to the RCT study Before start-up of the study, we investigated different opportunities in relation to the IT platform used. Among others, we visited a training centre for older people where a physiotherapist was placed in front of a screen and a camera and supervised patients suffering from COPD in exercises via an online real-time videoconference system. This IT platform was also able to gather up to eight people at a time – all able to see and communicate with each other. We estimated that this TR method was the closest to being a face-to-face intervention. We assessed that our target group of older persons would greatly benefit from real-time supervision by the physiotherapist because studies have shown that

communication between the older person and the exercise instructor has positive effects on adherence to an exercise programme and its outcome [2, 12]. These COPD citizens used a tablet on which they received supervised online real-time exercises. However, one challenge was that the tablet screen was divided into the number of citizens that participated in the exercises that specific day. That means that the screen pictures sometimes turned out to be very small, depending on the numbers of participants. For these citizens with COPD, using a tablet was a challenge for those with reduced vision. Therefore, we decided to install a 21-inche computer screen and, furthermore, a maximum of four exercising participants at a time.

Online access

A priori, we decided to use dongles if an internet connection was not already installed in the participant's home. However, an unstable network was an exclusion criterion. To optimise the sound quality, we used external microphone and speakers. We also chose to use external webcams to ensure a high image quality.

Additional initiatives

Initially, we were very aware that technology could be challenging in our target population of very old people. Therefore, we first prepared text descriptions only but these were later combined with pictures. These descriptions ranged from turning on the computer to handling the IT platform. Both required only a few clicks.

However, it was necessary with follow-up visits or phone calls when the participants had problems with, e.g., how to log on or log off the computer system.

Despite the above-mentioned changes in the target group and a further attempt to recruit participants from a geriatric fall clinic, we had to acknowledge that it was not possible to complete this TR study in this group of older patients.

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Appendix II

The electronic Health Literacy Assessment questionnaire (Study 2 & Study 4)

The items in the eHLA are presented on a 4-point Likert scale. For Tool 1 (Technological familiarity), 1 represents no familiarity with computer use at all and 4 represents complete familiarity. For Tool 2 (Technological confidence), 1 represents no confidence at all and 4 complete confidences. Lastly, in Tool 3 (Incentives for engaging with technology), 1 means complete disagreement and 4 complete agreements. Higher scores in all tools indicate greater digital literacy.

Technology familiarity "Rate on a scale from not at all familiar to completely familiar"

How familiar are you with the following items?	Not at all familiar			Completely familiar
	1	2	3	4
Keyboard	☐	☐	☐	☐
Settings	☐	☐	☐	☐
Copy paste	☐	☐	☐	☐
Wifi	☐	☐	☐	☐
Operating system	☐	☐	☐	☐
User name	☐	☐	☐	☐

Technology confidence…? "On a scale from not at all confident to completely confident, rate your use of computers"

How confident do you feel …?	Not at all confident			Completely confident
	1	2	3	4
Using a computer in general?	☐	☐	☐	☐
Using another computer than your own?	☐	☐	☐	☐
Finding information online?	☐	☐	☐	☐
Using touch screen?	☐	☐	☐	☐

Incentives for engaging with technology "On a scale from completely disagree to completely agree, rate your experience of computers"

How much do you agree or disagree with the following statements:	Completely disagree			Completely agree
	1	2	3	4
I'm interested in using computers.	☐	☐	☐	☐
I'm fond of my computer.	☐	☐	☐	☐
I'm not afraid to try out new functions on computers.	☐	☐	☐	☐
I'm open to new ways of using computers	☐	☐	☐	☐

The Functional Recovery Score (FRS) (Study 2, 3 and 4)

FRS is a bedside assessment tool. FRS covers Basic Activities of Daily Living (BADL) by asking about bathing, dressing, eating, and toileting; and Instrumental Activities of Daily Living (IADL) including *shopping, laundering, light housework, food preparation, banking, transportation.* The last item *mobility* covers walking inside and outside or whether the patient is a non-walker and applies to both medical patients and patients after hip fracture surgery [1, 2]. FRS ranges from 0 to 100 points. The higher the score, the higher the participant's functional capacity [1].

De Morton Mobility Index (DEMMI)

DEMMI is a functional test that measures mobility in frail older people who often lie in bed or sit in a chair, and in older people who manage independently in everyday life without personal help. DEMMI ranges from 0 to 100 points. Higher scores indicate higher mobility [3].

Falls Efficacy Scale-International (FES-I*)*

FES-I measures fear of falling. FES-I ranges from 0 to 64 points. FES-I is rated on a 4-point Likert scale; the more worried the participant is, the higher the score.

*The Multidimensional Prognostic Index (*MPI) is a cumulative deficit model founded on the Comprehensive Geriatric Assessment consisting of eight domains. The domains establish Activities of Daily Living (ADL), Instrumental Activities of Daily Living, Instrumental ADL, social aspects, number of drugs, risk of developing pressure sores, severity of morbidities, cognitive and nutritional

status. A computer program divides the measured patients into three levels: MPI-1 as non-frail, MPI-2 as moderately frail, and MPI-3 severely frail [4].

Digital Interventions (RCT and Study 2)

The KMD Viva platform employed an encrypted application that the physiotherapist downloaded onto the patients' computers. This platform made it possible for the patients and physiotherapist involved to see and communicate with each other both individually and in groups. The IT platform divided the computer screen into smaller screens per number of participants in the training session. All patients used a static computer with a 21-inch screen, external webcam, and microphone/loudspeaker. This screen size makes it more likely for older people with reduced vision to see the supervised exercises [5].

For those patients with an unstable internet connection, we connected the computer to an internet dongle. The physiotherapist and the patients used the same equipment.

The Otago Exercises (RCT and Study 2*)*

The Otago exercises consisted of a walking plan, balance exercises, and a set of leg muscle strengthening exercises that all progressed in difficulty, for instance, by using extern ankle cuff weights [6]. The patients were also handed an exercise sheet on which the Otago exercises were described in detail. This ensured that the exercises could be carried out as self-training on days between the supervised training sessions.

Before starting the group interventions, the patients were trained individually, with individual durations depending on feeling safe and confident using the computer and the IT platform and so that they felt well participating in the group sessions. The Otago exercise programme was used in the same way in both the individual training and the training in groups.

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