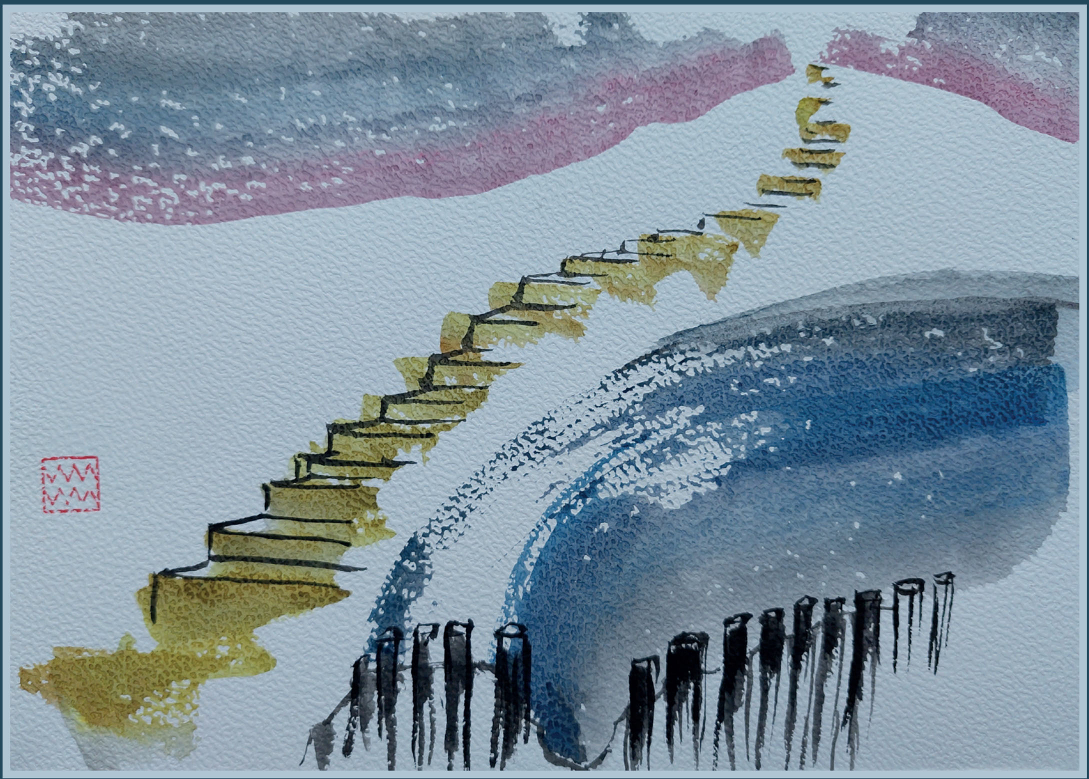
OPTIMIZING GERIATRIC REHABILITATION

Evidence-based fitness training and patient-centred goal-setting



Lizette Wattel

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OPTIMIZING GERIATRIC REHABILITATION

Evidence-based fitness training and patient-centred goal-setting

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General introduction

Geriatric rehabilitation

In the coming decades, a growing proportion of the Dutch population will be above the age of 65, as it is anticipated that they will make up 25% of the expected 19.2 million population by 2040. Moreover, the majority of them will be living alone. [1] As people age, they generally have more chronic diseases, and experience a decline in physical fitness. As a result, older adults are vulnerable to developing disabilities and increased dependency. [2-5]

When older adults (sub)acutely deteriorate in functioning – for example, due to a stroke or hip fracture – they can benefit from geriatric rehabilitation (GR), defined as a multi-dimensional approach of "diagnostic and therapeutic interventions, with the purpose to optimize functional capacity, promote activity and preserve functional reserve and social participation in older people with disabling impairments." [6] The largest subgroup of patients in GR (about 44%) is admitted for an orthopedic condition as a result of a trauma or elective surgery involving the lower limbs and pelvis. [7] This thesis will focus on this group and refer to them as orthopedic GR patients. This population is predicted to grow based on the growth seen in previous years, as the number of hip fractures increased from 13,500 in 2008 to 19,000 by 2021, growing by approximately 420 hip fracture patients per year. [1] One in four patients with injuries in the emergency departments in the Netherlands are admitted due to a hip fracture. [8]

GR usually starts off with a comprehensive geriatric assessment to identify a patient's specific problems and needs. Subsequently, rehabilitation goals are drawn up, which form the basis of the patient-specific multidisciplinary rehabilitation plan. [6]

Goal setting in geriatric rehabilitation

Ideally, rehabilitation goals are set in dialogue with the patient and informal caregivers. This process of establishing or negotiating rehabilitation goals is called 'goal setting'. [9] Both professionals and patients consider it important to genuinely involve GR patients and their informal caregivers in goal setting. However, in daily practice, GR professionals are reluctant about this involvement, and even if they are willing, this can still prove difficult. GR professionals overestimate the patient's influence in their own goal setting, while patients themselves feel that goals are mainly set by professionals. [10-13]

Aging, physical fitness and functioning

The process of aging is associated with cellular and molecular changes that cause structural and functional decline in most physiological systems, such as the cardiovascular, ventilatory, and musculoskeletal systems. [3,14-16] Structural and functional changes in the cardiovascular system – such as increased vascular stiffening and a decreased maximal heart rate – lead to a reduced exercise capacity. [15] Structural and functional changes also occur in the respiratory system, such as reduced compliance of the chest wall and increased breathing effort. However, gas exchange is well preserved at rest and during exertion, despite a reduced alveolar surface area and increased ventilation-perfusion heterogeneity. [16] In the musculoskeletal system, muscle size and strength decrease, as well as the neuromuscular activation. [3] Another change in the muscle function is the reduced number and function of mitochondria, resulting in a decrease in maximal oxygen uptake. [17] As a result, aging is associated with a decline in physical fitness, reflected in muscle strength and endurance. Furthermore, because physical functioning is highly dependent on physical fitness,[18-21] aging is also associated with impaired physical functioning.

Training in orthopedic geriatric rehabilitation

The GR goals that form the basis of the rehabilitation plan are generally functional by nature, such as rising from a chair or climbing stairs. The focus of the exercise training is placed on practicing functional activities. In practice, the achievement of the functional goals is often impeded by the reduced physical fitness of this older target group.[22 23] Physical fitness training – including aerobic and strengthening exercises – has been shown to improve frail older adults' physical functioning in terms of the ability to perform basic daily living activities.[24-27] As a result, physical fitness training should be considered an important part of the GR program.

Orthopedic GR programs show considerable variation concerning the amount of physiotherapy and physical activity,[28,29] and – most likely – also physical fitness training. Several international guidelines have been published, providing exercise recommendations for improving physical fitness in older adults.[30-32] One might question whether these recommendations could not be followed for orthopedic GR patients just as well. In general, frailty and poor health are seen as the greatest barriers to physical fitness training in older adults,[33] and individuals in orthopedic GR show strong variety in frailty and (multi)morbidity. Training should be adjusted for older adults with one or more medical conditions, in a manner that 'effectively and safely treats those conditions.'[30] However, it is unclear how this can be achieved. Moreover, therapists might not be aware of the guidelines, or they might simply be too cautious. There is clear anecdotal information from clinicians in the field of GR that orthopedic GR patients are undertrained. This is corroborated by research in adult rehabilitation with less vulnerable patients, demonstrating that a substantial portion of these patients do not meet the guidelines to improve aerobic fitness or muscle strength.[34 35] Based on these signs, the broader literature, the lack of concrete recommendations for physical fitness training in orthopedic GR, and the variation in rehabilitation programs, current rehabilitation programs are likely to be sub-optimal. This might in turn result in sub-optimal physical fitness and physical functioning.

Aims of this thesis

The aims of this thesis are twofold. The first aim is to develop recommendations for physical fitness training in orthopedic GR, which requires evidence-based information on the characteristics of physical fitness training that should be used to improve physical fitness in orthopedic GR patients. Additionally, it is necessary to identify the characteristics of the physical fitness trainings currently provided in orthopedic GR and assess these in light of the existing guidelines for enhancing physical fitness. Furthermore, as several patient-related and environmental factors also affect the feasibility and efficacy of physical fitness training, it is essential to gain a better understanding of which of these factors are involved and how. The second aim of this thesis is to develop an evidence-based practical guideline for patient-centered goal setting.

Setting of the performed studies

The studies in this thesis were developed and performed in the UNO Amsterdam 'living lab,' a collaboration between scientific researchers and professionals of care organizations in the central and western part of the Netherlands. This collaboration between research and practice provides the opportunity to jointly develop or discuss research proposals, conduct research, discuss preliminary findings, and bring results into practice. In this way, the collaboration within UNO Amsterdam ensures that research aligns with issues raised by daily practice and solutions are made applicable for this practice.

Outline of this thesis

The Fit4Frail study was conducted to develop recommendations for physical fitness training. This study makes up the major part of this thesis, and its results are described in chapters 2 to 6.

The first three chapters focus on the characteristics of physical fitness training that should be applied to improve physical fitness in patients admitted to orthopedic GR. Chapter 2 presents the results of a systematic review of the literature concerning the characteristics and effectiveness of aerobic fitness training in older adults. The focus of this review is placed on older adults with a wide variety of health statuses, aiming to do justice to the diversity of vulnerabilities in older adults. Given that multiple systematic reviews have been published for these individual health statuses, an umbrella review was considered appropriate to perform a systematic review of systematic reviews. Chapter 3 presents the results of an international Delphi study conducted to reach expert consensus about exercise testing and training in frail older adults in orthopedic GR. For exercise testing, this concerned tests to determine and monitor the target exercise intensity and evaluate the effect of training. For training, this concerned the so-called FITT characteristics of training, namely the frequency (how often?), intensity (how hard?), time (how long?) and type (what?) of training. Chapter 4 describes the feasibility of the talk test to determine training intensity and evaluate the effect of aerobic fitness training in studies in orthopedic GR.

Chapters 5 and 6 focus on the current practice of orthopedic GR, exploring how physical fitness training is performed and which factors influence this training. Chapter 5 presents the results of an explorative observational study of the content of physical fitness training of patients in orthopedic GR, as well as changes in their physical fitness and physical functioning. Chapter 6 describes the findings of an interview study into the barriers and facilitators of physical fitness training in orthopedic GR. In this study, individual interviews were held with patients, their relatives and their responsible nurses, and focus group interviews were held with multidisciplinary GR teams.

Chapter 7 focuses on patient-centered goal setting as the other topic of this thesis. It describes a participatory action research project with members of the UNO Amsterdam that resulted in developing an evidence-based practical guideline for patient-centered goal setting in GR.

Finally, chapter 8 provides the summary and general discussion of this thesis. The main findings are summarized, results in the previous chapters are reflected on, and recommendations for research and clinical GR practice are provided.

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02

Effectiveness and characteristics of physical fitness training on aerobic fitness in vulnerable older adults: an umbrella review of systematic reviews

Visser D*, Wattel EM*, Gerrits KHL, van der Wouden JC, Meiland FJM, de Groot AJ, Jansma EP, Hertogh CMPM, Smit EB. Effectiveness and characteristics of physical fitness training on aerobic fitness in vulnerable older adults: an umbrella review of systematic reviews. BMJ Open. 2022 May 31;12(5):e058056. doi: 10.1136/bmjopen-2021-058056.

* Dennis Visser and Elizabeth M Wattel contributed equally and are joint first authors.

Abstract

Objectives: To present an overview of effectiveness and training characteristics of physical training on aerobic fitness, compared to alternative or no training, in adults over 65 years with various health statuses, providing a basis for guidelines for aerobic training of vulnerable older adults that can be used in geriatric rehabilitation.
Design: An umbrella review of systematic reviews that included both randomised controlled trials and other types of trials.
Data Sources: Medline, EMBASE, CINAHL and the Cochrane Library were searched on September 9, 2019.
Eligibility criteria for selecting studies: We included systematic reviews reporting on physical training interventions that are expected to improve aerobic fitness, presenting results for adults aged 65 years and older, describing at least one of the FITT characteristics: Frequency, Intensity, Time or Type of exercise, and measuring aerobic fitness at least before and after the intervention.
Data extraction and synthesis: Two independent reviewers extracted the data and assessed the risk of bias. A narrative synthesis was performed.
Results: We included 51 papers on 49 reviews. Thirty-three reviews reported a positive effect of training on aerobic fitness, eleven reviews remained inconclusive and five reviews reported no effect. Training characteristics varied largely. Frequency: 1-35 sessions/week, Intensity: light-vigorous, Time: <10-120 minutes/session and Types of exercise: many. The methodological quality was most often low. Subgroup analyses revealed positive effects for all health conditions except for trauma patients. Exercise characteristics from current existing guidelines are widely applicable. For vulnerable older adults, lower intensities and lower frequencies were beneficial. Some health conditions require specific adjustments. Information on adverse events was often lacking, but their occurrence seemed rare.
Conclusion: Physical fitness training can be effective for vulnerable older adults. Exercise characteristics from current existing guidelines are widely applicable, although lower frequencies and intensities are also beneficial. For some conditions, adjustments are advised.
PROSPERO registration: CRD42020140575.

Key words: Exercise Therapy, Aerobic Fitness, Vulnerable Older Adults, Systematic Review, Geriatric Rehabilitation

Strengths and limitations of this study

- This review of systematic reviews provides a summary of the scientific literature on training of aerobic fitness in older adults with a wide variety of health statuses.
- This review focuses on training characteristics, effects of aerobic fitness and adverse events.
- The narrative analyses does justice to the diversity of vulnerabilities in older adults.
- An important challenge is the interpretation of the large variety of interventions, outcomes and description of the training characteristics within the studies.

Introduction

Geriatric rehabilitation can be defined as diagnostic and therapeutic interventions aimed at restoring functional ability or enhancing residual physical function in vulnerable older people with disabling impairments.[1, 2] Patients in geriatric rehabilitation are vulnerable with regards to their health status, typically characterised by a wide range of frailty, comorbidity and disability.[1-3] Ageing is associated with physiological changes that result in reductions in functional capacity, such as a reduction in aerobic fitness and in muscle performance. This deterioration can be a cause of disabling impairments, but hindering functional recovery. Therefore, the training of functional capacity can be considered an essential focus for geriatric rehabilitation. An important element of functional capacity is aerobic fitness, i.e., the ability of the circulatory and respiratory systems to supply oxygen during sustained physical activity. This can be improved through a number of therapeutic interventions such as walking, rowing and cycling.[7]

There are several international guidelines that provide exercise recommendations for improving aerobic fitness in healthy (older) adults or in adults with a specific disease or condition. In general, these recommendations are based on the training principle of progressive overload. This principle implies that training should impose a greater load on the body than it is normally accustomed to and should increase throughout a training program.[7] Exercise below a minimum training load will not challenge the body sufficiently enough to result in increased physical fitness.[8] This relation between training load and gain in physical fitness is not linear. Training itself has a ceiling effect: the closer the patients' fitness approaches their personal ceiling, the greater the training intensity needed for improvement. Conversely, if the training load is too high, it can lead to adverse effects, for example, a decrease in training effect, myocardial infarction and in extreme cases, sudden cardiac death.[13-16] It is thus important to find the optimal equilibrium between under- and over-training.

Training load is determined by the Frequency, Intensity and Time of training.[17] Together with the Type of exercise performed, these characteristics are referred to as the FITT characteristics, which are used for exercise prescription. Exercise intensity, for example expressed as the proportion of maximal oxygen uptake, is the most important of these four characteristics as it has the largest influence on the training load and, therefore, on the exercise dose. Frequency refers to how often the exercise is performed, usually represented in the number of sessions per week. Time is the length of the physical activity, typically expressed in minutes per session. The Type of exercise refers to the specific physical activity performed, such as walking or swimming.[7]

Although guidelines provide a multitude of exercise recommendations, they lack specific recommendations on aerobic exercise for the vulnerable group of patients in geriatric rehabilitation. These patients often face problems regarding frailty, comorbidity or disability, and their interaction.[3] Further, the underlying problems are wide-ranging. It is unclear whether and how the FITT characteristics of, for example, the American College of Sports Medicine (ACSM), apply to this group. This is important as application of inappropriate FITT characteristics may lead to adverse events or to suboptimal training, resulting in the inadequate recovery of independence.[8, 18] As well as a lack of specific training guidelines for vulnerable older adults, an overview of the evidence with regards to physical fitness training in vulnerable older adults is also lacking. Currently, there are several reviews available reporting on the effect of physical fitness training on aerobic fitness in healthy older adults, or in older patients with specific diagnoses.[20-22] The combination of the body of evidence of such systematic reviews regarding both healthy and impaired older adults might help to improve the exercise prescription in vulnerable older adults who are undergoing geriatric rehabilitation. Therefore, the research questions for this study are:

1. What is the effect of physical fitness training on aerobic fitness outcomes compared to alternative or no training in adults over 65 years old with various health statuses?
2. What are the training characteristics in studies that showed an improvement in aerobic fitness in adults over 65 years old?

Methods

Design

An umbrella review was performed[23] and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[24] Before the start of the study, a review protocol was created and registered at the PROSPERO International Prospective Register of Systematic Reviews (CRD42020140575). Deviations from the protocol are reported in relevant parts of this methods section.

Data sources

We performed a systematic computerised search to identify systematic reviews reporting on the effect of physical fitness training on aerobic fitness in older adults. Four electronic databases were searched from their inception: Medline, EMBASE, CINAHL and the Cochrane Library. The search strategy for Medline is provided in Supplementary File A. We adapted the search strings accordingly for the other databases. The search was conducted on September 9, 2019.

Eligibility criteria

We included reviews that met all of the following criteria: (1) the review was a systematic review, according to our minimal criteria that the search strategy and in- and exclusion criteria were described; (2) the reported intervention was physical training that was expected to improve aerobic fitness; (3) the review had to present results for adults aged 65 years and older; (4) the description of the intervention contained at least one of the FITT characteristics: Frequency, Intensity, Time or Type of exercise; (5) aerobic fitness was measured at least before and after the intervention.

The design of the studies included in the systematic reviews could be either randomised controlled trials (RCTs) or other types of studies (non-RCTs), such as before-after studies, non-randomised, or quasi-randomised trials. We did this to ensure that we did not miss relevant studies on vulnerable patients for which RCT designs may not be feasible. We only included reviews published in English, with no restrictions on publication year.

Data extraction and synthesis

Two investigators (DV, EBS) independently reviewed the titles and abstracts. Potentially relevant articles were identified and the full texts were retrieved for independent assessment using the inclusion criteria. Any disagreements were resolved by consensus or in consultation with a third reviewer (HLG) when necessary. The validated Joanna Briggs Institute (JBI) Data Extraction Form for Systematic Reviews and Research Syntheses was used and adapted for data extraction. Data from each included systematic review were extracted independently by both reviewers (DV, EBS). Results were compared and any discrepancies were resolved through discussion. We tabulated review characteristics, such as participants, setting, number of included studies and review results, such as effect of training on aerobic fitness, and training characteristics using the FITT characteristics.[7] Our primary outcome was aerobic fitness by any measure, for example: $\dot{V}O_2max$ and $\dot{V}O_2peak$,[25] six minute walk test (6MWT),[26] endurance capacity with Graded Exercise Testing, exercise tolerance with a BORG-scale, heart rate response during a graded or incremental exercise test and its recovery,[29] and muscle fatigue measured as the decline in maximal power and EMG activity after an incremental exercise test.[30]

The methodological quality of each included review was assessed independently by the two reviewers (DV, EBS), using the second version of “A MeaSurement Tool to Assess systematic Reviews” (AMSTAR 2).[31] The results of the quality assessment were compared and any discrepancies were resolved through discussion.

A narrative synthesis was used to describe the characteristics of aerobic fitness training and the effect on aerobic fitness in older or frail patients. A narrative analysis enables us to handle the expected large variety in health statuses, interventions and outcomes. For the evaluation of the effect on aerobic fitness, reviews were classified into one of the following categories: “positive effect”, “negative effect”, “inconclusive” or “no effect”, depending on the effect on aerobic fitness outcomes, such as $\dot{V}O_2max$ or 6MWT. Reviews, both meta-analyses and narrative reviews, were classified as “positive” if all of the comparisons, or at least all of the comparisons with non-exercise controls, had a statistically significant positive result. Reviews with narrative analyses were also classified as “positive” if at least 75% of the included comparisons had a statistically significant positive result. The same criteria (in the other direction) were used for classifying reviews as “negative”. Reviews, both with meta-analyses and with narrative analyses, were classified as having “no effect” if none of the comparisons had a statistically significant effect. Further, reviews were classified as “inconclusive” if the comparisons returned mixed results: some statistically significant positive results alongside not significant results. This classification of reviews was not described in-depth in the PROSPERO-protocol.

In addition, two subgroup analyses were performed. The first focused on reviews that specifically reported on dose-response relationships of aerobic fitness interventions to explore optimal training characteristics of aerobic fitness. This was not explicitly stated in the PROSPERO-protocol, but was added as further insights into dose effects are important for optimal exercise prescription. The second, predefined subgroup analysis explored the effects of aerobic fitness training in groups with specific health statuses or diagnoses, such as trauma patients and patients with respiratory diseases. In this second analysis, only reviews with complete FITT characteristics and with a risk of bias analysis were included. In the analyses of smaller subgroups, the reviews with incomplete reporting of FITT characteristics could represent an inaccurate picture as it is unknown if the not-reported FITT characteristics are within the range of the other reviews in the same subgroup. Moreover, we exclude studies with an unknown risk of bias as it is impossible to judge the quality of these studies in the analyses.

Patient and public involvement
No patient involved.

Data sharing statement
All data relevant to the study are included in the article or uploaded as supplementary information.

Results

The PRISMA flowchart can be found in Figure 1. It shows that 2,978 records were screened and 62 articles were assessed for full-text analysis. We finally included 51 articles in the narrative synthesis, of which three were based on the same data, leaving 49 individual systematic reviews for analysis[15, 19-22, 32-77]. Supplementary File B shows the characteristics of the included reviews, and Supplementary File C describes the interventions and a summary of the evidence from the included reviews. A list of excluded reviews is presented in Supplementary File D.

Quality assessment
The quality of included reviews is presented in Supplementary File E. According to the AMSTAR 2 ratings, sources of bias were, for example, lacking a report of a full PICO (14 reviews), no reported protocols prior to the start of the study (35 reviews) and no adequately explained decision to include RCTs, non-RCTs or their combination (44 reviews). Other sources of bias were: an incompletely described or incomprehensive literature search strategy (45 reviews) and the absence of a list of excluded studies in 41 reviews. A risk of bias analysis was performed in 40 reviews, but in only 13 did the authors take this risk of bias into account when discussing their results.

Participants
The total number of participants was 28,085 with a median number of 399 and a range of 92 to 5,230 participants per review. Only one review did not report the number of included patients. Due to large differences in reporting methods, we were not able to calculate a mean age for all of the participants. However, the mean age per review, at least for the subgroup of studies that reported on aerobic fitness outcomes, was at least 65 years. Gender was reported in only half of the included reviews. Reviews differed largely with respect to the health conditions of the studied population, varying from healthy participants to frail, hospitalised or institutionalised participants and many reviews focused on patients with specific diseases, such as heart failure or COPD. The experimental setting was unclear in the majority of studies. The settings that were reported mainly concerned community-dwelling older adults and, to a lesser extent, institutionalised patients, hospitalised patients or a mixed group.

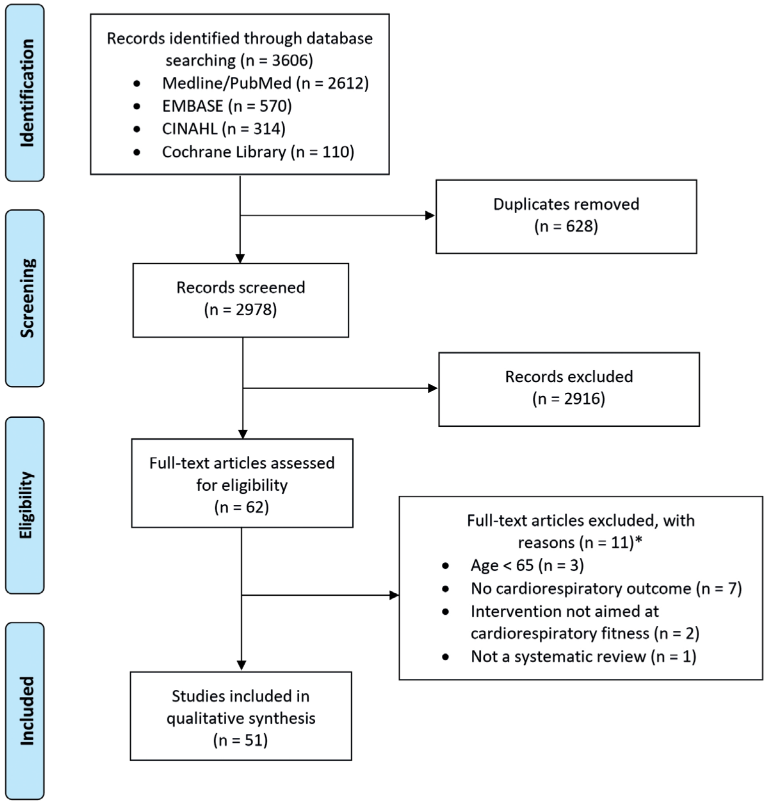

Figure 1. PRISMA Study flowchart.
* Full-text articles could be excluded for more than one reason, an overview per article can be found in appendix 4.

Characteristics of the interventions
Of the included reviews, 30 reported on all of the FITT characteristics of the underlying intervention studies. The frequency of interventions ranged from one session per week to five sessions per day. The exercise intensity was measured in several ways, for example, via estimated heart rate value, a percentage of the maximum workload or walking speed, or a predefined experienced exertion. The duration of training sessions lasted from several minutes to 120 minutes per session. The most common type of intervention was a mixed aerobics exercise program. Mixed programs were either combinations of different aerobic exercises or aerobic exercises combined with alternative forms of training, such as strength training. Walking and cycling were usually the major aerobic components in these mixed programs. Both were also widely used as single interventions. Other interventions consisted of: dancing, Pilates, interactive gaming, Nordic walking and rowing. The total duration of programs ranged from four days to two years.

Outcome measures

Twenty-three of the included reviews reported multiple outcome measures of aerobic fitness, mainly a combination of distance covered (in meters) on various walking tests and $\dot{V}O_2$ max or $\dot{V}O_2$peak, which were both measured in different ways. The distance covered during walking tests was reported as the sole outcome measure of aerobic fitness for 16 reviews, and the $\dot{V}O_2$max or $\dot{V}O_2$peak was the sole outcome measure in 8 reviews. In the remaining 2 reviews, the outcome measure was not specified. Further, less commonly used outcome measures were time to reach a predefined rate of perceived exertion and the peg-and-ring test, among others.

Effect of physical training on aerobic fitness

The effect of training on aerobic fitness is displayed in Table 1. Twenty-nine reviews contained a meta-analysis. Twenty-two of these reviews were classified as having a “positive effect”, 3 were “inconclusive” and 4 were classified as having “no effect”. Of the narrative reviews, 11 reviews were classified as having a “positive effect”, 8 were “inconclusive” and only 1 showed “no effect”. None of the reviews was classified as having a “negative effect”.

Table 1. Effect of aerobic fitness training according to health status or diagnosis.

	(Healthy) older adults	Frail older adults	Hospitalised after critical illness	Cardio-vascular disease	Cognitive impairment	Metabolic disease	Oncologic disease	Respiratory disease	Trauma	Mixed*	**TOTAL**
MA: positive effect for all comparisons	3 [40,52,65]			5 [22,44,45,69,75]	1 [58]	1 [46]	1 [72]	4 [21,59,63,67]		3 [37,49,50]	**18**
MA: positive effect, only for comparisons with non-exercise controls	1 [19]			1 [42]						2 [41,70]	**4**
NAn: positive effect for all studies	2 [38,54]	1 [47]		1 [60]	2 [3,48]						**6**
NAn: positive effect, only for all studies with non-exercise controls								1 [76]			**1**
NAn: positive effect for >75% of all studies		1 [33]	1 [55]			1 [39]				1 [71]	**4**
SUBTOTAL POSITIVE RESULTS	6	2	1	7	3	2	1	5	0	6	**33**
MA: inconclusive				1 [66]				2 [43,61]			**3**
NAn: inconclusive		2 [35,73]	1 [74]	2 [64,77]			3 [15,20,56]				**8**
SUBTOTAL INCONCLUSIVE RESULTS	0	2	1	3	0	0	3	2	0	0	**11**
MA: no effect	1 [68]			1 [32]				1 [62]	1 [57]		**4**
NAn: no effect		1 [34]									**1**
SUBTOTAL NOT SIGNIFICANT RESULTS	1	1	0	1	0	0	0	1	1	0	**5**
TOTAL	**7**	**5**	**2**	**11**	**3**	**2**	**4**	**8**	**1**	**6**	**49**

MA: Meta-analysis; NAn: Narrative analysis.
*: reviews of studies with multiple health conditions/diagnoses, for example with healthy and frail participants and participants with impaired balance.

Subgroup analysis: Dose-response relationships

Four reviews reported that they could not draw conclusions about dose-response relationships. One review found no dose-response relationships between physical training and aerobic capacity in older patients with heart failure.[75] Three publications, by the same authors and all based on the same 41 underlying studies, reported on dose-response relations of cardiorespiratory interventions in sedentary older adults.[51-53] In their most recent review, they concluded that a maximal gain in $\dot{V}O_2max$ could be induced by aerobic training at a mean intensity of 66-73% of heart rate reserve (HRR), when engaging in 40-50 minutes per session for 3-4 days per week for 30-40 weeks. The older adults began attaining $\dot{V}O_2max$ improvements at lower training intensities of 35-50% of HRR, and at a training length of at least 20-24 weeks. The studies in these reviews are 23 RCTs and 18 non-RCTs. The authors did not account for a risk of bias when interpreting the results.

Subgroup analyses: categories with specific health status or diagnosis

The reviews with complete FITT characteristics and with a risk of bias analysis could be divided into nine categories according to health status or diagnoses of their participants: (healthy) older adults (N=1), frail older adults (N=2), older adults hospitalised for an acute medical illness (N=1), cardiovascular disease (N=5), cognitive disorders (N=2), oncologic disease (N=3), respiratory disease (N=7), and trauma (N=1). Three studies, reporting on participants with mixed conditions, were not included in this analysis. For each review, the intervention and the summary of results is presented in Supplementary File C. In this file, the reviews that are included in this subgroup analysis are highlighted in italics.

(Healthy) older adults

One review reported on (healthy) older adults.[19] This study showed positive effects on $\dot{V}O_2peak$ and 6MWT from combined aerobic and strength training, compared to non-exercise controls. Two to three sessions per week were given, with light to vigorous intensity for 30-90 minutes. Total duration of the program varied from 6 to 52 weeks.

Frail older adults

Two reviews included frail older people,[33, 73] with one showing a positive effect,[33] while the other was inconclusive.[73]

Older adults hospitalised for acute medical illness

One review reported on older adults hospitalised for an acute medical illness and showed positive results.[55] Almost all of the FITT characteristics showed broad ranges.

Cardiovascular diseases

The group of cardiovascular diseases consisted of patients after heart surgery, with peripheral arterial disease or with an abdominal aortic aneurysm. Two reviews focused on patients after heart surgery. One found a positive effect on aerobic fitness after the training program in an uncontrolled before-after study.[69] The other review on heart surgery patients showed inconclusive results from *additional* aerobic or resistance training added to standard aerobic cardiac rehabilitation.[66] Two reviews investigated peripheral artery disease, of which one reported a positive effect and the other inconclusive results. One review showed positive effects on (pain-free) walking distance after a training program consisting of walking at an intensity that evoked severe claudication pain.[45] Another review demonstrated inconclusive results both in walking tests and in $\dot{V}O_2$peak compared to non-exercise controls, and no effect when aerobic exercise was compared to other types or intensities of exercise. Both the type and intensity of the training differed from the positive review: the types consisted of (treadmill) walking, lower limb aerobics, pole striding and arm cranking at a vigorous intensity, or at an intensity that evoked moderate to maximum claudication pain. One review reported on the effect of preoperative exercise for patients with an abdominal aortic aneurysm and showed inconclusive results.[77]

Cognitive disorders

Both reviews showed a positive effect on walking tests. The severity of cognitive disorders varied from Mild Cognitive Impairment (MCI) to dementia. Blankevoort reported better outcomes for programs with a longer duration,[36] and Lam showcased an effective increase in training in studies with an intensity of 30-60% of $\dot{V}O_2$max or 40% HRR that gradually progressed to 85%.[58]

Oncologic diseases

One review reported a positive effect in patients with prostate cancer.[72] The other two reviews had inconclusive findings for patients with colorectal cancer[20] and small-cell lung cancer.[15] The review showcasing a positive effect seemed to have a higher frequency and intensity than the inconclusive reviews.

Respiratory disease

The group concerning respiratory diseases consisted of patients with COPD, non-cystic fibrosis bronchiectasis or non-malignant, dust-related respiratory diseases. Five reviews studied patients with moderate to severe COPD. Positive effects on aerobic fitness were found for aerobic training both in stable COPD patients and in patients shortly after an exacerbation, and both for home-based and for outpatient rehabilitation. The effect of (additional) resistance training is not clear; one review showed an inconclusive effect[61], while another study showed no statistically significant effect.[62] The review on non-cystic fibrosis bronchiectasis was judged to be inconclusive, with positive effects on 6MWT but no effect on $\dot{V}O_2$max.[59] The review on patients with non-malignant, dust-related respiratory disease demonstrated positive effects.[43]

Trauma patients

The last category consisted of trauma patients with hip fractures in one review.[57] Low-frequency and moderate intensity programs showed no effect on aerobic fitness.

Adverse events

Twenty reviews intended to report on adverse events, but they all concluded that there was a lack of information on adverse events in the underlying studies. Of these twenty reviews, nine reviews either found no adverse events or no difference in the presence of adverse events, compared to non-exercise controls[22, 45, 78]. Seven reviews reported no serious or very few adverse events. One review reported serious adverse events that occasionally resulted in discontinuation of the exercise and even resulted in one death.[37] The training programs described in this review were for individuals with severe hypertension, mixed diagnoses or heart failure patients, and had a frequency of 3 sessions per week, lasting 20-60 minutes for a duration of 12-24 weeks and were of light to vigorous intensity.

Description of excluded studies
Eleven of the 62 full-text papers were excluded after assessment (Figure 1). The most important reasons for exclusion in this phase were the lack of aerobic outcomes, a participant mean age of under 65, or a lack of a subgroup analysis for this age criterion (see Supplementary File E).

Discussion

This umbrella review was set up to study the effectiveness and characteristics of physical fitness training on aerobic fitness in vulnerable older adults and included 51 papers on 49 individual systematic reviews (N= 28,085 participants). The majority of the included reviews found a statistically significant positive effect of physical fitness training on aerobic fitness. We found a large heterogeneity in the reported FITT characteristics of the included interventions. Only one review found dose-effect relations for healthy older adults. For almost all categories of researched health statuses, studies with positive effects of physical fitness training were found with some variation in the FITT characteristics reported between the categories.

Comparison with current guidelines
For older adults, the ASCM published general recommendations for physical activity (in conjunction with the American Heart Association (AHA)),[9] and specific critical issues for exercise and training.[4] Guidelines for aerobic training in the position stand were derived from one of the papers based on the review of Huang that we included in this umbrella review. It states that "aerobic exercise training programs of sufficient intensity (>60% of pre-training $\dot{V}O_2$max), frequency, and length (>3 sessions per week for 16 weeks) can significantly increase $\dot{V}O_2$max in healthy middle-aged and older adults". Recently, expert guidelines were published for exercising in older adults, including slightly adjusted FITT criteria and modality-specific adaptations.[12] Our review shows that for healthy older adults the guidelines of ACSM/AHA still apply to a great extent, although lower frequencies of 2-3 sessions per week are also beneficial.[19] Another finding from our review is that for most groups of older adults with impaired health, cardiorespiratory fitness can be improved with programs that are offered less frequently and with less intensity than the ACSM/AHA guidelines prescribe.[19, 21, 33, 36, 45, 58, 63, 69, 76] This lower intensity is in line with the expert guidelines of Izquierdo et al.[12] Also in accordance with Izquierdo and colleagues, for the most vulnerable older adults, short sessions were most appropriate. The latter raises the question as to whether training load is best determined by separate FITT characteristics or whether it should be merged in an overarching measure that is based on an interdependency between Frequency, Intensity and Time. In such an overarching measure, the underlying FITT characteristics can be adjusted to a patient's needs as long as the combination of the characteristics meets the conditions of the overarching measure.[78]

Adverse events
Due to a lack of information on adverse events in the reviews, no firm conclusions can be drawn about safety, although the available information indicates that serious adverse events rarely occur.

Interpretation of results in the context of physiological principles of training

Aerobic fitness is the ability of the circulatory and respiratory systems to supply oxygen to the tissues. The transport of oxygen consists of several steps from ventilation of the alveoli to extraction of the oxygen from the blood at the tissue level.[79] In normal ageing, changes in the respiratory, cardiovascular and musculoskeletal systems lead to a decrease in aerobic fitness[4] that can be enhanced by specific health conditions. Impairment of one step in the aerobic pathway may be compensated by other steps. This means that the training of aerobic fitness in vulnerable older adults can focus on either improvement of impaired steps in the oxygen transport pathway, or on improvement of other, compensating steps. [79] An example of a mechanism of improvement of the impaired step is seen in the reviews concerning peripheral artery disease, where training at an intensity that induces severe claudication pain seems to be more beneficial for increasing (pain-free) walking distance than training at a moderate pain level or at a certain percentage of $\dot{V}O_2$max.[45, 64] Intensity beyond the pain threshold may lead to an increase in the local production of collateral blood vessels[80]. An improved vascularisation of the lower limbs leads to an increase in the oxygen delivery and thus contributes to improved aerobic fitness. The mechanism in which training focuses on the improvement of compensating steps is also expected for COPD patients, where the lung function decrease is irreversible. Therefore, it is likely that training which emphasises improvement of cardiovascular or muscle functioning will be successful in improving aerobic fitness in this patient group.[80] From this perspective, it seems surprising that we only found inconclusive results for resistance training, with no effect on $\dot{V}O_2$max and positive results on 6MWT and the peg-and-ring test. These results show that although the $\dot{V}O_2$max cannot improve (due to irreversible lung damage), submaximal performance (6MWT, peg-and-ring test) can improve through compensating mechanisms.[81]

Our review shows that for frail older adults, short session durations, from as little as eight minutes, are beneficial when they include both aerobic and resistance training. Most programs were progressive in time or intensity. This suggests that the programs were fit to the abilities of the frail older adults, and thus able to provide a suitable stimulus for improvement of aerobic fitness. The combination of aerobic and resistance training suggests that multiple steps in the aerobic pathway are trained leading to a general improvement of the aerobic pathway.

Another finding of our review is the fact that many reviews included studies with short intervention durations. A deeper exploration of those studies revealed improvements in aerobic fitness for interventions with a duration of less than six weeks (not reported in the results section). Generally, the cardiovascular system is the major limiting factor in aerobic fitness, and adaptations to the cardiovascular system are expected after at least six weeks.[82] The findings of the studies with short interventions in our review suggest that in those patients the improvements in aerobic fitness are induced by capillary and/or mitochondrial adaptations that can be initiated within 14 days of endurance training.[83]

In Table 2, we summarise our interpretation of the findings of this review, in comparison with the existing guidelines.

Table 2. Summary of the evidence.

Healthy older adults • The guidelines of ACSM and AHA apply to a great extent, although lower frequencies of 2 to 3 sessions per week are also beneficial. • Optimal training programs are 3 to 4 sessions per week, ranging from 40 to 50 minutes, for 32 to 36 weeks at a moderate to vigorous intensity of 66-73% of HRR.
Vulnerable older adults: general • For almost all researched health conditions, aerobic fitness can improve through training. • High frequencies, short sessions and low intensity seem appropriate for *the most vulnerable older adults*. For example, after acute medical illness, heart surgery or exacerbation COPD. • For *most patient groups,* aerobic fitness can improve in programs with a lower frequency and intensity than ACSM and AHA guidelines prescribe.
Vulnerable older adults: specific health conditions • For *frail older adults* aerobic fitness can improve in programs with shorter sessions and programs that consist of both aerobic and resistance training. • For *patients after cardiovascular surgery* and for *patients with COPD* there is no evidence that the addition of extra aerobic or resistance training to an aerobic training program does improve cardiovascular fitness. • For *patients with peripheral artery disease* walking at an intensity that evokes severe claudication pain improves (pain-free) walking distance. • For *patients with non-malignant, dust-related diseases* low frequencies (2-3 per week) and relatively short sessions (15-30 minutes) are advised. • For patients with non-small-cell lung cancer vigorous intensities are advised. • For *patients after trauma* training programs with a low frequency, relatively short sessions and program duration do not improve their cardiovascular fitness • For *patients with abdominal aortic aneurysm* there is no evidence that exercise improves aerobic fitness.

ACSM = American College of Sports Medicine; AHA = American Heart Association; COPD = Chronic Obstructive Pulmonary Disease; HRR = Heart Rate Reserve.

Strengths and limitations

An important strength of our review is our conceptual approach to the "geriatric rehabilitation population". This population is characterised by a combination of older age and vulnerability, with a large degree of heterogeneity, which is difficult to operationalise within inclusion criteria. For that reason, we decided to use an age criterion (>65 years), and to include reviews with a large variety of health statuses, which may influence the degree of vulnerability. A second strength is the use of a narrative approach which enabled us to make the variety in the evidence visible, instead of reducing the evidence to a simplified number that may not be applicable to a specific situation. Through these choices, we aimed to do justice to the heterogeneity of vulnerability in older adults.

Our review has several limitations. Firstly, there is significant heterogeneity among the designs of the studies included in the reviews, ranging from RCTs to studies without a control group. This results in evidence of varying scientific quality, including a great variety in the risk of bias. Secondly, in the subgroup analyses on categories with specific health statuses, we excluded the reviews with incomplete FITT characteristics and the reviews without a risk of bias analysis. This decision had the disadvantage that not all of the available evidence was used for our final conclusions of these subgroup analyses. Nevertheless, this decision led to better justified evidence. A third limitation is the fact that the reported training prescription may not always reflect the actual performed training. Authors should make an effort to report on these measures as well. A last limitation is the large variation of the interventions, the outcomes, and the description of the FITT characteristics across studies, in particular with regards to the intensity. Intensity is described with robust measures (such as percentage of $\dot{V}O_2$peak, and their derivative measures, such as percentage of maximal heart rate), with measures that depend on multiple body functions (for example, a percentage of the speed on a given walking test) and lastly with measures that are hard to interpret or compare, such as “comfortable walking speed” or an unspecified “moderate to high” intensity.

Due to this large heterogeneity in intensity measures, it is difficult to ascertain which measure is the best representation of intensity of aerobic fitness training. Training should be based on an intensity that enforces physiological adaptations. For this purpose, the so-called ventilatory thresholds have been proposed, which represent the extent to which the aerobic system is able to meet the energy demand. The aerobic thresholds are dependent on aerobic fitness and can be used for safe and personalised exercise prescription. These thresholds are not so much determined by a fixed percentage of, for example $\dot{V}O_2$max, but require specialised equipment that is usually not available in exercise settings for vulnerable older adults. In just two of the reviews, were these thresholds used. The development of easily accessible methods to establish the ventilatory thresholds could contribute to a more personalised prescription of exercise intensity.

Recommendations

Future research should focus on easily accessible methods that reflect relevant markers of aerobic exercise intensity more appropriately, such as based on the ventilatory thresholds, and on the feasibility of an overarching measure for training load that relates to the FITT characteristics. The effect of aerobic training programs with low frequencies combined with light intensities should be further assessed, and finally, effective aerobic training programs for trauma patients (e.g., after hip fracture) should be developed and investigated.

Conclusions

In conclusion, physical fitness training can be an effective intervention to improve aerobic fitness in older adults in general, and also in the majority of categories of older adults with specific health statuses or diagnoses, including the most frail and vulnerable older adults. The effective training characteristics of Frequency, Intensity, Time and Type comply to a great extent to the guidelines of the ACSM and the AHA. For vulnerable older adults, we found evidence that lower frequencies of two to three sessions per week and lower intensities were most beneficial, for most categories. For some conditions, specific adjustments to the FITT characteristics are advised. These findings can be used for better exercise prescription for vulnerable older adults in general, and thus the specific group of patients in geriatric rehabilitation.

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Competing interests
The authors declare that they have no competing interests.

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Ethics approval
Not applicable for this type of research.

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Supplementary files

Supplementary file A. Search strategy in Medline

#1 Frail elderly
"Aged"[Mesh] OR "Geriatric Psychiatry"[Mesh] OR "Geriatric Nursing"[Mesh] OR "Health Services for the Aged"[Mesh] OR "Geriatric Assessment"[Mesh] OR "Alzheimer Disease"[Mesh] OR "Dementia"[Mesh] OR frail*[tiab] OR elder*[tiab] OR eldest[tiab] OR geriatri*[tiab] OR old age*[tiab] OR oldest old*[tiab] OR senior*[tiab] OR senium[tiab] OR very old*[tiab] OR septuagenarian*[tiab] OR octagenarian*[tiab] OR octogenarian*[tiab] OR nonagenarian*[tiab] OR centarian*[tiab] OR centenarian*[tiab] OR supercentenarian*[tiab] OR older people[tiab] OR older subject*[tiab] OR older patient*[tiab] OR older age*[tiab] OR older adult*[tiab] OR older man[tiab] OR older men[tiab] OR older male*[tiab] OR older woman[tiab] OR older women[tiab] OR older female*[tiab] OR older population*[tiab] OR older person*[tiab] OR ageing[tiab] OR community dwelling[tiab] OR "mini mental state"[tiab] OR alzheimer[tiab] OR alzheimer's[tiab] OR alzheimers[tiab] OR mmse[tiab] OR gds[tiab] OR dementia[tiab] OR demented[tiab] OR psychogeriatrics[tiab]

OR

Setting: Hospital, nursing home, homecare etc.

"Hospitals"[Mesh] OR "Nursing Homes"[Mesh] OR "Home Care Services"[Mesh] OR "Housing for the Elderly"[Mesh] OR "Senior Centers"[Mesh] OR "Ambulatory Care"[Mesh] OR "Institutionalization"[Mesh] OR "Long-Term Care"[Mesh] OR "Hospitalization"[Mesh] OR hospital*[tiab] OR home[tiab] OR homes[tiab] OR housing[tiab] OR Community Health Service*[tiab] OR communit*[tiab] OR senior center*[tiab] OR senior centre*[tiab] OR outpatient*[tiab] OR ambulatory[tiab] OR Institution*[tiab] OR "Long-Term Care"[tiab] OR Hospitalization[tiab] OR Hospitalisation[tiab]

#2 Physical fitness
"Gymnastics"[Mesh] OR "Physical Conditioning, Human"[Mesh] OR "Running"[Mesh] OR "Swimming"[Mesh] OR "Walking"[Mesh] OR "Sports"[Mesh] OR "Physical Exertion"[Mesh] OR "Exercise Therapy"[Mesh] OR "Exercise Movement Techniques"[Mesh] OR Motor Activit*[tiab] OR Physical Activit*[tiab] OR Locomotor Activit*[tiab] OR Exercis*[tiab] OR Physical Exercis*[tiab] OR Aerobic Exercis*[tiab] OR training[tiab] OR Physical Condition*[tiab] OR Physical fitness[tiab] OR Physical endurance[tiab] OR movement therap*[tiab] OR fitness training[tiab] OR Weight-Bearing[tiab] OR running[tiab] OR jogging[tiab] OR walk*[tiab] OR bicycle[tiab] OR cycle[tiab] OR bicycling[tiab] OR cycling[tiab] OR rowing[tiab] OR swim*[tiab] OR ambulation[tiab] OR step[tiab] OR steps[tiab] OR treadmill[tiab] OR skate*[tiab] OR skating[tiab] OR handbike*[tiab]

#3 Outcome (muscle strength, cardiovascular fitness, endurance etc.)
"Muscle Fatigue"[Mesh] OR "Physical Endurance"[Mesh] OR "Physical Fitness"[Mesh] OR "muscle fatigue"[tiab] OR "muscular fatigue" [tiab] OR "muscle morphology"[tiab] OR Physical Endurance*[tiab] OR Anaerobic Threshold*[tiab] OR "exercise tolerance"[tiab] OR "muscle

fatigue"[tiab] OR "physical Endurance"[tiab] OR "fatigue resistance"[tiab] OR "physical fitness"[tiab] OR "aerobic capacity"[tiab] OR "VO2peak"[tiab] OR "VO2max"[tiab] OR "HR responses"[tiab] OR "heart rate response"[tiab] OR "aerobic fitness"[tiab] OR "endurance"[tiab] OR "cardiovascular function"[tiab] OR "cardiovascular fitness"[tiab] OR "cardiorespiratory function"[tiab] OR "cardiorespiratory fitness"[tiab] OR "2 min walk test"[tiab] OR "4 min walk test"[tiab] OR "6 min walk test"[tiab]

#4 Review humans/ humans
(("Review Literature as Topic"[Mesh] OR "Review"[Publication Type] OR "Meta-Analysis as Topic"[Mesh] OR review[tiab] OR meta-analys*[tiab] OR "Meta-Analysis "[Publication Type] OR systematic[sb]) NOT ("Letter"[Publication Type] OR "Editorial"[Publication Type] OR "Comment"[Publication Type]))

NOT ("animals"[MeSH Terms] NOT "humans"[MeSH Terms])

Supplementary file B. Characteristics of all included reviews.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Ada 2010	To examine the beneficial and harmful effects of mechanically assisted walking with body weight support in subacute, non-ambulatory patients after stroke in the short and the long term. Cardiorespiratory fitness is a secondary outcome.	n=4 2006 - 2010	Stroke patients in inpatient rehabilitation n=348 Mean age range 63 to 73	F: 5 sessions/week I: - T: 20 to 60 minutes/session T: Any type of mechanically assisted walking and assisted overground walking Total duration: 4 to 6 weeks or until discharge from inpatient rehabilitation Control conditions: Not-AT	3/6 Meta-analysis, 6MWT PEDro scores
Angevaren 2008	To assess the effectiveness of physical activity, aimed at improving cardiorespiratory fitness, on cognitive function in older people without known cognitive impairment. Cardiorespiratory fitness is a secondary outcome.	n=6 1989 - 2002	Frail older adults with age related illnesses, not cognitively impaired, and not recovering from surgical treatment n=667 Age range 55-91	F: 2 to 7 sessions/week I: 70% HRmax, HR at VT, HR of 95 to 125, 50 to 75% VO2 max, 50 to 65% HRR or 85% HRR T: 8 to 60 minutes/session T: Aerobic exercise programs (walking, cycling, jogging, running, mixed exercise) Total duration: 8 to 26 weeks Control conditions: UC, No-Ex, Not-AT/RT	11/11 Narrative analysis VO2max CLEAR NPT
Anthony 2013	To examine the beneficial and harmful effects of exercise programmes performed primarily in the seated position for frail older people who are unable to perform standard evidence-based exercise programmes. Cardiorespiratory fitness is a primary outcome.	n=10 1997 - 2005	Frail older adults in various settings n=82 Mean age 80,5	F: 2 sessions/week I: - T: - T: Chair based exercise Total duration: 3 months Control conditions: UC, No-Ex, Not-AT	1/6 Narrative analysis 6 MWD Jaded scale

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Baker 2007	To systematically review all health outcomes to concurrent strength, aerobic, and balance training in older adults to assess the current level of evidence regarding the feasibility and efficacy of current guidelines. Cardiorespiratory fitness is a primary outcome.	n=8 1993 - 2007	Community living frail older adults n=479 Mean age range 67 to 84	F: 3 sessions/week I: 13 to 16 on BORG scale, 70% HRmax, 70% HRR, 65-70% VO2peak T: 8.3 to 45 minutes/session T: Walking, cycling ergometer training, rowing ergometer training Total duration: 12 weeks - 6 months Control conditions: No-Ex	4/15 Narrative synthesis 6 MWD, VO2peak Modified from Delphi list (Verhagen et al)
Blankevoort 2010	To investigate whether physical activity can improve mobility, lower-extremity strength, balance, walking endurance and BADL in elderly individuals with dementia. Cardiorespiratory fitness is a primary outcome.	n=6 1995 - 2009	Older adults with dementia n=253 Mean age range 78.8 to 87.1	F: 2 to 3 sessions/week I: start at 30% VO2 max up to 60% VO2max T: 30 to 60 minutes/session T: Walking, strength, balance aerobic exercises, functional skills Total duration: 12 weeks to 2 years Control conditions: UC, No-Ex	5/16 Meta-analysis 2 MWT, 6 MWT, 2-min step test Downs and Black checklist and Sackett et al checklist.
Bouaziz 2015	To assess the health benefits of endurance training alone or combined with diet for obese people aged over 60. Cardiorespiratory fitness is a primary outcome.	n=8 1995-2014	Obese older adults n=832 Mean age range 61 to 76.2	F: 3 to 7 sessions/week I: 40 to 85% HRR, 50 to 75% VO2max, 60 to 85% HRmax T: 12 to 90 minutes/session T: Cycling on ergometer, walking, treadmill walking Total duration: 12 to 36 weeks Control conditions: UC, No-Ex, AT	26/26 Narrative VO2max (23 studies) Not reported

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Bouaziz 2016	To assess the potential health benefits of multicomponent training for adults aged 65 years or over. Cardiorespiratory fitness is a primary outcome.	n=8 2000-2015	Older adults n=NOT REPORTED Mean age range 70 to 83	F: 3 sessions/week I: - T: 90 minutes/session T: Combination of endurance, strength, balance and flexibility training (2 non-RCTs) or combination of endurance, strength, balance, flexibility and coordination training (1 RCT) Total duration: 10 to 36 weeks Control conditions: NOT REPORTED	3/27 Narrative synthesis VO2peak Not specified
Bouaziz 2018	To estimate to what extent the exact benefits of aerobic training are in terms of VO2peak among healthy and unhealthy seniors aged 70 years or older. Cardiorespiratory fitness is a primary outcome.	n=6 1989 -2013	Older adults, both healthy and with chronic health conditions n=348 Mean age range 70 to 79	F: 3 to 4 sessions/week I: 50% to 85% of VO2peak, 40 to 80% of HRR, 50% to 95% of HRmax T: 15 to 60 minutes/session T: Walking, cycling on ergometer, treadmill walking and walking/running on a mini-trampoline Total duration: 12 to 26 weeks Control conditions: UC, Not-AT	10/10 Meta-analysis VO2peak Cochrane Collaboration risk of bias assessment
Bruns 2016	To assess the effects of prehabilitation in patients aged over 60 years undergoing colorectal surgery. Cardiorespiratory fitness is a secondary outcome.	n=4 2010-2015	Patients undergoing elective colorectal surgery n=353 Mean age range 60 to 72	F: 3 to 7 sessions/week I: 40 to 80% peak HR T: 20 to 30 minutes/session T: Cardiopulmonary aerobic exercise Total duration: 24 to 38 days Control conditions: UC, No-Ex, Not-AT	5/5 Narrative VO2 at VT, 6MWT Cochrane risk of bias tool

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Bueno de Souza 2018	To examine evidence from RCTs to determine the effects of mat Pilates on measures of physical functional performance in the older persons. Cardiorespiratory fitness is a primary outcome.	n=5 2011-2017	Healthy older adults in various settings n=156 Mean age 65.8	F: 2 to 3 sessions/week I: - T: 60 minutes/sessions T: Pilates Total duration: 8 to 24 weeks Control conditions: No-Ex	3/9 Meta-analysis 6MWT, VO2max PEDro score
Bullo 2018	To summarize and analyse the effectiveness of Nordic walking interventions on the physical fitness, the body composition, and the quality of life in the elderly population. Cardiorespiratory fitness is a primary outcome.	n=6 2013-2017	Older adults with various health conditions n=536 Mean age 60 to 92	F: 2 to 3 sessions/week I: 60 to 70% max ability, progressive intensity up to 12 to 14 RPE, 50 to 60% HRmax, moderate intensity (12 to 14 RPE), moderate to high intensity (HR 100 to 120 bpm), comfortable pace T: 20 to 80 minutes/session T: Nordic walking Total duration: 6 to 35 weeks Control conditions: No-Ex	9/15 Meta-analysis 6 MWT, 12 MWT, 5mWT, 2minST , VO2max Cochrane Collaboration Back review Group.
Cugusi 2017	To appraise the available evidence on the health effects and clinical relevance of Nordic walking in individuals with established cardiovascular diseases and, to determine a precise estimate of Nordic walking-induced changes on outcomes in individuals diagnosed with cardiovascular diseases. Cardiorespiratory fitness is a primary outcome.	n=5 2002-2016	Older adults with various cardiovascular diseases: coronary artery disease, peripheral arterial disease, hart failure, post stroke survivors. n=766 Age range 40-80	F: 2 to 5 sessions/week I: - T: 30 to 60 minutes/session or 2.5 to 3km T: Nordic walking Total duration: 3 to 24 weeks Control conditions: UC, No-Ex, AT	15/15 Meta-analysis 6 MWT, VO2peak PEDro score

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Dale 2015	To assess the effects of exercise training on exercise capacity, health-related quality of life and levels of physical activity in people with non-malignant dust-related respiratory diseases compared with control, placebo or another non-exercise intervention. Cardiorespiratory fitness is a primary outcome.	n=7 2008-2014	Older adults with non-malignant dust-related respiratory diseases n=39 Mean age range 67 to 72	F: 2 to 3 sessions/week I: 80% of walking speed on initial 6MWT and progressed weekly, initial intensity of 60% peak work at baseline incremental cycle test and progressed weekly T: 15 to 30 minutes/session T: Cycling, walking Total duration: 8 weeks Control conditions: No-Ex	2/2 Meta-analysis 6 MWT, peak work rate. Cochrane Risk of Bias and GRADE.
Doyle 2019	To assess the clinical outcomes of aerobic exercise commenced within two weeks of cardiac surgery. Cardiorespiratory fitness is a primary outcome.	n=5 1984-2016	Older adults undergoing cardiac surgery n=2175 Mean age 66	F: 1 to 14 sessions/week I: 3 to 7 RPE (10pt scale), 10 to 13 RPE, 65 to 75% max HR, anaerobic threshold T: 3 to 60 minutes/session T: Walking, stationary cycling or both Total duration: length of hospital stay to 6 months Control conditions: UC	18/18 Meta-analysis 6MWT, VO2peak Not reported
Fukuta 2016	To determine the effects of cardiovascular drug or exercise intervention on exercise capacity and quality of life in patients with heart failure with preserved ejection fraction. Cardiorespiratory fitness is a primary outcome.	n=2 2003-2013	Older adults with heart failure with preserved of >40% ejection fraction. n=245 Mean age 67.6	F: 2 to 3 sessions/week I: - T: 20 to 60 minutes/session T: Walking, walking and cycling, cycling and cycling and resistance training Total duration: 12 to 24 weeks Control conditions: UC, No-Ex	5/13 Meta-analysis, 6 MWD, VO2peak Not reported

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Gardner 2014	To provide a comprehensive and up-to-date summary of the effects of exercise on treatment-related adverse effects for patients with prostate cancer receiving androgen-deprivation therapy. Cardiorespiratory fitness is a primary outcome.	n=6 2003-2012	Older adults with prostate cancer n=565 Mean age range 63 to 72	F: 1 to 5 sessions/week I: 55% to 85% HRmax, 11 to 15 RPE, 50% to 75% peak oxygen uptake T: 15 to 60 minutes/session T: Walking, aerobic exercises Total duration: Control conditions: NOT REPORTED	10/10 Narrative synthesis 6MWT, 400m walk, time to reach RPE15 in treadmill protocol. Downs and Black checklist.
Golledge 2019	To summarize evidence from randomized controlled trials of the efficacy of structured home exercise programmes, in comparison to controls not receiving an exercise programme, in improving walking performance and objectively measured physical activity in patients with peripheral artery disease Cardiorespiratory fitness is a secondary outcome.	n=5 1966-2018	Older adults with peripheral arterial disease n=524 Mean age range 57 to 70	F: 3 to 5 sessions/week I: until severe leg discomfort experienced, a speed that evokes strong claudication pain, severe discomfort (12–14 on Borg rating), a brisk pace that elicits pain within 3–5minutes T: 10 to 50 minutes/session T: Walking Total duration: 6 to 36 weeks Control conditions: No-Ex	11/11 Meta-analysis 6 MWT Cochrane collaboration tool for assessing risk of bias

2

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Gomes-Neto 2019	To determine the effects of whole-body vibration training on metabolic abnormalities, mobility, balance and aerobic capacity in older adult patients with type 2 diabetes and to provide information concerning the vibration exercise regimens that may be most suitable for improving health in this population. Cardiorespiratory fitness is a primary outcome.	n=5 2011-2017	Patients with type 2 diabetes n=59 Age range 45 to 80	F: 3 sessions/week I: - T: 12 to 24 minutes/session T: Whole to body vibration training alone or in combination with exercises on the spot Total duration: 8 to 12 weeks Control conditions: NOT REPORTED	2/7 Meta-analysis 6 MWT PEDro score
Halloway 2015	To examine the effect of prehabilitation randomized clinical trial interventions on physical activity behaviour and dimensions of physical fitness in older adults. Cardiorespiratory fitness is a primary outcome.	n=5 1996-2014	Frail older adults scheduled for total hip arthroplasty n=30 Mean age range 67	F: 2 to 4 sessions/week I: - T: 30 minutes/session T: Walking, individual exercises Total duration: 3 to 6 weeks Control conditions: UC	1/7 Meta-analysis 6 MWT Not reported
Hernandez 2015	To identify and characterize the scientific literature regarding the effects of exercise on Alzheimer's Disease. Cardiorespiratory fitness is a secondary outcome.	n=5 2003-2013	Patients with Alzheimer's disease n=131 Age not reported, but likely>65	F: 3 to 5 sessions/week I: moderate to intensive (subjective inability to speak a sentence) T: 15 to 45 minutes/session T: Walking, multimodal exercise, cycling Total duration: 2 to 6 months Control conditions: No-Ex, No control	5/14 Narrative synthesis 6 MWT, SWT, VO2 Own criteria

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Heyn 2008	To compare endurance and strength outcomes of cognitively impaired and cognitively intact older adults who participate in similar randomized exercise trials, and to provide a quantitative answer concerning the relative benefits of exercise for impaired and non-impaired elderly. Cardiorespiratory fitness is a primary outcome.	n=13 1974-2004	Older adults with and without cognitive impairment n=1057 Mean age range 74 to 91	F: 2 to 5 sessions/week I: - T: 30 to 90 minutes/session T: Aerobic training, variable-intensity group exercise program, multicomponent functional fitness training, endurance exercises Total duration: 2 to 40 weeks Control conditions: No-Ex	15/41 Meta-analysis 1 mile walk, 6MWT, 2 MWT, max Walking Time, 6 min aerobics, Walking endurance. UTMB/TLC Interventions Trial Quality Form
Howes 2017	To update and extend the available evidence for the physical and cognitive effects of active computer gaming in older adults. Cardiorespiratory fitness is a primary outcome.	n=4 2003-2015	Healthy and frail older adults n=427 Mean age range 71 to 85	F: 1-4 sessions/week I: - T: 45 to 90 minutes/session T: Active computer gaming Total duration: 4 weeks to 6 months Control conditions: No-Ex, Not-AT, AT	8/25 Meta-analysis 6 MWT Cochrane Risk of Bias and GRADE.
Huang 2002	To determine the effects of controlled endurance or aerobic exercise training on physiological changes in cardiovascular function and pulmonary function among older adults aged 60 years and over. Cardiorespiratory fitness is a primary outcome.	n=4 1983-2001	Sedentary healthy older adults n=2102 Mean age range 67 to 67	F: 1 to 5.2 sessions/week I: 60 to 85% HRmax, 52 to 82% VO2max, 35 to 80% HRR, 100.4 to 129 bpm as absolute number of HRmax T: 18,7 to 60 minutes/session T: Walking, jogging, cycling, aerobic dance and aerobic games Total duration: 8 to 52 weeks Control conditions: UC	41/41 Meta-analysis VO2max Not reported

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Huang 2005	To determine the effects and direction of endurance training programs on VO2max in sedentary older adults, to quantify the magnitude of observed changes, and to examine the influence of certain variables, such as study design, individual physical characteristics, and characteristics of training programs on the changes. Cardiorespiratory fitness is a primary outcome.	n=6 1983-2000	Sedentary healthy older adults n=2102 Mean age range 67 to 68	F: 1 to 4.9 sessions/week I: 60% to 85% HRmax, 50% to 82% VO2max, 35% to 80% HRR, 107 to 129 bpm HRmax T: 20 to 60 minutes/session T: Walking, jogging, cycling, stair to climbing, aerobic dance, tai chi chuan, outdoor performance or aerobic games Total duration: 8 to 52 weeks (22.7±12.1 weeks) Control conditions: UC	41/41 Meta-analysis VO2max Jadad scale
Huang 2016	To qualify the dose–response relationship between different training regimens and the induced VO2max improvements. Cardiorespiratory fitness is a primary outcome.	n=not reported, hand searching 1983-2000	Sedentary healthy older adults n=2102 Mean age range 67 to 69	F: 2.9 to 4.9 sessions/week I: exercise intensity varied and was expressed as percent maximum heart rate (% HRmax), percent VO2max reserve (%VO2R) % VO2max, % VO2R, % HRR, or HRmax T: 20 to 60 minutes/session T: Walking, jogging, running, cycling, stair climbing, aerobic dancing, outdoor aerobic performance, and aerobic games Total duration: 8 to 52 weeks Control conditions: UC	41/41 Meta-analysis VO2max Instrument not reported

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Hurst 2019	To systematically review and meta-analyse the effects of same session combined exercise training on measures of fitness in adults aged over 50 years, while also exploring the modifying effects of study and subject characteristics. Cardiorespiratory fitness is a primary outcome.	n=5 1991-2018	Healthy community-dwelling older adults n=1131 Mean age 70.1	F: 2 to 3 sessions/week I: 50 to 75% HRmax, 60 to 80% HRR, 80% HRVT2 or RPE 12 to 14 T: 30 to 90 minutes/session T: Combined (strength and endurance) training and endurance training ((Treadmill) walking, running, cycling, cross-trainer, stationary cycling, dance) Total duration: 6 to 52 weeks Control conditions: UC, AT, RT	24/27 Meta-analysis VO2peak, 6MWT Cochrane Collaboration's tool for assessing risk of bias
Hwang 2015	To examine the effectiveness of dance programs in improving the physical health of all older adults, both those with health conditions and those considered healthy. Cardiorespiratory fitness is a primary outcome.	n=1 2004-2013	n=97 Mean age range 52	F: 2 sessions/week I: - T: 50 minutes/session T: Dance Total duration: 12 weeks Control conditions: UC	1/18 Narrative analysis VO2max Criteria provided by Sackett and Megens and Harris
Kanach 2018	To examine the effects of structured exercise (defined as aerobic walking, with or without complementary modes of exercise) on performance measures, mobility, functional status, healthcare utilization and Quality of Life, in older adults hospitalized for acute medical illness. Cardiorespiratory fitness is a primary outcome.	n=3 2000-2014	Older adults who were hospitalized for an acute medical episode: chronic respiratory disease, COPD, diabetes mellitus. n=556 Mean age range 60 to 78	F: 5 to 35 sessions/week I: 125% of best 6 MWD, 85% predicted VO2max T: 10 to 60 minutes/session T: Aerobic walking, combined training with aerobic component Total duration: hospital length of stay to 18 months Control conditions: UC, No-Ex	4/11 Narrative analysis VO2max, 6 MWD, endurance shuttle walk Cochrane Risk of Bias assessment

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Keogh 2012	To systematically review the literature for the chronic benefits of exercise in reducing symptoms and improving quality of life in prostate cancer patients. Cardiorespiratory fitness is a primary outcome.	n=3 2003-2010	Patient with prostate cancer n=289 Mean age range 66 to 72	F: 2 to 7 sessions/week I: - T: - T: Aerobics training or aerobics training combined with either strength or eccentric training Total duration: 8 to 26 weeks Control conditions: NOT REPORTED	12/12 Narrative analysis 400 m walk, 6 MWT, SWT, METS, VO2max An adaptation of Sackett reported by Megens and Harris.
Kuijlaars 2019	To systematically review RCTs on the short- (4mo) and long-term (>4mo) effectiveness after hospitalization on body functions, activities, and participation (conform the ICF) of supervised home-based exercise therapy in older patients (65y) after hip fracture compared with a control intervention (including usual care). Cardiorespiratory fitness is a secondary outcome.	n=3 1997-2014	Older adults after hip fracture n=67 Mean age 79.3	F: 1 to 2 sessions/week I: 65 to 75% predicted HRmax T: 30 to 40 minutes/session T: Walking and stair walking Total duration: 3 months Control conditions: No-Ex	2/9 Meta-analysis 6MWT PEDro scale.

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Lam 2018	To examine the effects and characteristics of physical exercise training on physical function and quality of life in people with cognitive impairment and dementia and to examine the effect of subject characteristics on training efficacy. Cardiorespiratory fitness is a secondary outcome.	n=5 1994-2016	Older adults with cognitive impairment dementia n=402 Mean age 82.0	F: 2 to 4 sessions/week I: 30 to 60% VO2max,62 or 40% of heart rate reserve that gradually progressed to 85% T: 30 to 90 minutes/session T: Aerobic training, walking exercise, or multimodal exercise Total duration: 9 weeks to 12 months Control conditions: UC, No-Ex	7/43 Meta-analysis 6MWT PEDro scale.
Lee 2017	To systematically review the effects of Pulmonary Rehabilitation or Exercise Training in non-Cystic Fibrosis bronchiectasis on (1) measures of exercise capacity and muscle strength; (2) health related quality of life; (3) symptoms; and (4) frequency of exacerbations and mortality. Cardiorespiratory fitness is a primary outcome.	n=6 2005-2014	Older adults with non-cystic fibrosis bronchiectasis n=164 Mean age range 57.3 to 71.2	F: 2 to 7 sessions/week I: 80% peak HR achieved on initial incremental exercise test, 75 to 85% of VO2max, 60% max of 6MWT T: 30 to 45 minutes/session T: (Treadmill) walking, cycling, stair climbing, ski machine Total duration: 8 weeks Control conditions: Not-AT, Ex-Adv	4/4 Meta-analysis 6MWD, SWT, endurance exercise capacity (set at 85% VO2peak uptake of maximal incremental treadmill test) Cochrane Risk of Bias.
Leggio 2019	To analyse the effects of the exercise training on cardiovascular outcomes in patients with heart failure with preserved ejection fraction Cardiorespiratory fitness is a secondary outcome.	n=8 2010-2017	Older adults with heart failure with preserved ejection fraction. n=348 Mean age range 61.9 to 70.1	F: 2-3 sessions/week I: - T: 20-40 to 60 minutes T: Aerobic exercise training, walking, and treadmill and bicycle ergometer Total duration: 4 to 16 weeks Control conditions: No-Ex	9/9 Narrative analysis VO2peak, 6 MWD. Downs and Black Quality Index.

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Li 2019	To explore the comprehensive effect of resistance training on the various types of exercise capacities of COPD patients. Cardiorespiratory fitness is a secondary outcome.	n=5 2004-2018	Older adults with moderate to severe COPD n=405 Mean age range 58.3 to 70.3	F: 3-5 sessions/week I: 40-80% of 1RM T: 40 minutes/session T: resistance training Total duration: 6-12 weeks Control conditions: No-Ex, Not-AT	11/11 Meta-analysis 6MWD, 6min-peg-and-ring test, constant work rate, UULEX, CPET. PEDro scale.
Liao 2015	To investigate the effects of resistance training alone or combined with endurance training on clinically relevant rehabilitation outcomes in advanced COPD, Cardiorespiratory fitness is a primary outcome.	n=7 1992-2014	Older adults with moderate to severe COPD n=333 Mean age range 67,7	F: 2 to 3 sessions/week I: 60% work rate, 1 level below the maximum level achieved on the unsupported arm test, intensity increased according to breathlessness and perceived arm exertion, 50% maximum work capacity, 3 metabolic equivalents, 60% peak VO2 T: 20 to 60 minutes/session T: Treadmill walking, cycle ergometer, arm cranking Total duration: 8 to 12 weeks Control conditions: No-Ex, AT	10/18 Meta-analysis 6MWD, 6min peg-and-ring test, max workload, VO2max. Modified Jadad scale.
Paneroni 2017	To evaluate, in patients with very severe but stable COPD, the effectiveness of exercise training defined as a change in functional capacity and health related quality of life. Cardiorespiratory fitness is a primary outcome.	n=4 1999-2014	Older adults with severe COPD n=396 Mean age 65.6 for all 10 studies	F: 1 to 5 sessions/week I: high intensity ranging from 70% to 90% of the maximum load or velocity reached during incremental tests in three studies T: 15 to 30 minutes/session T: Cycling, (treadmill) walking or a combination Total duration: 4 to 52 weeks Control conditions: UC, No-Ex	8/10 Meta-analysis 6MWT Cochrane collaboration tool modified by the Jadad Scale score.

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Parmenter 2013	To identify whether any mode of structured exercise improves physical fitness, or performance-based tests of function, and to identify if improvements in physical fitness measures. Cardiorespiratory fitness is a primary outcome.	n=9 1974-2011	Older adults with intermittent claudication n=924 Mean age range 59 to 76	F: 2 to 5 sessions/week I: intensity focussed on moderate to maximum pain or 60 to 90% VO2peak T: 16 to 60 minutes/session T: (Treadmill) walking, lower limb aerobics, pole striding, arm cranking Total duration: 6 to 76 weeks Control conditions: UC, No-Ex, Ex-Adv	24/24 Narrative analysis 6MW-ICD, 6MW-TWD, SWT-ICD, SWT-TWD,VO2peak. Modified PEDro scale
Patel 2012	To review systematically the comparative effectiveness of yoga, compared with other exercise interventions, for older adults as shown on measures of health and physical functioning. Cardiorespiratory fitness is a primary outcome.	n=5 1989-2009	Healthy older adults in various settings n=265 Mean age range 67 to 72	F: 1 (+home exercise) to 2 sessions/week I: - T: 60 to 90 minutes/session T: (Supervised) aerobic exercise, resistance training Total duration: 16 to 26 weeks Control conditions: UC, AT	4/11 Meta-analysis VO2max 10-item quality checklist by Chalmers et al.
Pengelly 2019	To identify exercise parameters and outcome measures used in cardiac rehabilitation programs following median sternotomy, in the elderly cardiac population. Cardiorespiratory fitness is a secondary outcome.	n=5 1997-2015	Older patients after coronary artery bypass graft, valve surgery or both. n=246 Mean age range 73 to 87	F: 5 to 7 sessions/week I: 60% 1RM (1 set 8-12 repetitions) , RPE 13/20, starting at 50% max power output T: 60-90 minutes/session T: aerobic strength and balance exercises, calisthenics Total duration: 3 to 4 weeks Control conditions: UC	9/11 Meta-analysis 6MWT, max. power output, VO2peak. Downs & Black tool.

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Puhan 2016	To assess effects of pulmonary rehabilitation after COPD exacerbations on hospital admissions (primary outcome) and other patient-important outcomes (mortality, health related quality of life and exercise capacity). Cardiorespiratory fitness is a secondary outcome.	n=6 1998-2016	Older adults with COPD after acute exacerbation n=1368 Mean age range 58 to 78	F: 2 to 35 sessions/week I: - T: 10 to 120 minutes/session T: Supervised and unsupervised inpatient and/or outpatient pulmonary rehabilitation (treadmill walking, walking, cycling, stair climbing, aerobic activities, endurance training) Total duration: 4 days to 6 months Control conditions: UC, No-Ex	18/22 Meta-analysis 6MWT, SWT, 3MWT. Cochrane Risk of Bias.
Rezende Barbosa 2018	To gather information in the literature regarding the influence of functional training on cardiorespiratory parameters. Cardiorespiratory fitness is a primary outcome.	n=5 2002-2016	Community living older adults n=227 Mean age range 69 to 83	F: - I: 65-70%VO2peak (15 min) T: 10 to 60 minutes/session T: Multimodal exercise programmes Total duration: 12 weeks to 11 months Control conditions: UC, AT	3/5 Meta-analysis VO2peak PEDro scale and GRADE.
Ribeiro 2017	To summarise the evidence on the impact of a cardiac rehabilitation program on functional capacity, exercise tolerance and health-related quality of life in aortic stenonis patients after intervention either by sAVR or TAVI. Cardiorespiratory fitness is a primary outcome.	n=7 2014-2015	Older adults after heart surgery (sAVr or TAVI). n=1797 Mean age range 68 to 86	F: 1 to 18 sessions/week I: intensity low to medium, 70% of HRmax predict or 14 RPE on Borg- scale T: 30 minutes/session T: Aerobic exercise, cycling or cycle ergometer, treadmill or outdoor walking, (group) gymnastics Total duration: 2 to 3 weeks Control conditions: No controls	5/5 Meta-analysis 6MWD PEDro scale.

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Rodrigues-Krause 2016	To verify the level of evidence regarding the adaptations of dance interventions on cardiovascular risk factors in older adults. The primary outcome was cardiorespiratory fitness.. Cardiorespiratory fitness is a primary outcome.	n=4 1990-2015	Older adults with various health conditions n=237 Mean age range 59 to 70	F: 1 to 3 sessions/week I: 70% VO2peak, 100-120 bpm, 13-14RPE T: 40 to 60 minutes/session T: Dance, aerobic training (cycle ergometer, treadmill or both) Total duration: 8 to 24 weeks Control conditions: No-Ex, AT, combi AT Not-AT	4/7 Meta-analysis VO2peak Downs & Black criteria.
Rodrigues-Krause 2019	To review the literature on the use of dance as a form of intervention to promote functional and metabolic health in older adults. Cardiorespiratory fitness is a primary outcome.	n=4 1984-2016	Older adults with various health conditions n=893 Age range 59 to 94	F: 1 to 3 sessions/week I: 50 to 75% VO2peak, 11 to 14 Borg scale (specifications unclear), 50 to 70% HRmax, 50 to 120 bpm music (salsa goes up to 180 bpm), 50 to 70% HRR, 4.0 to 7.5 METs/hour or low to moderate intensity (unspecified) T: 30 to 90 minutes/session T: Dance (folk dance, aerobic dance, Argentine tango, waltz, foxtrot). Aerobic training (cycle ergometer, treadmill or both). Total duration: 6 to 104 weeks Control conditions: No-Ex, AT, combi AT Not-AT	12/49 Narrative analysis VO2max, 6MWT, half mile walking test, 2minST. Own criteria

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Rosero 2019	To assess the different modalities or combinations of preoperative physical exercise interventions on the outcomes of functional capacity, mental wellness, and medical care in patients with non-small-cell lung cancer after surgery. Cardiorespiratory fitness is a secondary outcome.	n=6 2011-2017	Hospital patients with non-small-cell lung cancer. n=648 Mean age 65	F: 3 to 14 sessions/week I: 60 to 80% peak work capacity T: 20 to 60 minutes/session T: Aerobic training, multicomponent training (aerobic exercise combined with IMT and/or strength training) Total duration: 1 to 4 weeks Control conditions: NOT REPORTED	9/10 Meta-analysis 6MWD, VO2peak PEDro scale.
Rydwik 2004	To describe the effect of physical training on physical performance in institutionalised multiple diagnoses older adults. Cardiorespiratory fitness is a primary outcome.	n=5 1989-2000	Institutionalised multiple diagnoses older adults n=554 Mean age range 84.6	F: 2 to 3 sessions/week I: 50 to 65% progressively, >70% or 80% (units of measurement unclear) T: 2 to 20 minutes/session T: Aerobic training Total duration: 9 to 52 weeks Control conditions: NOT REPORTED	4/16 Narrative analysis VO2max, heart rate, walking/ wheelchair endurance (average speed). Modified SBU form.
Ryrso 2018	To investigate the effect of a supervised early pulmonary rehabilitation program, initiated during or within 4 weeks, in patients hospitalized with a COPD exacerbation compared with usual care. Cardiorespiratory fitness is a secondary outcome.	n=10 1998-2018	Older adults with COPD after acute exacerbation n=723 Mean age range 59 to 75	F: 2 to 7 sessions/week I: 60 to 80% of max work load , >75% of max walking distance, 60-70% VO2max or HRmax, Borg breathlessness score 3-4 T: 30 to 40 minutes/session T: (Treadmill) walking, cycling and/ or tailored aerobic activities/exercise (supervised and unsupervised) Total duration: 10 days to 6 months Control conditions: UC, No-Ex	11/13 Meta-analysis 6MWT, SWT. Cochrane Risk of Bias and Grade criteria.

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Scheerman 2018	To identify the effect of physical interventions on physical performance and physical activity in older patients during hospitalization. Additionally, we aimed to compare the effect of patient tailored physical interventions e.g. continuously adapted to the capabilities of the patient to the effect of non-patient tailored interventions. Cardiorespiratory fitness is a primary outcome.	n=5 2006-2017	Older adults hospitalized with various diagnoses n=260 Mean age 79.2	F: 3 to 18 sessions/week I: - T: 1 to 45 minutes/session T: tai chi principles, muscle strengthening exercises, electrical stimulation, walking (backward and forward). Total duration: 1 to 6 weeks Control conditions: UC	3/15 Narrative analysis 6 MWT. PEDro scale.
Slimani 2018	To establish the effects of physical training on quality of life, aerobic capacity, and left ventricular ejection fraction in older heart failure patients, and to quantify dose-response relationships according to training modalities and program variables. Cardiorespiratory fitness is a primary outcome.	n=3 1999-2017	Older adults with heart failure n=2624 Age not reported (inclusion criteria 50+ for African population and 65+ for populations from developed countries)	F: 1 to 13 sessions/week I: - T: 25 to 60 minutes/session T: Aerobic training, resistance training or a combination of both Total duration: 6 to 54 weeks Control conditions:	11/25 Meta-analysis 6MWT Not reported

Supplementary file B. Continued.

Article author year	Objective	No. of databases/ sources searched Date range of included studies	Participants	Intervention of interest Control Conditions	No. of included studies/total no. of studies in the review Method of analysis Outcome measure(s) Appraisal instrument
Vieira 2010	To assess the benefits of home-based pulmonary rehabilitation in patients with COPD for exercise capacity, and to assess the risks of home-based pulmonary rehabilitation and whether findings are consistent across populations of COPD, supervision and exercise training program variation. Cardiorespiratory fitness is a primary outcome.	n=4 1977-2007	Older adults with severe COPD n=728 Mean age range 38 to 78 N 728 -% men	F: 4 to 14 sessions/week I: 70% max SWT T: 15 to 45 minutes/session T: Walking, stair climbing, cycling or a combination Total duration: 3 to 52 weeks Control conditions: UC	12/12 Narrative analysis 4-min, 6-min or 12-min walk test, the shuttle walk test, work rate, VO2max. The PEDro scale
Wee 2018	To assess the impact of preoperative exercise in abdominal aortic aneurysm patients, including those who are not indicated for surgery. Cardiorespiratory fitness is a primary outcome.	n=3 2008-2017	Patients with abdominal aortic aneurysm. n=227 Mean age range 69 to 73	F: 2 to 3 sessions/week I: moderate to high T: 22 to 45 minutes/session T: continuous exercise, high intensity training Total duration: 4 to 12 weeks Control conditions: UC, Ex-Adv	4/4 Narrative analysis VO2peak, aerobic threshold, ventilatory threshold PEDro scale.

n=number; *sAVR*: surgical aortic valve replacement; *TAVI*: trans catheter aortic valve implantation; *COPD*: chronic obstructive pulmonary disease
Intervention of interest and control conditions:

FITT characteristics: Frequency, Intensity, Time per session, Type of exercise
HR: heart rate; *HRmax*: maximum heart rate; *HRR*: heart rate reserve; *HRVT2*: heart rate at the second ventilatory threshold; *VT*: ventilatory threshold;; *VO2max* / *VO2peak*: maximum oxygen consumption; *VO2R*: maximum oxygen consumption reserve; *RPE*: rate of perceived exertion; *bpm*: beats per minute; *MET*: metabolic equivalent;
AT: aerobic fitness training; *No-Ex*: intervention other than exercise, e.g. wait list, social acitivity, education, stress management, mental training, nutritional advise, breathing exercise; *UC*: no intervention, e.g. usual care, usual daily activities, usual exercise program, waiting list; *Not-AT*: exercise intervention other than aerobic training, e.g. stretching and toning, yoga, balance training, resistance training; *Ex-Adv*: Exercise advise.

Outcome measures
2minST: 2 minute step test; *3MWT*: 3 minute walking test; *5mWT*: 5 meter walking test; *6MWT*: 6 minute walking test; *6MWD*: 6 minute walking distance; *12MWT*: 12 minute walking test; *CPET*: cardio pulmonary exercise test; *ICD*: initial claudication distance; *SWT*: shuttle walk test; *TWD*: total walking distance; *UULEX*: Unsupported Upper Limb Exercise.

Supplementary file C. Interventions and summary of the evidence of all included reviews.

Reviews with complete FITT characteristics AND risk of bias analysis highlighted in italics

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Ada 2010	3 RCT n=348 Cardiovascular disease	F: 5 session/week I: NOT REPORTED T: 20 to 60 minutes/session T: Any type of mechanically assisted walking and assisted overground walking Total duration: 4 to 6 weeks or until discharge from inpatient rehabilitation	The short-term effect (after 4 weeks training) of additional mechanically assisted walking on walking capacity in patients after stroke (6MWT) is not statistically significant (35 m; 95%CI –13 to 84). The quality of the underlying studies was high.	MA: <u>not statistically significant</u> result
Angevaren 2008	*11 RCT n=667 Frail older adults*	*F: 2 to 7 session/week I: 70% HRmax, HR at VT, HR of 95 to 125, 50 to 75% $\dot{V}O_2$ max, 50 to 65% HRR or 85% HRR T: 8 to 60 minutes/session T: Aerobic exercise programs (walking, cycling, jogging, running, mixed exercise) Total duration: 8 to 26 weeks*	*Eight out of 11 studies reported that aerobic exercise interventions in older people with known cognitive impairment resulted in increased aerobic capacity in the intervention group (increase in $\dot{V}O_2$max of 14%) 10/11 of the underlying studies had an unclear risk of bias.*	*NAn: <u>positive</u> result for >75% of all studies*
Anthony 2013	1 RCT n=82 Frail older adults	F: 2 session/week I: NOT REPORTED T: NOT REPORTED T: Chair based exercise Total duration: 3 months	The effect of chair based exercise in frail older persons on aerobic performance (6MWT) is not statistically significant (2.1 % increase, p=0.23). The quality of the underlying study is low, and allocation was not concealed	NAn: <u>not statistically significant</u> result

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Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Baker 2007	4 RCT n=479 Frail older adults	F: 3 session/week I: 13 to 16 RPE on Borg scale, 70% HRmax, 70% HRR, 65 to 70% $\dot{V}O_2$peak T: 8.3 to 45 minutes/session T: Walking, cycling ergometer training, rowing ergometer training Total duration: 12 weeks to 6 months	Multimodal exercise training in frail older people has a statistically significant effect on aerobic performance (6MWT) in only one out of three studies, and a statistically significant increase in aerobic capacity in the one study ($\dot{V}O_2$peak increase ES 0.84). The effect of risk of bias was not evaluated.	NAn: <u>inconclusive</u>
Blankevoort 2010	*4 RCT, 1 nonRCT n=255 Cognitive impairment*	*F: 2 to 3 session/week I: start at 30% $\dot{V}O_2$max up to 60% $\dot{V}O_2$max T: 30 to 60 minutes/session T: Walking, strength, balance & aerobic exercises, functional skills Total duration: 12 weeks to 2 years*	*Physical exercise in older people with dementia has a statistically significant effect on aerobic performance in 5 out of 5 studies (several walking tests, mean ES 1.08; 95%CI 0.31 to 3.79), with longer duration showing larger effects. Four out of 5 studies were high quality RCT's, 1 study was a case series. Risk of bias was moderate to high (1 to 5 /7 points, with 7 points = low risk of bias.*	*NAn: <u>positive</u> result for all studies*
Bouaziz 2015	15 RCT, 11 nonRCT n=832 Metabolic diseases	F: 3 to 7 session/week I: 40 to 85% HRR, 50 to 75% $\dot{V}O_2$max, 60 to 85% HRmax T: 12 to 90 minutes/session T: Cycling on ergometer, walking, treadmill walking Total duration: 12 to 36 weeks	Exercise therapy in obese people has a statistically significant effect on aerobic capacity (increase $\dot{V}O_2$max 11 to 34%) in 7 out of 8 studies. Exercise therapy combined with diet has a statistically significant effect on aerobic capacity (increase $\dot{V}O_2$max 1 to 25%), larger than diet alone. The type of diet does not affect the effect. The quality of the underlying studies was not assessed.	NAn: <u>positive</u> result for >75% of all studies

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Bouaziz 2016	1 RCT, 1 nonRCT n=NOT REPORTED (Healthy) older adults	F: 3 session/week I: NOT REPORTED T: 90 minutes/session T: Combination of endurance, strength, balance and flexibility training or combination of endurance, strength, balance, flexibility and coordination training. Total duration: 10 to 36 weeks	Multicomponent training in older adults shows positive effects on cardiorespiratory capacity (Increase in $\dot{V}O_2$max 10 to 20%) compared to baseline (2/2 studies) or to controls (1/1 study) The quality and risk of bias of the underlying studies was not assessed.	NAn: <u>positive</u> result for all studies
Bouaziz 2018	10 RCT n=348 Mixed	F: 3 to 4 session/week I: 50% to 85% of $\dot{V}O_2$peak, 40 to 80% of HRR, 50% to 95% of HRmax T: 15 to 60 minutes/session T: Walking, cycling on ergometer, treadmill walking and walking / running on a mini-trampoline Total duration: 12 to 26 weeks	Aerobic training in older adults has a statistically significant positive effect on aerobic capacity in 9/10 studies (increase in $\dot{V}O_2$max 6.5 to 30%). Pooled analyses of all studies, and adjusted to health status all showed positive results. Statistically significant heterogeneity was detected in all analyses. Greater gain was measured when subjects trained at 40 (sedentary) to 85% of $\dot{V}O_2$peak, and after 16 weeks training (average) and 24 to 26 weeks for sedentary individuals. None of the included studies was at high risk of bias.	MA: <u>positive</u> result for all comparisons
Bruns 2016	*3 RCT, 2nonRCT* *n=353* *Oncologic disease*	*F: 3 to 7 session/week* *I: 40 to 80% peak HR* *T: 20 to 30 minutes/session* *T: Cardiopulmonary aerobic exercise* *Total duration: 24 to 38 days*	*Physical prehabilitation in older colectoral surgery patients has a positive effect on aerobic capacity ($\dot{V}O_2$ at ventilatory threshold, 2.9 ml/kg/min increase) in one study, in aerobic performance (6MWT, 42, ($p<0.01$)) in 2 out of 3 studies. Inconclusive results were found in one study with several outcome measures.* *Studies had a moderate risk of bias.*	*NAn: <u>inconclusive</u>*
Bueno de Souza 2018	3 RCT n=156 (Healthy) older adults	F: 2 to 3 session/week I: NOT REPORTED T: 60 minutes/sessions T: Pilates Total duration: 8 to 24 weeks	Pilates in older people has a statistically significant effect on aerobic performance (6MWT increase of 30 to 130m, SMD 2.00; 95%CI 1.44 to 2.56) and no effect on aerobic capacity ($\dot{V}O_2$max). The evidence for aerobic performance is rated “moderate”, the evidence for aerobic capacity “limited”.	MA: <u>positive</u> result for all comparisons

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Bullo 2018	5 RCT, 4nonRCT n=536 Mixed	F: 2 to 3 session/week I: 60 to 70% max ability, progressive intensity up to 12 to 14 RPE, 50 to 60% HRmax, moderate intensity (12 to 14 RPE), moderate to high intensity (HR 100 to 120 bpm), comfortable pace T: 20 to 80 minutes/session T: Nordic walking Total duration: 6 to 35 weeks	Nordic walking (NW) in older people has a statistically significant effect on aerobic performance in 8 out of 9 studies (6MWT, 12MWT, 2 min step test, 5m WT: increase of 9 to 22%). NW showed a large effect compared to sedentary(ES 0.91; 95%CI 0.56 to 1.28) and resistance training (ES 0.75; 95%CI 0.03 to 1.47) controls, but walking therapy was more effective (ES -0.21; 95%CI -.64 to 0.21). The effect on aerobic capacity is also statistically significant ($\dot{V}O_2$max increase of 2.4 to 13.6%). The studies were rated low quality and heterogeneous.	MA: positive result, only for comparisons with non-exercise controls
Cugusi 2017	15 RCT n=766 Cardiovascular disease	F: 2 to 5 session/week I: NOT REPORTED T: 30 to 60 minutes/session or 2.5 to 3km T: Nordic walking Total duration: 3 to 24 weeks	Nordic Walking (NW) additional to conventional cardiovascular rehabilitation (CCVR) in individuals with coronary artery disease has a positive effect on exercise capacity (METs: SMD 0.49; 95%CI 0.04 to 0.93) and no effect on aerobic performance (6MWT: SMD 0.12; 95% CI -0.32 to 0.56). For peripheral artery disease patients NW has a statistically significant effect compared to non-exercise controls on aerobic capacity (exercise duration: SMD 0.93; 95%CI 0.52 to 1.34; $\dot{V}O_2$max: SMD 0.64; 95%CI 0.23 to 1.04). But compared to traditional walking (TW), NW is less effective (TW vs NW ES 0.1 to 0.6 for exercise duration and $\dot{V}O_2$max). For patients with heart failure NW showed positive but not always statistically significant results compared to CCVR and usual care. In a meta-analysis these findings were not established ($\dot{V}O_2$max SMD 0.29; 95%CI -0.10 to 0.68; 6MWT 0.29; 95%CI -.0.04 to 0.62). For post-stroke survivors NW-treadmill training showed positive results compared to traditional treadmill training (SMD: 0.80; 95%CI 0.08 to 1.52). Due to the overall low to moderate quality of the studies included in the present review (median PEDro score: 5), cautious interpretation of the studies' findings is recommended.	MA: positive result, only for comparisons with non-exercise controls

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Dale 2015	*2 RCT n=39 Respiratory disease*	*F: 2 to 3 session/week I: 80% of walking speed on initial 6MWT and progressed weekly, initial intensity of 60% peak work at baseline incremental cycle test and progressed weekly T: 15 to 30 minutes/session T: Cycling, walking Total duration: 8 weeks*	*For patients with non-malignant dust-related respiratory diseases exercise training has a positive effect on aerobic performance (6MWT increase of 54m; 95%CI 34 to 73) and no effect in maximal exercise capacity (peak work rate increase of 10 watts; 95%CI -0.4 to 4.4). The quality of this evidence is rated very low, although the risk of bias is judged very low.*	*MA: inconclusive*
Doyle 2019	11 RCT, 7 nonRCT n=2175 Cardiovascular disease	F: 1 to 14 session/week I: 3 to 7 RPE (10pt scale), 10 to 13 RPE, 65 to 75% max HR, anaerobic threshold T: 3 to 60 minutes/session T: Walking, stationary cycling or both Total duration: length of hospital stay to 6 months	Aerobic exercise early after cardiac surgery has a positive effect on aerobic fitness, both when started immediate postoperative (6MWT mean difference 69.5m; 95%CI 39.2 to 99.7) and when started early postoperative ($\dot{V}O_2$peak mean difference 3.20ml/kg/min; 95%CI 1.45 to 4.95). However, for the early started aerobic exercise for 6MWT the number of patients was too small, and controls tend to improve a little more.	MA: positive result for all comparisons
Fukuta 2016	5 RCT n=245 Cardiovascular disease	F: 2 to 3 session/week I: NOT REPORTED T: 20 to 60 minutes/session T: Walking, walking and cycling, cycling and cycling and resistance training Total duration: 12 to 24 weeks	Exercise training in patients with heart failure with preserved ejection fraction has a positive effect on aerobic capacity ($\dot{V}O_2$peak: weighted mean difference 2.283 ml/kg/min; 95%CI 1.318 to 3.248) and on aerobic performance (6MWD: weighted mean difference 30.275; 95%CI 4.315 to 56.234)	MA: positive result for all comparisons

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Gardner 2014	*5 RCT, 5 nonRCT n=565 Oncologic disease*	*F: 1 to 5 session/week I: 55% to 85% HRmax, 11 to 15 RPE, 50% to 75% peak oxygen uptake T: 15 to 60 minutes/session T: Walking, aerobic exercises Total duration: NOT REPORTED*	*Exercise training in patients with prostate cancer receiving androgen-deprivation therapy has inconclusive effects on aerobic capacity ($\dot{V}O_2max$: a positive effect in 1 study and not statistically significant in 3 studies), and in exercise performance (6MWT: positive in 2 studies, not statistically significant in 1 study; 400m walk: positive in 2 studies, not statistically significant in 1 study; Time to reach rate of perceived exertion of 15 in treadmill protocol: 1 positive study). Rik of bias scores are of the underlying studies are low to moderate (scores 4 to 6 out of 7), due to the fact that not all underlying studies were RCTs and participants and therapists were not blinded.*	*NAn: <u>inconclusive</u>*
Golledge 2019	*11 RCT n=524 Cardiovascular disease*	*F: 3 to 5 session/week I: until severe leg discomfort experienced, a speed that evokes strong claudication pain, severe discomfort (12–14 on Borg rating), a brisk pace that elicits pain within 3–5minutes T: 10 to 50 minutes/session T: Walking Total duration: 6 to 36 weeks*	*Structured home based exercise programs in patients with peripheral artery disease has a positive effect on aerobic performance (6MWT: SMD 0.28; 95%CI 0.09 to 0.47; walking distance treadmill SMD 0.32; 95%CI 0.15 to 0.50; claudication onset distance on treadmill SMD 0.45; 95%CI 0.27 to 0.62) compared to non-exercise controls. The majority of the underlying studies did not report on blinding of the assessors.*	*MA: <u>positive</u> result for all comparisons*
Gomes-Neto 2019	2 RCT n=59 Metabolic diseases	F: 3 session/week I: NOT REPORTED T: 12 to 24 minutes/session T: Whole to body vibration training alone or in combination with exercises on the spot Total duration: 8 to 12 weeks	Whole body vibration in older patients with diabetes type 2 has a positive effect on aerobic performance (6MWT/1 mile track walk: SMD 0.73; 95%CI 0,20 to 1.27) compared to not-descried controls. The included studies scored 2/10 and 5/10 on Pedro scale.	MA: <u>positive</u> result for all comparisons

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Halloway 2015	1 RCT n=30 Frail older adults	F: 2 to 4 session/week I: NOT REPORTED T: 30 minutes/session T: Walking, individual exercises Total duration: 3 to 6 weeks	Prehabilitation prior to elective total hip surgery in frail patients has a positive effect on aerobic performance in 1 out of 1 study (6MWT: Effect Size (d) 0.37) compared to controls that received usual care. Risk of bias of the underlying study was not assessed.	NAn: positive result for all studies
Hernandez 2015	5 RCT n=131 Cognitive impairment	F: 3 to 5 session/week I: moderate to intensive (subjective inability to speak a sentence) T: 15 to 45 minutes/session T: Walking, multimodal exercise, cycling Total duration: 2 to 6 months	Exercise programs (both multimodal and aerobic programs) in patients with Alzheimer's disease (AD) show positive effects in aerobic capacity in 1 out of 1 study ($\dot{V}O_2$ at cycle ergometer test) and aerobic performance in 3 out of 3 studies(shuttle walk (1/1), 6MWT (2/2)) in all studies. One study showed different effects for moderate and for severe AD, with negative results for severe AD. Other studies showed a positive effect for severe AD. 2/5 studies had no control group. In the other 3 studies assessors AND participants were blinded in 1 of 3.	NAn: positive result for all studies
Heyn 2008	14 RCT, 1 nonRCT n=1057 Mixed	F: 2 to 5 session/week I: NOT REPORTED T: 30 to 90 minutes/session T: Aerobic training, variable-intensity group exercise program, multicomponent functional fitness training, endurance exercises Total duration: 2 to 40 weeks	Exercise programs in cognitively intact older adults had a statistically significant positive effect on aerobic performance in 4 out of 6 studies (6MWT or other walking endurance test, ES 0.047 to 2.169). In cognitively impaired older adults 2 out of 9 studies showed positive results on aerobic performance (6MWT or other walking endurance test, ES 0,230 to 0.555). A quality assessment was performed but not used in the interpretation of results.	MA: positive result for all comparisons
Howes 2017	8 RCT n=427 Mixed	F: 1 to 4 session/week I: NOT REPORTED T: 45 to 90 minutes/session T: Active computer gaming Total duration: 4 weeks to 6 months	Active computer gaming in older adults shows a small positive effect on aerobic performance (6MWT and other walking distance test: SMD 0.29; 95%CI 0.04 to 0.55). Subgroup analyses on types of control (active – no exercise) showed no effect in either group. Sensitivity analyses showed a dose-effect relation: a moderate effect for >120 minutes per week , and a large effect for studies >150 minutes per week. This evidence was graded as very low quality	MA: positive result for all comparisons

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Huang 2002, 2005, 2016	23 RCT, 18 nonRCT n=2102 (Healthy) older adults	F: 1 to 4.9 session/week I: 60% to 85% HRmax, 50% to 82% $\dot{V}O_2$max, 35% to 80% HRR, 107 to 129 bpm HRmax T: 20 to 60 minutes/session T: Walking, jogging, cycling, stair to climbing, aerobic dance, tai chi chuan, outdoor performance or aerobic games Total duration: 8 to 52 weeks	Aerobic exercise in sedentary older adults shows a positive effect on aerobic capacity ($\dot{V}O_2$max: Standardized ES: 0,64; 95%CI 0,56 to 0,73, i.e. an increase of 3,50 ml/kg/min; 95%CI 1,83 to 5,17). A greater increase was seen in studies with a longer duration (>20/24/32 weeks), intensity 60 to 65% of $\dot{V}O_2$max, time>30 min. The quality of the underlying studies was variable, but the risk of bias was not included in the interpretation of the results.	MA: <u>positive</u> result for all comparisons
Hurst *2019*	*20 RCT, 4 nonRCT* *n=1131* *(Healthy) older adults*	*F: 2 to 3 session/week* *I: 50 to 75% HRmax, 60 to 80% HRR, 80% HRVT$_2$ or RPE 12 to 14* *T: 30 to 90 minutes/session* *T: Combined (strength and endurance) training and endurance training ((Treadmill) walking, running, cycling, cross-trainer, stationary cycling, dance)* *Total duration: 6 to 52 weeks*	*Combined aerobic and strength training in healthy olde2r adults shows a positive effect on aerobic capacity ($\dot{V}O_2$peak: increase of 3.6 ml/kg/min; 95%CI 2.8 to 4.4) and on aerobic performance (6MWT: increase of 29.6m; 95%CI 9.1 to 50.1) compared to non-exercise controls. There was a not statistically significant effect on aerobic capacity ($\dot{V}O_2$peak) compared to aerobic training alone and a not statistically significant effect on aerobic endurance (6MWT) compared to strength training alone.* *The risk of bias in underlying studies was low or unclear, and authors mentioned a possible bias due to the exclusion of studies with other outcome measures than the predefined ($\dot{V}O_2$peak and 6MWT)*	*MA: <u>positive</u> result, only for comparisons with non-exercise controls*
Hwang 2015	1 nonRCT n=97 (Healthy) older adults	F: 2 session/week I: NOT REPORTED T: 50 minutes/session T: Dance Total duration: 12 weeks	Dancing interventions older adults improve aerobic capacity ($\dot{V}O_2$max) in 1 out of 1 study. No specific outcome measure was reported. The quality of the study was moderate, the design was quasi-experimental.	NAn: <u>positive</u> result for all studies

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Kanach 2018	*4 RCT n=556 Older adults, hospitalized for acute medical illness*	*F: 5 to 35 session/week I: 125% of best 6 MWD, 85% predicted $\dot{V}O_2max$ T: 10 to 60 minutes/session T: Aerobic walking, combined training with aerobic component Total duration: hospital length of stay to 18 months*	*Structured exercise Interventions for older adults hospitalized with acute medical illness shows positive results on aerobic capacity ($\dot{V}O_2max$) in one single study, and on aerobic performance (6MWT and shuttle walk test) in 3 out of 4 studies, all compared to non-exercise controls. The evidence is of low quality.*	*NAn: positive result for >75% of all studies*
Keogh 2012	8 RCT, 4 nonRCT n=289 Oncologic disease	F: 2 to 7 session/week I: NOT REPORTED T: NOT REPORTED T: Aerobics training or aerobics training combined with either strength or eccentric training Total duration: 8 to 26 weeks	Group based exercise in prostate cancer patients shows positive results for aerobic capacity in 2 out of 3 studies (increase in $\dot{V}O_2max$ 9%, in METs 47%), and for aerobic performance in 2 out of 4 studies (increase in 6MWT 9%, in 400m walk 11%). Homebased exercise in this group shows positive results for aerobic endurance in 2 out of 4 studies (increase in 6MWT 11%, shuttle walk 13%). The evidence for group based exercise is judged as grade A, and the evidence for home based evidence is judged as grade B.	NAn: inconclusive
Kuijlaars 2019	*2 RCT n=67 Trauma*	*F: 1 to 2 session/week I: 65 to 75% predicted HRmax T: 30 to 40 minutes/session T: Walking and stair walking Total duration: 3 months*	*Supervised home-based exercise therapy in patients after hip fracture shows no statistically significant results for aerobic performance (6MWT). The evidence was of moderate quality, risk of bias of the underlying studies was moderate to due to the lack of allocation concealment, blinding of participants and therapists, and in one study blinding of assessors.*	*NAn: not statistically significant result*

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Lam 2018	*7 RCT n=402 Cognitive impairment*	*F: 2 to 4 session/week I: 30 to 60% $\dot{V}O_2$max,62 or 40% of heart rate reserve that gradually progressed to 85% T: 30 to 90 minutes/session T: Aerobic training, walking exercise, or multimodal exercise Total duration: 9 weeks to 12 months*	*Physical exercise in older people with cognitive impairment shows a positive effect on aerobic performance (increase in 6MWT 50m; 95%CI 18 to 81) compared to non-exercise controls. In institutionalized programs these results could not be established. Trials that reported positive findings adopted either specific aerobic training, walking exercise, or multimodal exercise, with a training duration ranging from 30 to 90 minutes/session, 2 to 4 session/week, for a total of 9 weeks to 12 months. Reported effective training intensity was 30 to 60% $\dot{V}O_2$max, or 40% of heart rate reserve that gradually progressed to 85%. Publication bias was present in this analysis. The quality of the evidence is moderate, risk of bias was low.*	*MA: <u>positive</u> result for all comparisons*
Lee 2017	*4 RCT n=164 Respiratory disease*	*F: 2 to 7 session/week I: 80% peak HR achieved on initial incremental exercise test, 75 to 85% of $\dot{V}O_2$max, 60% max of 6MWT T: 30 to 45 minutes/session T: (Treadmill) walking, cycling, stair climbing, ski machine Total duration: 8 weeks*	*Exercise training in patients with non-cystic fibrosis bronchiectasis shows no effect on aerobic capacity ($\dot{V}O_2$max) in 1 single study, and a positive effect on aerobic performance (shuttle walk test: MD 66.62m; 95%CI 51.57 to 81.68; 6MWD: increase of 32m (1 study)). Risk of bias in the underlying studies was low or unclear.*	*MA: <u>positive</u> result for all comparisons*
Leggio 2019	9 RCT n=348 Cardiovascular disease	F: 2 to 3 session/week I: NOT REPORTED T: 20-40 to 60 minutes T: Aerobic exercise training, walking, and treadmill and bicycle ergometer Total duration: 4 to 16 weeks	Exercise training in patients with heart failure with preserved ejection fraction has a positive effect on aerobic capacity ($\dot{V}O_2$peak) and on aerobic performance (6MWD) in 1 out of 1 study. Risk of bias was moderate in all underlying studies.	NAn: <u>positive</u> result for all studies

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Li *2019*	*11 RCT* *n=405* *Respiratory disease*	*F: 3 to 5 session/week* *I: 40 to 80% of 1RM* *T: 40 minutes/session* *T: resistance training* *Total duration: 6 to12 weeks*	*Resistance training in elderly patients with COPD shows a positive effect on aerobic performance in two out of three measures (6MWD WMD 54.52; 95%CI 25.47 to 83.56; 6min peg-and-ring test: WMD 25.17; 95%CI 10.17 to 40.16; no statistically significant effect in constant work rate endurance test) and on aerobic capacity in 1 out of 2 measures (UULEX: SMD 0.41 95%CI 0.03 to 0.79; no statistically significant effect in CPET).* *Risk of bias in the underlying studies was moderate to high.*	*MA: <u>inconclusive</u>*
Liao *2015*	*10 RCT* *n=333* *Respiratory disease*	*F: 2 to 3 session/week* *I: 60% work rate, 1 level below the maximum level achieved on the unsupported arm test, intensity increased according to breathlessness and perceived arm exertion, 50% maximum work capacity, 3 metabolic equivalents, 60% $\dot{V}O_2$peak* *T: 20 to 60 minutes/session* *T: Treadmill walking, cycle ergometer, arm cranking* *Total duration: 8 to 12 weeks*	*Resistance training in elderly patients with COPD shows no effect on aerobic performance (6MWD; 6 minute peg-and-ring test; max workload) and on aerobic capacity ($\dot{V}O_2$max).* *Risk of bias of the underlying studies was high, especially because in most studies no intention to treat analysis was performed.*	*NAn: <u>not statistically significant</u> result*
Paneroni *2017*	*8 RCT* *n=396* *Respiratory disease*	*F: 1 to 5 session/week* *I: high intensity ranging from 70% to 90% of the maximum load or velocity reached during incremental tests in three studies* *T: 15 to 30 minutes/session* *T: Cycling, (treadmill) walking or a combination* *Total duration: 4 to 52 weeks*	*Aerobic training in patients with very severe COPD shows a positive effect on aerobic performance (6MWT: WMD 67.1m; 95%CI 37.9 to 98.9).* *Risk of bias of the underlying studies was high.*	*MA: <u>positive</u> result for all comparisons*

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Parmenter 2013	*24 RCT* *n=924* *Cardiovascular disease*	*F: 2 to 5 session/week* *I: intensity focussed on moderate to maximum pain or 60 to 90% $\dot{V}O_2$peak* *T: 16 to 60 minutes/session* *T: (Treadmill) walking, lower limb aerobics, pole striding, arm cranking* *Total duration: 6 to 76 weeks*	*Exercise in patients with intermittent claudication has a positive effect on aerobic performance in 10 out of 16 studies (6MWT-ICD 3/5 studies; 6 MWT-TWD 4/7 studies; shuttle walk-ICD: 1/2 studies; shuttle walk-TWD: 2/2 studies) and on aerobic capacity in 9 out of 24 studies ($\dot{V}O_2$peak 9/24 studies) compared to non-exercise controls. It has a positive effect on aerobic performance in 0 out of 9 studies (6MWT-ICD 0/2 studies; 6 MWT-TWD 0/3 studies; shuttle walk-ICD: 0/2 studies; shuttle walk-TWD: 0/2 studies) and on aerobic capacity ($\dot{V}O_2$peak) in 0 out of 14 studies compared to exercise controls.* *The risk of bias is high due to the fact that assessors were not blinded.*	*NAn: inconclusive*
Patel 2012	4 RCT n=265 (Healthy) older adults	F: 1 (+home exercise) to 2 session/ week I: NOT REPORTED T: 60 to 90 minutes/session T: (Supervised) aerobic exercise, resistance training Total duration: 16 to 26 weeks	Yoga in older adults shows a positive effect on aerobic capacity ($\dot{V}O_2$max SMD 0.54; 95%CI 0.08 to 1.00) compared to aerobic exercise. Risk of bias in the underlying studies is not clear.	MA: positive result for all comparisons
Pengelly 2019	*2 RCT, 7 nonRCT* *n=246* *Cardiovascular disease*	*F: 5 to 7 session/week* *I: 60% 1RM (1 set 8 to 12 repetitions) , RPE 13* *20, starting at 50% max power output* *T: 60 to 90 minutes/session* *T: aerobic strength and balance exercises, callisthenics* *Total duration: 3 to 4 weeks*	*Additional training (duration 60 to 90 minutes, and additional resistance training and balance training) in cardiac rehabilitation in patients following median sternotomy has a positive effect on aerobic performance (6MWT increase of 27m; 95%CI 7 to 47) an no effect on aerobic capacity ($\dot{V}O_2$max and maximal power output) compared to standard care consisting of aerobic and callisthenic exercises alone.* *Risk of bias of the studies not properly reported for the two relevant studies, study quality was fair to good.*	*MA: inconclusive*

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Puhan 2016	18 RCT n=1368 Respiratory disease	F: 2 to 35 session/week I: NOT REPORTED T: 10 to 120 minutes/session T: Supervised and unsupervised inpatient and/ or outpatient pulmonary rehabilitation (treadmill walking, walking, cycling, stair climbing, aerobic activities, endurance training) Total duration: 4 days to 6 months	Pulmonary rehabilitation following exacerbation of COPD shows a positive effect on aerobic performance (6MWT increase 62m; 95%CI 38 to 86; I2=87% (13 studies), 3MWT no statistically significant increase (1 study)). The evidence was rated high quality, and was not downgraded for statistical heterogeneity because the pooled effect is large and well above MIC (i.e. 30m).	MA: <u>positive</u> result for all comparisons
Rezende Barbosa 2018	3 RTC n=227 (Healthy) older adults	F: NOT REPORTED I: 65 to 70%$\dot{V}O_2$peak (15 min) T: 10 to 60 minutes/session T: Multimodal exercise programmes Total duration: 12 weeks to 11 months	Functional training in different populations has no effect on aerobic capacity ($\dot{V}O_2$max difference -1.0; 95%CI -5.4 to 3.3). Risk of bias in the studies was high.	NAn: <u>not statistically significant</u> result
Ribeiro 2017	*5 RCT* *n=1797* *Cardiovascular disease*	*F: 1 to 18 session/week* *I: intensity low to medium, 70% of HRmax predict or 14 RPE on Borgscale* *T: 30 minutes/session* *T: Aerobic exercise, cycling or cycle ergometer, treadmill or outdoor walking, (group) gymnastics* *Total duration: 2 to 3 weeks*	*Cardiac rehabilitation programme after transcatheter aortic valve implantation (TAVI) and surgical aortic valve replacement (sAVR) has a positive effect on aerobic performance (6MWT increase of 71m (38%; SMD 0.69; 95%CI 0.47 to 0.91) post-TAVI, and an increase of 87m (38%, SMD 0.79; 95%CI 0.43 to 1.15) post-sAVR) compared to at the start of the programme.* *Due to the fact that the studies had no control groups the risk of bias is high.*	*MA: <u>positive</u> result for all comparisons*

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Rodrigues-Krause 2016	3RCT, 1 nonRCT n=237 Mixed	F: 1 to 3 session/week I: 70% $\dot{V}O_2$peak, 100 to 120 bpm, 13 to 14RPE T: 40 to 60 minutes/session T: Dance, aerobic training (cycle ergometer, treadmill or both) Total duration: 8 to 24 weeks	Dance interventions in older adults show an positive effect on aerobic capacity ($\dot{V}O_2$peak increase of 3.4ml/kg/min; 95%CI 1.08 to 7.78) compared to non-exercise controls, and no effect on aerobic capacity ($\dot{V}O_2$peak) compared to other exercises. Risk of bias was considered serious, due to lack of blinded assessment of the outcome, lack of intention to treat principle for data analysis and considerable heterogeneity among studies.	MA: positive result, only for comparisons with non-exercise controls
Rodrigues-Krause 2019	10 RCT, 2 nonRCT n=893 Mixed	F: 1 to 3 session/week I: 50 to 75% $\dot{V}O_2$peak, 11 to 14 Borg scale (specifications unclear), 50 to 70% HRmax, 50 to 120 bpm music (salsa goes up to 180 bpm), 50 to 70% HRR, 4.0 to 7.5 METs/ hour or low to moderate intensity (unspecified) T: 30 to 90 minutes/session T: Dance (folk dance, aerobic dance, Argentine tango, waltz, foxtrot). Aerobic training (cycle ergometer, treadmill or both). Total duration: 6 to 104 weeks	Dancing in older adults shows a positive effect compared to non-exercise controls on aerobic capacity ($\dot{V}O_2$peak) in 4 out of 6 studies, and on aerobic endurance (6MWT) in all 8 studies. There were no effects on aerobic capacity compared to other exercise interventions (2 studies), although in one study the intensity of dance was higher than walking. Risk of bias in the majority of studies was high, due to a lack of appropriate description of the generation of randomized sequences and of the methods of allocation concealment.	NAn: positive result for >75% of all studies
Rosero 2019	*9 RCT* *n=648* *Oncologic disease*	*F: 3 to 14 session/week* *I: 60 to 80% peak work capacity* *T: 20 to 60 minutes/session* *T: Aerobic training, multicomponent training (aerobic exercise combined with IMT and or strength training)* *Total duration: 1 to 4 weeks*	*Preoperative physical exercise interventions in patients with non-small-cell lung cancer has a positive effect on aerobic performance (6MWT SMD 0.27; 95%CI 0.11 to 0.44) and on aerobic capacity ($\dot{V}O_2$peak SMD 0.78; 95%CI 0.35 to 1.12) compared to controls.* *Risk of bias was moderate in the majority of the studies although participants and therapists could not be blinded.*	*MA: positive result for all comparisons*

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Rydwik 2004	*4 RCT* *n=554* *Frail older adults*	*F: 2 to 3 session/week* *I: 50 to 65% progressively, >70% or 80% (units of measurement unclear)* *T: 2 to 20 minutes/session* *T: Aerobic training* *Total duration: 9 to 52 weeks*	*Physical training in institutionalized elder persons had a positive effect on 'endurance' in 2 out of 4 studies.* *The evidence was judged low to high, and risk of bias was also low to high*	*NAn: <u>inconclusive</u>*
Ryrso 2018	*11 RCT* *n=723* *Respiratory disease*	*F: 2 to 7 session/week* *I: 60 to 80% of max work load , >75% of max walking distance, 60 to 70% $\dot{V}O_2$max or HRmax, Borg breathlessness score 3 to 4* *T: 30 to 40 minutes/session* *T: (Treadmill) walking, cycling and/or tailored aerobic activities / exercise (supervised and unsupervised)* *Total duration: 10 days to 6 months*	*Early supervised pulmonary rehabilitation (PR) following COPD-exacerbations shows a positive effect on aerobic performance (6MWT increase 76.89m; 95%CI 21.34 to 132.45; SWT increase 54.70m; 95%CI 30.83 to 78.57) at the end of treatment compared to usual care. The subgroup analysis showed no difference in the effect between PR initiated during admission and after discharge.* *Rik of bias was serious, due to unclear sequence generation, allocation concealment and blinding of assessors.*	*MA: <u>positive</u> result for all comparisons*
Scheerman 2018	3 RCT n=260 Older adults, hospitalized for acute medical illness	F: 3 to 18 session/week I: NOT REPORTED T: 1 to 45 minutes/session T: tai chi principles, muscle strengthening exercises, electrical stimulation, walking (backward and forward). Total duration: 1 to 6 weeks	Physical interventions in older patients during hospitalization showed a positive effect on aerobic performance (6MWT) in 1 out of 3 studies. Risk of bias was moderate, due to the fact that blinding of therapists and patients is not possible. Assessors were blinded in all studies.	NAn: <u>inconclusive</u>

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Slimani 2018	11 RCT n=2624 Cardiovascular disease	F: 1 to 13 session/week I: NOT REPORTED T: 25 to 60 minutes/session T: Aerobic training, resistance training or a combination of both Total duration: 6 to 54 weeks	Physical Training in Older Patients With Heart Failure has a positive effect on aerobic performance (6MWT ES 0.43; 95%CI 0.15 to 0.71) compared to controls with unknown conditions. Resistance training had a larger effect (ES = 1.71; 95%CI 1.03 to 2.39), aerobic training had a smaller effect (ES = 0.51; 95%CI 0.30 to 0.72). Combined aerobic and resistance training had no statistically significant effect (ES = 0.15;95%CI −0.24 to 0.53). Dose–response analyses showed that none of the training variables predicted changes in aerobic capacity or cardiac function. Risk of bias of the underlying studies was not assessed.	MA: positive result for all comparisons
Vieira 2010	*12 RCT* *n=728* *Respiratory disease*	*F: 4 to 14 session/week* *I: 70% max SWT* *T: 15 to 45 minutes/session* *T: Walking, stair climbing, cycling or a combination* *Total duration: 3 to 52 weeks*	*Home-based pulmonary rehabilitation in COPD-patients shows an increase in aerobic performance (diverse walking tests 8/9 increase in intervention group vs 2/9 in controls) and aerobic capacity (work rate and* $\dot{V}O_2max$*: 2/5 positive in intervention vs (0/5 increase AND 2/5 decrease in controls)). Compared to hospital-based rehabilitation no differences were found.* *Risk of bias was high in the majority of studies due to lack of concealed allocation and of blinding of assessors.*	*NAn: positive result, only for all studies with non-exercise controls*

Supplementary file C. Continued.

Article author year	Number/ type of relevant studies, Number (n) of participants, Group	Characteristics of the intervention	Summary of the evidence	Conclusion
Wee 2018	*4 RCT n=227 Cardiovascular disease*	*F: 2 to 3 session/week I: moderate to high T: 22 to 45 minutes/session T: continuous exercise, high intensity training (HIT) Total duration: 4 to 12 weeks*	*Preoperative exercise for patients with abdominal aortic aneurysm has a positive effect on $\dot{V}O_2$peak and in anaerobic threshold in 1 out of 2 studies. For patients without an indication for surgery no increase in $\dot{V}O_2$peak was found (0/2), but a positive effect on anaerobic (1/1) en ventilatory threshold (1/2). Risk of bias was high, due to lack of blinding of the assessors in the majority of studies.*	*NAn: inconclusive*

Appendix 3 Interventions and summary of the evidence of all included reviews.
Type of relevant studies: *RCT*: Randomized controlled trial; *nonRCT*: other design than Randomized controlled trial
Characteristics of the intervention: Frequency, Intensity, Time and Type of exercise. *1RM*: 1 repetion maximum; *6MWD*: 6 minute walking distance; *6MWT*: 6 minute walking test; bpm: beats per minute; *HRmax*: Maximum heart rate; *HRR*: Heart rate reserve; *HRVT2*: Heart rate at the second ventilatory threshold; *MET*: metabolic equivalent; *RPE*: rate of perceived exertion; *VT*: ventilatory threshold; *$\dot{V}O_2$max:* maximum oxygen consumption; *$\dot{V}O_2$peak:* peak oxygen consumption
Summary of the evidence: *1RM*: one repetition maximum; *6MWD*: 6 minute walking distance; *6MWT*: 6 minute walking test; *CI*: confidential interval; *COPD*: chronic obstructive pulmonary disease; *CPET*: Cardio Pulmonary Exercise testing; *ES*: Effect size; *ICD*: initial claudication distance; *MD*: Mean difference; *MET*: metabolic equivalent; *sAVR*: Surgical aortic valve replacement; *SMD*: standardized mean difference; *SWT*: Shuttle walk test; *TAVI*: Transcatheter aortic valve implantation; *TWD*: total walking distance; *UULEX*: Unsupported Upper Limb Exercise test; *$\dot{V}O_2$max:* maximum oxygen consumption; *$\dot{V}O_2$peak:* peak oxygen consumption; *WMD*: weighted mean difference;
Conclusion*: MA:* Meta-*analysis*; *NAn:* Narrative analysis

Supplementary file D. List of excluded reviews.

Review	Reason for exclusion
Aamann, 2018[1]	Age of participants <65
Al-Jundi, 2013[2]	Not a systematic review and no cardiorespiratory outcomes
Baschung Pfister, 2015[3]	No cardiorespiratory outcomes
Bennett, 2019[4]	Age of participants <65
Bullo, 2015[5]	No cardiorespiratory outcomes
Burton, 2019[6]	Intervention not aimed at cardiorespiratory fitness and no cardiorespiratory outcomes
Cardim, 2016[7]	Intervention not aimed at cardiorespiratory fitness
Heyn, 2004[8]	No cardiorespiratory outcomes
Keysor, 2001[9]	No cardiorespiratory outcomes
Knips, 2019[10]	Age of participants <65
van der Bij, 2002[11]	No cardiorespiratory outcomes

References

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10. van der Bij AK, Laurant MG, Wensing M. Effectiveness of physical activity interventions for older adults: a review. *Am J Prev Med.* 2002;22(2):120-133.

Supplementary file E. The quality of included reviews.

Review	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9 RCT	Item 9 NRSI	Item 10	Item 11 RCT	Item 11 NRSI	Item 12	Item 13	Item 14	Item 15	Item 16
Ada, 2010	+	-	+	+/-	-	+	+	+/-	+	NA*	-	+	NA**	+	+	+	-	-
Angevaren, 2008	+	+	-	+	+	+	+	+	+	NA*	-	+	NA**	+	+	+	+	+
Anthony, 2013	-	-	-	+/-	-	-	-	-	+	NA*	-	NA**	NA**	NA**	-	-	NA**	-
Baker, 2007	-	-	-	-	+	+	+	+	+	NA*	-	NA**	NA**	NA**	-	+	-	+
Blankevoort, 2010	-	-	+	-	+	-	-	+/-	+	+	-	-	-	-	-	-	-	+
Bouaziz, 2015	+	-	-	-	+	-	-	+/-	-	-	-	NA**	NA**	NA**	-	-	NA**	+
Bouaziz, 2016	-	-	-	-	+	-	-	-	-	-	-	NA**	NA**	NA**	-	+	NA**	+
Bouaziz, 2018	+	-	-	-	+	-	-	+/-	+	NA*	-	+	NA**	-	-	+	+	+
Bruns, 2016	-	+/-	-	-	+	+	-	+/-	+	+	-	NA**	NA**	NA**	-	+	NA**	+
Bueno- de Souza, 2018	+	-	-	-	+	-	-	+	+	NA*	-	+	NA**	-	+	-	-	+
Bullo, 2018	+	-	-	-	+	-	-	+/-	+	-	-	-	-	-	-	+	-	+
Cugusi, 2017	-	-	-	+/-	+	+	+	+/-	+	NA*	-	+	NA**	-	-	+	+	-
Dale, 2015	+	+	-	+	+	+	+	+	+	NA*	+	+	NA**	+	+	+	+	+
Doyle, 2019	+	-	-	-	+	+	-	+/-	-	-	-	+	-	-	-	+	-	+
Fukuta, 2016	+	-	-	+/-	+	-	-	+/-	-	NA*	-	+	NA**	-	-	+	+	+
Gardner, 2014	+	-	-	-	+	+	-	+/-	+	+	-	NA**	NA**	NA**	-	+	NA**	+
Golledge, 2019	+	-	-	+/-	+	+	-	+/-	+	NA*	-	+	NA**	-	-	-	+	+
Gomes-Neto, 2019	-	-	-	+/-	+	+	-	-	+	NA*	-	+	NA**	-	-	+	-	+
Halloway, 2015	-	-	+	-	-	+	-	+	-	NA*	-	NA**	NA**	NA**	-	+	NA**	+
Hernandez, 2015	-	+/-	-	-	+	-	-	-	-	-	-	NA**	NA**	NA**	-	-	NA**	-
Heyn, 2008	+	-	-	-	-	-	-	+/-	-	NA*	-	-	NA**	-	-	-	-	-
Howes, 2017	-	+	-	-	-	+	-	+/-	+	NA*	-	+	NA**	-	-	+	+	+

Supplementary file E. Continued.

Review	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9 RCT	Item 9 NRSI	Item 10	Item 11 RCT	Item 11 NRSI	Item 12	Item 13	Item 14	Item 15	Item 16
Huang, 2002, 2005, 2016	+	-	-	-	-	+	+/-	+/-	-	-	-	+	-	-	+	+	+	+
Hurst, 2019	+	+/-	-	-	+	+	-	+/-	+	-	-	+	-	-	-	+	+	+
Hwang, 2015	-	-	-	-	-	-	-	+/-	-	-	-	NA**	NA**	NA**	-	-	NA**	-
Kanach, 2018	+	-	-	+/-	+	+	-	+/-	+	-	-	NA**	NA**	NA**	-	+	NA**	-
Keogh, 2012	-	-	-	+/-	-	-	-	-	-	-	-	NA**	NA**	NA**	-	-	NA**	+
Kuijlaars, 2019	+	+/-	-	+/-	+	+	-	+	+	NA*	-	+	NA**	-	-	+	-	+
Lam, 2018	+	-	-	-	+	-	-	+	+	NA*	-	+	NA**	+	+	+	+	+
Lee, 2017	+	+/-	-	+/-	+	+	-	+	+	NA*	-	+	NA**	+	-	+	-	+
Leggio, 2019	+	-	-	-	+	-	-	-	+	NA*	-	NA**	NA**	NA**	-	+	NA**	+
Li, 2019	+	-	-	-	+	-	-	+/-	+	NA*	-	+	NA**	+	+	+	-	+
Liao, 2015	+	-	-	-	-	+	-	+/-	+/-	NA*	-	+	NA**	-	-	+	-	+
Paneroni, 2017	+	-	-	+/-	+	+	-	+	+	NA*	-	+	NA**	-	-	+	+	+
Parmenter, 2013	+	-	-	+/-	-	-	-	+/-	+	NA*	-	NA**	NA**	NA**	-	+	NA**	+
Patel, 2012	+	-	-	-	+	+	-	+	-	NA*	+	+	NA**	-	-	-	-	+
Pengelly, 2019	+	+/-	-	-	-	+	-	+/-	+/-	+	-	+	-	-	-	+	-	+
Puhan, 2016	+	+	-	+	+	+	+	+	+	NA*	+	+	NA**	+	+	+	+	+
Rezende Barbosa, 2018	-	+/-	-	+/-	-	+	-	-	+	NA*	-	+	NA**	+	+	-	+	+
Ribeiro, 2017	+	+/-	-	-	+	+	-	-	+	-	-	-	-	-	-	+	+	+
Rodrigues-Krause, 2016	+	+/-	+	-	+	+	-	+/-	+	+	-	+	-	-	-	+	+	+
Rodrigues-Krause, 2019	+	-	+	-	-	-	-	+	+	-	-	NA**	NA**	NA**	-	-	NA**	+

Supplementary file E. Continued.

Review	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9 RCT	Item 9 NRSI	Item 10	Item 11 RCT	Item 11 NRSI	Item 12	Item 13	Item 14	Item 15	Item 16
Rosero, 2019	+	-	-	-	+	+	+	+/-	+	NA*	-	+	NA**	-	-	+	+	+
Rydwik, 2004	+	-	-	-	-	-	-	+/-	+	NA*	-	NA**	NA**	NA**	+	+	NA**	-
Ryrso, 2018	+	-	-	-	+	+	-	+	+	NA*	-	+	NA**	+	+	+	-	+
Scheerman, 2018	+	-	-	-	+	+	-	+/-	+	NA*	-	NA**	NA**	NA**	+	+	NA**	+
Slimani, 2018	+	-	-	+/-	-	+	-	-	-	NA*	-	+	NA**	-	-	+	+	+
Vieira, 2010	+	-	-	-	-	+	-	+	+	NA*	-	NA**	NA**	NA**	-	-	NA**	+
Wee, 2019	+	+	-	+/-	+	+	-	+/-	+/-	-	-	NA**	NA**	NA**	-	-	NA**	+

Appendix 5 Results of AMSTAR 2 review quality assessment.

Legend: *RCT*: randomized controlled trials; *NRSI*: non-randomized studies of interventions; “+”*:* yes; ”-“: no; “+/-“: partial yes; *NA**: Includes only RCT’s; *NA***: No meta-analysis conducted

Item 1 Did the research questions and inclusion criteria for the review include the components of **PICO**?; *Item 2* Did the report of the review contain an explicit statement that the **review methods were established prior to** conduct of the review and did the report justify any significant deviations from the protocol?; *Item 3* Did the review authors **explain their selection of the study designs** for inclusion in the review?; *Item 4* Did the review authors use a **comprehensive literature search strategy**?; *Item 5* Did the review authors perform **study selection in duplicate**?; *Item 6* Did the review authors perform **data extraction in duplicate**?; *Item 7* Did the review authors provide **a list of excluded studies** and justify the exclusions?; *Item 8* Did the review authors **describe the included studies in adequate detail**?; *Item 9* Did the review authors use a **satisfactory technique for assessing the risk of bias (RoB)** in individual studies that were included in the review?; *Item 10* Did the review authors **report on the sources of funding** for the studies included in the review?; *Item 11* If meta-analysis was justified did the review authors use **appropriate methods** for statistical combination of results? (Only complete this item if meta-analysis of other data synthesis techniques were reported); *Item 12* If meta-analysis was performed did the review authors **assess the potential impact of RoB** in individual studies on the results of the meta-analysis or other evidence synthesis?; *Item 13* Did the review authors **account for RoB in individual studies when interpreting/ discussing the results** of the review?; *Item 14* Did the review authors provide a satisfactory **explanation for, and discussion of, any heterogeneity observed** in the results of the review?; *Item 15* If they performed quantitative synthesis did the review authors carry out an adequate **investigation of publication bias** (small study bias) and discuss its likely impact on the results of the review?; *Item 16* Did the review authors report any **potential sources of conflict of interest**, including any funding they received for conducting the review?;

03

Exercise testing and training in frail older adults with an orthopedic impairment participating in a geriatric rehabilitation program: An international Delphi study

Groen WG*, Wattel EM*, de Groot AJ, Meiland FJM, Hertogh CMPM, Gerrits KHL. Exercise testing and training in frail older adults with an orthopedic impairment participating in a geriatric rehabilitation program: an international Delphi study. Eur Geriatr Med. 2023 Oct;14(5):985-997. doi: 10.1007/s41999-023-00819-5.

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Abstract

Background: Little is known about exercise testing and training in orthopedic geriatric rehabilitation. This study aims to obtain expert-consensus-based recommendations on this matter.

Methods: Using an online Delphi study we aimed to reach international expert consensus on statements related to testing and training of endurance capacity and muscle strength. Participants needed to have relevant research or clinical expertise. Statements were evaluated and explanatory comments could be provided. After each round anonymous results were presented to participants. Statements could be adjusted or new ones could be formulated if necessary. Consensus was defined as >75% of participants agreeing.

Results: Thirty experts completed the first round. Twenty-eight (93%) the second and 25 (83%) completed the third round. The majority of experts were physical therapists. Consensus was reached on a total of 34 statements. The statements and comments reflected the need for a pragmatic and tailored approach in this population both for testing and training. For example, for testing endurance capacity, a six minute walk test was promoted and for testing muscle strength, performance in a functional activity was suggested. Ratings of perceived exertion were promoted for monitoring intensity of endurance and muscle strength training in patients without cognitive impairment.

Conclusion: In orthopedic GR, endurance and muscle strength testing should be pragmatic and is preferably performed in functional activities. For endurance training existing guidelines of the American College of Sports Medicine can be strived for but adapted as needed and for muscle strength training only lower intensities are agreed upon.

Keywords: geriatric rehabilitation, exercise, fractures, Delphi study

Key summary points

Aim: To obtain expert-consensus-based recommendations for exercise testing and prescription for orthopedic geriatric rehabilitation.

Findings: For endurance training existing guidelines of the American College of Sports Medicine can be strived for but adapted as needed and for muscle strength training only lower intensities are agreed upon.

Message: In orthopedic geriatric rehabilitation, endurance and muscle strength testing should be pragmatic and is preferably performed in functional activities.

Introduction

Geriatric Rehabilitation (GR) is defined as a multidimensional approach of "diagnostic and therapeutic interventions, with the purpose to optimize functional capacity, promote activity and preserve functional reserve and social participation in older people with disabling impairments".[1] The largest subgroup of patients (about 40%) in GR are those who are admitted for an orthopedic problem as a result of a trauma (acute orthopedic) or elective surgery related to the lower extremities and pelvis.[1] We will refer to this group of group as orthopedic GR patients. To improve functional performance, these patients often engage in exercise training supervised by physical therapists as part of multidisciplinary treatment.[2] The focus of this exercise training is on regaining functional independence through practicing functional activities so that a patient is able to return home as soon as possible. Because of this focus on physical functioning, strength and endurance training are not always at the forefront of the GR trajectory. Strength and endurance training are part of the total rehabilitation trajectory, but the content varies in practice and is often not based on evidence based guidelines, which may lead to suboptimal functional outcomes. This may be partly caused by the lack of guidelines for specific patient populations. In addition, also generic guidelines are not always adhered to. In the field of GR, therapists seem not fully aware of the potential of strength and endurance training for improving activities of daily living. However physical functioning is highly dependent on physical fitness[3,4] making it an important target.

There have been some recommendations for exercise training in older adults[5-7] as well as results from meta-regression analyses resulting in "optimal" training characteristics for endurance[8] and muscle strength training[9] in older healthy adults. One could question why these recommendations could not just be followed for orthopedic GR patients. First, the orthopedic GR population concerns a specific group of patients that is a very heterogeneous group with many comorbidities, frailty and disability.[10] Second, although a number of studies have been performed in frail older adults post fracture, their exercise programs are highly heterogeneous regarding their exercise programming and descriptions of exercise programs are often poorly reported.[11-13] Consequently, there is also a lack of evidence on how to set (based on valid exercise testing) and monitor training intensities for frail older adults in general and thus also for orthopedic GR patients.

The absence of evidence based guidelines inevitably leads to variation in daily clinical practice with regard to Frequency, Intensity, Type and Time (FITT) characteristics used in training and therefore to suboptimal treatment (i.e. under- or overtreatment). The art of exercise training is that it should be performed at the proper intensity and duration. This induces physiological overload and triggers adaptation as a result of super compensation during the subsequent resting period. Undertreatment (i.e. training at lower than optimal intensity or volume) may lead to suboptimal gains in physical fitness and -functioning whereas overtreatment (training at higher than optimal intensity or volume) may lead to further aggravation of the impairment or to adverse events. To be able to evaluate the exercise program and to train at the right intensities, proper evaluations should be made of (baseline) physical fitness by valid and reliable exercise testing methods.

To date there is a lack of evidence regarding exercise testing and training requirements (e.g. which tests to use, and how and which training characteristics to apply) in orthopedic GR patients. Therefore we performed a Delphi study to obtain expert- consensus based practical guidelines for exercise testing and prescription for these patients.

Methods

Study design

An online Delphi procedure was performed to reach consensus on exercise programming characteristics during orthopedic geriatric rehabilitation in frail older adults. Consensus or "collective agreement" is widely regarded as a useful method in the absence of scientific evidence. The objectives of the study were presented to all participants and informed consent was obtained before the start of the first Delphi round. The study did not need institutional review board approval as by Dutch law this type of research is exempted from review. All invited participants also provided consent to be acknowledged in this article.

Expert Panel

International experts were selected by three Delphi moderators (W.G., L.W. and K.G.). Experts needed to either have extensive knowledge of exercise physiology in frail older patients or extensive practical experience in exercise testing and training in frail older patients with an orthopedic impairment. Specifically, the experts needed to fulfill at least one of the following criteria 1) having a track record of at least 5 research publications in the field of exercise testing or training in frail older persons (preferably orthopedic rehabilitation), 2) having at least 5 years of recent experience in the field of exercise testing and training in orthopedic geriatric rehabilitation either as physiotherapist or as a physician, 3) having expertise, otherwise verifiable regarding the topic of exercise testing and training in orthopedic GR (e.g. educational experts on the topic). Participants were not informed about the identity of other participants in the study until completion of the study. Academics were primarily contacted via email as identified by publications or via a google search and Dutch geriatric PTs via the Dutch collaborative academic networks of elderly care (SANO). Additionally, some experts were approached via Twitter as a first contact. In all instances, when a first contact was established interested participants were sent a formal invitation letter by email with the purpose and procedures of the study.

Delphi process

General process

The Delphi process comprised three rounds. We used Survalyzer software (Survalyzer BV, Utrecht, The Netherlands) to create the online questionnaires and to present feedback to the participants. All materials throughout the entire study were made available in both English and Dutch. The first questionnaire was sent in May 2021 and the deadline for filling out the third questionnaire round was August 2021. In case a panel member did not respond a reminder email was sent. We sought to reach consensus on the following four selected topics: 1) testing endurance capacity, 2) training endurance capacity, 3) testing muscle strength, 4) training muscle strength. Statements were developed by the moderators (W.G., L.W. and K.G.), based on their expertise and literature review on this topic. For example, with regard to FITT

characteristics for muscle strength training we used the recommendations from Borde et al..
[9] A background information document and the questionnaire that were used in round one (Online Resources 1 and 2 respectively), were tested and revised for content, clarity, and lay-out by a clinical exercise scientist, a geriatric physical therapist and an elderly-care physician involved in geriatric rehabilitation.

In each round participants were asked to independently evaluate the statements using a 4-point Likert scale ('strongly agree', 'agree', 'disagree', 'strongly disagree'), or the option to select 'don't know'. A free-text response option was available for every statement to elaborate on or explain the responses. Lastly, participants were given the opportunity to provide a general comment per topic and for the questionnaire as a whole. Consensus was defined as >75% of participants scored "agree" or "totally agree" on a statement in any of the rounds [14] (including potential "I don't know" responses in the denominator). All statements on which consensus was reached were omitted in the second round. Statements with insufficient consensus were rephrased by the research team making use of the comments that were provided by the Delphi panel members. The Delphi study was finished after a predefined number of three rounds even if there were remaining statements for which consensus was not yet reached.

Round 1

The main part consisted of the above mentioned 4 topics. In total 29 statements were presented. Additionally, 8 closed and 10 open-ended questions were posed to gain better understanding on several topics (e.g. about the feasibility and validity of several methods for monitoring the intensity of endurance training) and to use for further construction of statements. In this round we also made an inventory of the sociodemographics and professional experience of the participants to describe the sample. The questions and statements posed in the three rounds are presented in Online Resource 2.

Rounds 2 and 3

Apart from rephrasing the statements where consensus was not reached, the moderators created new statements based on the input that was provided in round 1 on the closed and open ended questions and these were presented for the first time in round 2. We showed the panel members the results of the statements in the first round in a bar chart (which were) accompanied by the anonymous comments that were provided in the free text response option by the Delphi members. Responses were translated by the research team to both Dutch and English. When the moderators team felt that the feedback was very lengthy for a particular statement then a short summary was added as an introduction to the new statement. The procedures for round 3 were similar to those described for round 2.

Data analysis

Descriptive statistics were used to describe participants' demographic characteristics and responses to each statement in all three rounds.

Results

In total 30 experts participated in the first round. Fourteen researchers were invited by email of which 11 agreed to participate and 8 completed the first round (participation rate of 57%). Three actively declined (2 because of limited time and one because of illness) and 3 that initially agreed in the end did not participate. The call for participation of physical therapists yielded 19 participants (participation rate unknown). Furthermore two elderly care physicians working in geriatric rehabilitation and one lecturer in geriatric exercise physiology were invited and all participated (100% participation rate). Twenty-eight (93%) completed the second and 25 (83%) completed the third round. The proportion of academics versus clinicians was fairly constant across the rounds. In the first round the fraction of researchers was 8/30 (27%), and was 7/28 (25%) and 5/25 (20%) in the second and third round respectively. The characteristics of the Delphi panelists are presented in Table 1.

Table 1. Characteristics of Delphi panel experts.

Main profession, (n=)	
• Physical therapist	19
• Researcher	8
• Elderly care physician	2
• Other, teacher in geriatric exercise physiology	1
Country of residence, (n=)	
• Australia	1
• Canada	2
• Denmark	1
• Netherlands	17
• Spain	1
• United Kingdom	5
• USA	3
Years of experience (scientific or clinical) regarding physical testing and or training elderly patients in general, mean (sd) ; range	18 (10) ; 5 – 38
Years of experience (scientific or clinical) regarding physical testing and or training elderly patients who are rehabilitating from an orthopedic procedure, mean (sd) ; range	15 (11) ; 0* - 38

*Teacher in geriatric exercise physiology

Evolution of statements throughout the study

In round 1, a total number of 29 statements were presented. Consensus was reached on six statements and they were omitted from round 2. In round 2, 32 statements were presented. Based on the results of round 1, 16 statements were adjusted and 16 new statements were formulated. Eight statements were provided with an introduction text or additional remarks based on the comments provided. In round 2, 24 statements were agreed upon leaving 8 with no consensus. In round 3, these 8 remaining statements were adjusted and presented again leading to consensus on another 4, leaving 4 with no consensus. In summary, after three rounds consensus was reached on 34 statements (Table 2) and in 4 cases no consensus was reached (Table 3).

Table 2. Statements with consensus reached

Statement per topic	Consensus reached in round	Agree (%)	I dont know (%)
TESTING ENDURANCE CAPACITY (8 STATEMENTS)			
The effects of endurance capacity training can be adequately evaluated by means of a 6 Minute Walking Test.	1	83	0
The 6 minute walking test is NOT appropriate to determine the target exercise intensity for endurance capacity training in orthopedic geriatric rehabilitation.	2	82	0
For most patients in orthopedic geriatric rehabilitation it is NOT feasible to perform a maximal exercise test (CPET).	2	96	0
For most orthopedic geriatric patients CPET is NOT an appropriate test to evaluate the effects of endurance capacity training.	2	96	4
For orthopedic geriatric patients that are not limited by pain and are able to exercise on a (recumbent)cycle ergometer, target exercise intensity (in Watts or HR) for endurance capacity training can be adequately determined by means of an Astrand test.	2	82	0
For most orthopedic geriatric patients the Astrand test is NOT an appropriate test to evaluate the effects of endurance capacity training.	2	93	4
For most orthopedic geriatric patients the Talk Test is NOT an appropriate test to evaluate the effects of endurance capacity training.	2	82	7
For the evaluation of the effect of endurance capacity training in orthopedic geriatric patients the most important outcome is a functional measure, like the performance on a 6 minute walking test or a patient specific goal.	2	93	0
TRAINING ENDURANCE CAPACITY (9 STATEMENTS)			
To achieve an adequate training stimulus, general guidelines for the improvement of endurance (aerobic capacity) should be tailored to individual patients. The ACSM-guidelines are the best available evidence for this purpose: • Frequency: at least 3 sessions/week (vigorous intensity), at least 5 sessions/week (moderate intensity) • Intensity: Borg 0-10 scale: 5-6 (moderate intensity), 7-8 (vigorous intensity) • TIme: 30 to 60 min/session (moderate intensity) ; 20 to 30 min/session (high intensity)	2	79	11
The ASCM-guideline can be tailored to a patients' needs by starting at a lower intensity and session duration, and progressively increasing intensity and session duration to the recommended guidelines.	2	93	4
The ACSM-guidelines can be tailored to a patients' needs by varying in the interplay between frequency, intensity and session duration, for example by providing more frequent, shorter sessions, or by providing longer sessions of lower intensity.	2	93	4
A frequency of 3-4x per week is suitable.	1	77	10
Only if the training stimulus is high enough, endurance capacity can improve by means of functional training (walking, sit to stand etc).	2	86	7

Table 2. Continued.

Statement per topic	Consensus reached in round	Agree (%)	I dont know (%)
For orthopedic geriatric patients the exercise intensity for endurance capacity training can be adequately monitored by a Modified Borg RPE (scale 0 to 10).	2	93	0
For orthopedic geriatric patients the exercise intensity for endurance capacity training can be monitored the best by a combination of the two aforementioned methods (Modified Borg RPE and ventilation). #	2	75	7
For orthopedic geriatric patients it is possible to monitor the intensity of endurance capacity training WITHOUT SPECIFIC exercise modes, such as walking on a treadmill or cycling on a bicycle ergometer.	2	89	7
Endurance capacity training should be continued* after orthopedic geriatric rehabilitation to further increase the effects or to help limit further age-related deterioration. *can include daily aerobic physical activities or exercise in different exercise settings e.g. local gym, home based exercise.	3	84	4
TESTING MUSCLE STRENGTH (5 STATEMENTS)			
For patients in orthopedic geriatric rehabilitation for whom improving muscle strength is a goal, a derived 1 RM (e.g. based on 8 or 10RM) test is suitable to determine the target training intensity.	2	89	0
For patients in orthopedic geriatric rehabilitation for whom improving muscle strength is a goal, the effects of muscle strength training can be adequately evaluated by a derived 1RM (e.g. based on 8 or 10 RM) test.	2	93	0
For patients in orthopedic geriatric rehabilitation for whom improving muscle strength is a goal, the effects of muscle strength training can be adequately evaluated by improvement in functional activities that have a significant strength component.	2	96	4
With functional strength training, the desired training intensity can be adequately determined by making functional adjustments to the task (eg by adjusting the height of a seat when getting up from a chair until the exercise can just be performed).	1	87	7
If the desired training intensity cannot be determined (for example due to pain) then it is still useful to do strength training at an intensity that does not cause pain.	1	83	3
TRAINING MUSCLE STRENGTH (12 STATEMENTS)			
A frequency of 2 x per week is suitable.	1	77	3
The number of 2-3 sets per muscle group is suitable.	1	87	7
Even if intensity cannot be monitored strength training in orthopedic geriatric rehabilitation is still useful.	2	93	0
An intensity of 40-60% of 1RM with at least 15 repetitions per set is adequate to improve local muscular endurance in orthopedic geriatric rehabilitation.	2	75	14

Table 2. Continued.

Statement per topic	Consensus reached in round	Agree (%)	I dont know (%)
The strength training guidelines can be tailored to a patients' needs by varying in the interplay between frequency, intensity and session duration, for example by providing more frequent, shorter sessions, or by providing longer sessions of lower intensity.	2	82	4
In orthopedic geriatric rehabilitation in most patients a gradual buildup of strength training intensity is necessary to ensure that the patients' technique is correct before intensity is increased to a recommended level.	2	86	0
Specific and controlled strength training using equipment (eg. a leg press or lat pulley) is NOT necessary to improve muscle strength.	2	86	0
The effect of functional strength training may be further enhanced by combining it with training on specialized equipment.	2	86	11
The intensity of strength training in orthopedic geriatric rehabilitation can be adequately monitored during functional activities (e.g. By the number of reps in a sit to stand exercise).	2	96	0
The maximum number of repetitions attained in a set (and compared to the target number of repetitions) is a feasible and valid measure of monitoring muscle strength training intensity in orthopedic geriatric rehabilitation.	3	76	4
The modified BORG RPE scale may be applicable to monitor strength training intensity in orthopedic geriatric patients, without cognitive impairments.	3	80	8
Muscle strength improvement can be expected after 6-9 weeks of resistance training and should be continued* after orthopedic geriatric rehabilitation to further increase the effects or to help limit further age-related deterioration. * can include daily strength-based physical activities or exercise in different settings e.g. local gym, home-based exercises.	3	92	0

This statement refers to two statements of which one consensus was reached (Modified Borg) and another on which consensus was not reached (i.e. the second statement presented in Table 3: "For orthopedic (…) whole sentences."

Table 3. Statements without consensus reached.

Topic	Statement	Agree (%)	I don't know (%)
Testing endurance capacity	For orthopedic geriatric patients that are able to exercise on a (recumbant) cycle ergometer AND are able to talk during low intensity exercise*, the Talk Test is an adequate tool to determine target exercise intensity (in Watts or HR) for endurance capacity training. * i.e. not limited by ventilatory or cognitive functioning	64	4
Training endurance capacity	For orthopedic geriatric patients that are able to exercise on a (recumbant) cycle ergometer AND are able to talk during low intensity exercise*, the exercise intensity for endurance capacity training can be adequately monitored by means of training at a level just below the ventilatory threshold, which means that the patient can just speak in whole sentences. * i.e. not limited by ventilatory or cognitive functioning	68	4
Testing muscle strength	For patients in orthopedic geriatric rehabilitation for whom improving muscle strength is indicated as a goal AND resistance exercise is possible, handheld dynamometry is a valuable tool to quantify possible effects of resistance training on local muscle strength, as an addition to more functional evaluation.	72	7
Training muscle strength	In patients that are not hindered by pain, an intensity associated with 70-79% of 1RM with a target number of repetitions per set of 7-9 is adequate to improve maximal muscle strength in orthopedic geriatric rehabilitation.	60	7

Qualitative feedback per topic throughout the Delphi rounds
To illustrate the evolution of the Delphi study we here present a selection of the qualitative feedback received and the course of the discussion on the various topics. For some quotes we added explanatory text between square brackets.

Testing endurance capacity
Of the statements and questions presented in round 1, some were related to specific endurance capacity testing methods such as the cardiopulmonary exercise test (CPET), 6 minute walk test (6MWT), Åstrand test and the Talk Test. Delphi panelists were pointing out that for orthopedic patients in GR a bicycle ergometer-based test is not a feasible option because of pain. Some questioned the feasibility of a CPET because it requires equipment and trained personnel, and indicated that the population is too frail to undergo a graded exercise test till maximum exertion (maximal exercise test). One Delphi member pointed out that in her practice – for this reason - they don't even have a bicycle ergometer. Much feedback was provided stating that functional testing should be considered. As one expert put it: *"Comment on all the tests so far - they are generally not suitable for frail older people who present with a hip fracture, which is the predominant case load. Therefore, all testing must be applicable and functional for this caseload. Most of the 'research' based cycle ergometer testing is therefore not suitable"*. The adjusted statement in round 2 "For the evaluation of the effect of endurance capacity training in orthopedic geriatric patients the most important outcome is a functional measure, like the performance on a 6 minute walking test or a patient specific goal" was, therefore, accepted by a large majority (93 %). Items that failed to reach consensus in any round were related to the Talk Test to determine target exercise intensity (Table 3). Issues raised in round 2 for instance are: *"There are so many older adults who cannot walk and talk or who slow down when speaking. I think this method is difficult for patients in their 80s."* When the statements were rephrased in such a way that cognition and ventilation are not impaired, the statements were still not accepted (Figure 2, overview box endurance testing and training).

Training endurance capacity
In the first round we presented the FITT characteristics as proposed by the meta-regression analysis of Huang et al. [8] based on 41 RCTs in older adults, but they were found to be too inflexible and too harsh for the orthopedic GR population. As one expert put it: *"I am really opposed to a one size fits all approach. The best training program is the one you can get them to do consistently. Starting with 14-15 RPE [rating of perceived exertion on a Borg scale] in the orthopedic population is likely unrealistic. That duration [50-53 weeks] is definitely unrealistic. If you are going to use one prescription as a starting point or guide, use the American College of Sports Medicine (ACSM) guidelines text to derive one. These are well established."* In line with this and other similar comments we adopted the ACSM FITT characteristics in our statements, [7,15] to which the panel agreed to subsequently, along with some supporting statements regarding tailoring of the exercise to the patient (Figure 2, overview box endurance testing and training). Additionally, it was pointed out that in many patients, activities of daily living can also improve by gradually performing more activities of daily living and that training of aerobic capacity per se should not be a goal in itself. As one expert puts it: *"Also with walking with a walker or other specific training (such as transfers) the patient can improve his or her endurance capacity. In some instances even better because it is more functional"*. In round 1, a number of potential ways for monitoring exercise intensity for endurance training were proposed. For monitoring

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intensity during endurance capacity training the Borg scale was evaluated as both feasible and valid. Other options were discarded as being infeasible and or invalid such as percentage of maximum heart rate or oxygen uptake as they would require (an infeasible) maximal test, as well as questionable appropriateness of such parameters in patients who are on cardiac medication. Training on the basis of breathing effort was not perceived as a valid option. In round 2 there was consensus on the statement that intensity of endurance exercise could be measured without using specific controlled exercise modes on a bicycle ergometer or treadmill. In line with this it was agreed by the panel that using the modified Borg scale (Scale 0-10 instead of the traditional 6-20) was the best way to monitor exercise intensity during endurance training. The addition of the observation if the patient can speak comfortably while training alongside the Borg score lowered the number of experts agreeing, meaning that indeed dyspnea is not viewed as key sign when monitoring. This is underscored by the statement on ventilation that was revised for round 3 (Table 3, second statement). It still did not reach consensus and there were given clear reasons for this in the comments. As one expert puts it: *"Not reliable enough. Sometimes patients have comorbidities and or cardiac medication that that hampers talking during exercise beforehand"*. Monitoring however was deemed to be essential but with a level of pragmatism attached to it.

Testing muscle strength

From the statements posed in round 1 and 2 it became clear that a <u>derived</u> 1 repetition maximum (1RM) test, for example based on 8RM, is the best choice to evaluate the effects of muscle strength training as well as to base training intensity on. One expert explicitly stated to not use a standard 1RM test (in which it is determined which high load can be lifted just once)*: "highly discourage 1RM testing in a population where prevalence of osteoporosis and vertebral fractures likely to be high. Estimated or derived 1 RM may be ok, but formal testing may not make sense at first."* Indeed there was also some skepticism regarding the uses of any form of formal 1RM testing. As one expert formulated: *"It is likely that many individuals in the healthy older adult demographic have never engaged in resistance training and I would not advise starting with a 1RM assessment for these individuals. This is also the case within orthopaedic geriatric patients and I believe 1RM testing is completely inappropriate and unnecessary. (…) ".* On the other hand, it was also found to be acceptable to base the exercise intensity on the performance on a functional task (as a pragmatic test), provided that it has a significant strength component. The intensity can then be adjusted by e.g. adjusting the height of a seat when getting up from a chair until the exercise can just be performed.

Training muscle strength

Regarding FITT characteristics, strength training for 2 sessions per week and 2-3 sets per training was found to be adequate by a majority of panel members. The number of repetitions of 7-9 was approved by many (but did not reach 75% consensus) and may vary according to the specific goal (e.g. may be higher when improvement in local muscular endurance is the goal). A long training period (literature suggested an optimal period as long as 50-53 weeks) was found to not be feasible in orthopedic GR setting. A gradual buildup was also suggested by several experts. The psychosocial aspects of strength training (i.e. improving motivation and adherence) was deemed important, but was out of scope of the current Delphi study. Also it was stressed that any strength training is better than none, as one expert mentioned: *"Anything is better than nothing - so even if I cannot measure intensity, I would use strength* *training in virtually all of my patients".* Regarding monitoring of intensity the panel almost unanimously agreed to monitor intensity by looking at the performance at functional activities (e.g. by the number of repetitions relative to the maximum number, in a sit to stand exercise). One expert is rather pragmatic and says: *"you can monitor intensity for any exercise if you standardize your approach to testing. For example, I could ask someone to warm up, then do as many pushups as possible. Let's say they do 8. I could prescribe 3 sets of 6 or 7 to start, and then ask them to increase the number they do every 2 weeks, but keeping 1-2 repetitions in reserve. So their intensity is a consistent percent of their max ability."* Many panelists commented that functional training should be the main focus but could be supported with specific muscle strength training using specialized equipment. *"It [specific and controlled strength training using equipment] is not necessary but is useful to have and can provide more variety to a program and potentially make it easier to train specific body parts around a fracture site."* Furthermore, although consensus was reached on one aspect of strength training intensity related to enhancing local muscular endurance, we could not reach consensus on more strenuous intensities. This may have been related on the one hand to the parameters itself *"Still seems too arbitrary for these patients who are diverse in their capacity"* and on the other hand on phrasing as it was phrased as improvement in <u>maximal</u> strength. *"It is more accurate to phrase this, adequate to improve 'muscular strength' rather than 'maximal' muscular strength - because, as noted by several respondents, this is not actually a maximum strength training protocol.. "* Some also wished for more flexibility in the parameter range to accommodate to the patient : *"I think a statement that better reflects the range of training options would be preferred (…). The intensity you have proposed would obviously work and I don't disagree with that - but we need to recognize that other training plans may be as effective."*

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Discussion

This study provides a first set of practical guidelines for exercise recommendations for older orthopedic patients admitted to GR. We reached consensus on a number of guiding statements regarding exercise testing and training for strength and endurance capacity in these patients. We found that the Delphi panel was very outspoken regarding the use of exercise testing for both strength and endurance. Generally stated, there is a lack of valid and feasible tests, and the panel called for pragmatic approaches, i.e. they found it acceptable to measure exercise intensity through observing performance in functional activities. Although this pragmatic approach may be found to be acceptable in clinical practice, it may be problematic in the context of clinical research where a high degree of validity and accuracy is required to be able to gather evidence on training effectiveness. In addition, we would argue that even in clinical practice it would be beneficial to have reliable and valid outcome measures e.g. to evaluate therapy success and to strive for this whenever possible. There was a general dismay among the Delphi panelists for testing on (bicycle)ergometers because of the patients' functional limitations and advanced cardiopulmonary exercise testing was found not to be feasible for most patients (reasons provided are e.g. having functional limitations and being frail) and settings (because equipment and skilled personnel is absent). The general tendency of experts was to encourage to just start practicing at the patients' current fitness level and gradually progress from there even without formal testing procedures, be it endurance or strength training. The panel found that observations of exercise intensity are then best made based on RPE (for endurance capacity training) and by monitoring the maximum number of repetitions attained in a set on a strength task and relating it to the intended number of repetitions. Based on the findings we provided a summary of suggestions for endurance capacity and muscle strength testing and training (Figures 1 and 2).

Testing of endurance capacity

	For determining target exercise intensity	For effect of training	Comment
6MWT	✗	✓	
CPET	✗	✗	Not feasible
Åstrand	✓	✗	If not limited by pain and able to cycle on ergometer
Talk test	?	✗	

Training of endurance capacity

Basic: FITT characteristics for endurance capacity training according to ACSM-guidelines

	Moderate intensity	Vigorous intensity
Frequency (sessions/week)	≥ 5	≥ 3
Intensity (Borg 0-10 scale)	5-6	7-8
Time (min/session)	30-60	20-30

Type of exercise:
- Typical endurance training exercises like walking on a treadmill or cycling on a bicycle ergometer, or functional training as long as the training stimulus is high enough.

Tailoring by:
- Starting at lower intensity and session duration and increasing to ACSM-guidelines.
- Varying in the interplay between FITT characteristics, e.g. shorter and more frequent sessions, longer sessions of lower intensity.

Monitoring exercise intensity by (also possible without treadmill or ergometer)
- Borg RPE + observation of ventilation.
- Borg RPE.

General comments:
- Endurance capacity training should be continued after orthopedic geriatric rehabilitation to further increase the effects or to help limit further age-related deterioration.

Figure 1. Summary of recommendations of endurance capacity testing and training

Testing of muscle strength

	For determining target exercise intensity	For effect of training
Performance of a functional task* that has a significant strength component	✓	✓
Derived 1RM (e.g. based on 8RM)	✓	✓

* *By making adjustments to the task, e.g. by adjusting the height of a seat when getting up from a chair until the exercise can **just** be performed.*

Training of muscle strength

Basic: FITT characteristics for endurance capacity training according to ACSM-guidelines

	Based on (derived) 1 RM
Frequency (sessions/week)	2
Intensity*	40-60% of 1RM for local muscular endurance**
Time	≥ 15 repetitions 2-3 sets

**A gradual buildup of strength training intensity is necessary to ensure that the patients' technique is correct before intensity is increased to a recommended level.*

*** No consensus was reached for other strength training intensities.*

Type of exercise:
- Functional training with a significant strength component and / or specific and controlled strength training using equipment (like weights of leg press).
  Addition of specific strength training to functional training might enhance the effect on muscle strength.

Tailoring by:
- Varying in the interplay between FITT characterisctics, e.g. shorter and more frequent sessions, longer sessions of lower intensity.
- If the desired training intensity cannot be determined (for example due to pain) then it is still useful to do strength training at an intensity that does not cause pain.

Monitoring exercise intensity by
- The maximum number of repetitions attained in a set (and compared to the target number of repetitions)
- Borg RPE in patients without cognitive impairment

General comments
- Even if intensity cannot be monitored strength training can be useful
- Muscle strength improvement can be expected after 6-9 weeks of resistance training and should be continued after orthopedic geriatric rehabilitation to further increase the effects or to help limit further age-related deterioration.

Figure. 2. Summary of recommendations regarding muscle strength testing and training

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Formal endurance capacity testing (e.g. by a CPET) was discouraged by the Delphi panel. And although there are some studies that show that cardiorespiratory fitness can be measured by a CPET in healthy older adults, [16] and frailty in itself is not a contraindication for performing a CPET the literature on its use in frail older adults with an impairment is scarce. Thus, there is a need for more research into feasible, valid and reliable ways for testing aerobic capacity in older patients in (orthopedic) GR.

With regard to endurance capacity training the panel endorsed the adherence to ACSM guidelines providing that the load is properly adapted when needed. [7, 15] What is notable however is that in our results endurance exercise training was far less prominently advocated than strength training and that endurance training was expected to occur in the slipstream of performing functional exercises. However our panel stressed that aerobic exercise, in one way or another, should be encouraged after discharge and that striving for ACSM guidelines is a good starting point. One interesting finding was that the Borg score was endorsed in patients that are not hindered by cognitive problems for muscle strength and endurance capacity training. In line with this, Bok et al. [17] argue in their recent review that subjective ratings of exercise intensity for endurance training may be as effective as intensities based on prior formal graded (maximal) testing. However most of the studies are performed in (young) adults. [17]

When we compare the consensus results of muscle strength testing and training to existing recommendations of ACSM [7] and of the National Strength and Conditioning Association [5] and of Izqueirdo et al, [6] we find that there is no explicit mention of exercise testing to determine or monitor exercise intensity, but rather an implicit reference to 1RM measurement for strength and intensity monitoring during training for endurance exercise (no a priori testing). There is indeed hardly any literature on exercise testing methods in frail older patients let alone orthopedic GR patients. For testing muscle strength, performance in a functional task (e.g. standing up from a chair for strength) as well as derived 1RM testing is suggested by our Delphi panel. This functional-based method is in some way related to a derived 1RM testing method. With regard to training, the parameters stated for strength training correspond with our findings regarding the number of training sessions and sets. The number of repetitions and intensity stated in the position statement are however somewhat different, with a lower number of repetitions and a broad intensity range starting at 20% and working up to 80% of 1RM. We did not reach consensus on intensities at the higher end of the spectrum (e.g. 70-80% of 1RM) potentially because of issues with phrasing and small range of repetitions. From the data it was however clear that the common notion of 80% 1RM for 8-12 repetitions was not actively promoted in the feedback, suggesting that such an approach may not be very common in orthopedic GR patients. In the literature there is some evidence that functional task exercise is more effective in improving daily functioning than (non-functional) resistance exercise. [18] In another study in the oldest old, strength exercises did improve leg muscle strength but failed to translate to improved physical functioning as measured by 4-step stair test and timed up and go test. [19] Apart from this, a study in frail recently hospitalized patients showed that a high intensity resistance exercise program (i.e. 60-80% of 1RM) led to more musculoskeletal injuries, [20] which shows that some caution may be needed for higher intensity programs. Also the short time that patients are in rehabilitation wards may contribute to a focus on functional activities such that patients can go home and perform basic activities of daily living themselves. However, returning home should not be an end the therapy. The panelists agree that -ideally- there should be a long term follow-up of both strength and endurance training activities integrated into the daily lives as much as possible. Currently it is unknown what the best way is –both from a health services and exercise physiology perspective to support orthopedic GR patients in the long run when they have returned home.

This study shows that with regard to orthopedic GR there are several remaining uncertainties that should be subject of further study. First, regarding exercise testing, there is a need of evidence on the several methods currently used in practice as well as the ones that are underutilized (e.g. testing protocols for endurance capacity). It is of interest to compare subjective (i.e. RPE based) with objective (i.e. derived 1RM based) strength training prescriptions with regard to efficacy in this population (or in frail patients in general) to strengthen the knowledge base on this issue. With regard to muscle strength training, the optimal (yet feasible) training intensities for orthopedic GR patients are still rather unknown and may also be related to the functional goals one wants to attain. It may be worthwhile examining which type of muscle strength (e.g. maximal strength, strength endurance, power) is required for different functional activities in orthopedic GR and what the optimal parameters are for each of those. Furthermore, alternative strength training methods that may enhance strength gains without the need for heavy loading such as resistance training with vascular occlusion [21] may be particularly promising in orthopedic GR patients where the load-taking capacity is often reduced. Lastly, for both strength and endurance training it was stressed that there should be a long term follow up to ensure full benefits and prevent future health issues. How to organize this transitional care to accommodate this goal in a sustainable and cost efficient manner is an important question for further research. Also, more research is needed on the impact of varying levels of frailty and cognition in this population and how to accommodate testing and training procedures to these measures. Our recent literature review about endurance training in patients with different types of frailty may provide a starting point for this. [10]

A strength of the study is that we included a diverse group of experts consisting of researchers and clinicians involved in the care for patients in orthopedic GR, which means that the statements are backed by practical and scientific views. Another strength is the relatively high compliance of participants across the different Delphi rounds, which limits the potential for bias from selective dropout. Limitations of the study include the relatively small number of experts and an overrepresentation of Dutch physiotherapists. We had a fixed number of three Delphi rounds and some statements in the first round may have been too explorative and other statements may have been rather provocative to reach a positive consensus on. Although physical therapists and clinical exercise physiologists can use this as a guide when training their frail patients in orthopedic GR. It is by no means a definite guideline but rather a starting point that may be amended in the coming years as more evidence will be becoming available. Lastly, the current findings are restricted to the views of experts. The patients' and carers' perspectives were investigated in another study which is submitted elsewhere.

We have reached agreement on multiple strength and endurance testing and training characteristics for frail older adults in orthopedic GR. Generally stated, methods used for testing and training should be pragmatic in nature and a functional approach to exercise training is preferred. For endurance training existing guidelines of the American College of Sports Medicine can be strived for but adapted as needed and for muscle strength training only lower intensities are agreed upon. There are several remaining uncertainties that need further study, such as the optimal muscle strength training intensity and optimal strategies for long term support of these patients at home or in the community.

Disclosures and declarations

Conflicts of interests

The authors have no competing interests to declare that are relevant to the content of this article.

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Compliance with ethical standards

The study did not need institutional review board approval as by Dutch law this type of research is exempted from review. The objectives of the study were presented to all participants and informed consent was obtained before the start of the study. All invited participants also provided consent to be acknowledged in this article.

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04

Aerobic exercise in frail patients admitted to orthopedic geriatric rehabilitation: a pilot study on the feasibility of the talk test to prescribe adequate exercise intensity.

Gerrits KHL, Groen WG, Hertogh CMPM, Wattel EM. Aerobic exercise in frail patients admitted to orthopedic geriatric rehabilitation: a pilot study on the feasibility of the talk test to prescribe adequate exercise intensity.
Submitted

Abstract

Purpose: This study aimed to evaluate the feasibility of the Talk Test as a method for prescribing safe and adequate aerobic exercise intensity in frail older adults undergoing orthopedic geriatric rehabilitation (GR).

Methods: The study included 93 frail older participants from two cohorts within the FIT4FRAIL project. Participants performed the Talk Test on a semi-recumbent cycle ergometer. Ventilatory thresholds were estimated, with outcomes measured as power output at the last positive response and first negative response to speech provocation. Feasibility was assessed by completion rates, success rates, and reported reasons for early test termination. Data were analyzed using descriptive statistics and cohort comparisons.

Results: Of the 79 participants who started the Talk Test, 52% achieved a last positive response, indicating moderate feasibility for estimating the ventilatory threshold. Completion rates were low (18%), with pain, fatigue and motivation cited as reasons for termination. Participants selected to perform a talk test showed higher success and completion rates than those who were not a priori selected for that specific purpose. The group median (IQR) power output at the last positive (15 (16) watts, n=41) and first negative stage (34 (20) , n=9) indicated significantly lower exercise capacity compared to age-predicted norms.

Conclusion: Although promising, The Talk Test, in its traditional form, demonstrated limited utility for prescribing safe aerobic exercise intensity in frail older adults undergoing orthopedic GR, as highlighted by low completion rates and patient-specific barriers. Methodological adaptations, including alternative testing protocols, are needed to enhance applicability in this population.

Key-words: ventilatory threshold; feasibility study; submaximal exercise testing; fitness assessment; exercise monitoring

Introduction

Patients admitted to orthopedic geriatric rehabilitation (GR) typically present with advanced age, high levels of comorbidity, and poor health status, [1] which are associated with reduced physical fitness and impaired functional ability to perform and sustain activities of daily living (ADL). [2-4] These limitations significantly impact their quality of life and independence.

Aerobic exercise is an effective intervention to improve aerobic fitness across a wide variety of health statuses in older adults. [5] Higher levels of physical fitness in both healthy and frail older adults are associated with greater independence and lower energy costs of daily activities. [6 7] Additionally, improvements in physical fitness lead to positive changes in comorbid conditions, enhanced mobility, and better exercise performance. [7] These findings underscore the critical importance of aerobic exercise training as a cornerstone of orthopedic GR, aimed at restoring functional ability and enhancing residual physical function in vulnerable older people with disabling impairments. [8 9]

While health related exercise guidelines for adequate aerobic exercise prescription apply to a great extent to this population, [5] observational data from physiotherapists in orthopedic GR settings suggest that prescribed intensities are often below recommended levels. Furthermore, studies on less frail rehabilitation populations reveal that a substantial proportion of patients fail to meet guidelines for improving aerobic fitness or muscle strength. [10] A major barrier to achieving adequate exercise intensity is the lack of suitable methods for prescribing and monitoring aerobic exercise in orthopedic GR patients.

Aerobic exercise should be executed in a safe intensity range especially in frail patients with an increased risk of significant morbidity and mortality. [11] At the same time, intensity levels of exercise must be sufficiently high to induce meaningful improvements in aerobic fitness. In clinical practice, the Borg Scale for Rating of Perceived Exertion (RPE) is frequently used to prescribe exercise intensity. Although this scale is reliable and valid in healthy older adults, it has shown to be less effective in physically deconditioned or cognitively impaired older adults, [12] where its subjectivity may result in suboptimal exercise prescriptions. Heart rate-based methods, while more objective, are less accurate in patients taking beta-blockers and exhibit substantial interindividual variability in training responses. [13 14] Research in sedentary but healthy individuals has demonstrated that exercise prescriptions based on personalized physiological indicators such as the ventilatory threshold (VT) and respiratory compensation point (RCP), marking the limits of moderate exercise intensity, result in greater responsiveness and more significant aerobic fitness improvements than general heart rate zone-based prescriptions. [15] In addition, such personalized and ‘threshold-based’ prescription rather than a ‘range-based’ approach is recommended to improve the benefits of rehabilitation in cardiovascular patients [16] and at the same time avoid overexertion and cardiac ischemia. [17 18]

Traditionally, the symptom-limited maximal cardiopulmonary exercise test (CPET) is considered the gold standard for assessing aerobic fitness and determining VT and RCP. However, CPET implementation in orthopedic GR is hindered by the lack of specialized equipment and trained personnel. For this reason the Talk Test has emerged as a promising, accessible, and low-resource alternative. This submaximal incremental exercise test estimates

VT and RCP based on an individual's ability to speak comfortably during exercise. The Talk Test has shown to be a valid alternative to determine the markers of moderate and vigorous exercise in various populations, including well-trained athletes, [19] healthy individuals, [20 21] sedentary adults [22] and patients with cardiovascular diseases. [23 24] Although the Talk Test is not specifically validated in orthopedic GR patients it seems reasonable to assume that the test could also be used to prescribe exercise intensity at a sufficient yet safe intensity, which would be around the VT, highlighting its potential utility in frail populations.

Despite these advantages, the Talk Test has not been investigated in the specific context of frail older adults undergoing orthopedic GR. This exploratory study, combining data from two cohorts, aims to evaluate the feasibility of the Talk Test as a method for prescribing safe and adequate aerobic exercise intensities in this frail population. By addressing this gap, we aim to provide insights into the potential of the Talk Test to support personalized exercise prescription in clinical practice for frail older adults.

Methods

Setting and participants

This observational pilot study was conducted as part of a larger project, FIT4FRAIL, and includes data from a sample of patients admitted to orthopedic GR.

The study was conducted in different inpatient GR wards, recruited from the University Network of Organizations of care for older adults of Amsterdam UMC (UNO Amsterdam), the Netherlands. We included patients from 2 different study cohorts in the FIT4FRAIL project. One cohort (C1) consisted of a sample of patients that were followed over time for a longitudinal study to investigate the content of physical fitness training and the changes in physical fitness and functioning during orthopedic GR. For this study the Talk Test was one of several tests that were used and we only included data from available tests at baseline. The second cohort (C2) consisted of a sample of patients that were specifically recruited for a cross-sectional study to test the feasibility of the Talk Test. In this case patients were only recruited if the health care practitioner (physiotherapist or physician) believed the person would be able to perform the test.

For both cohorts, patients were eligible when being aged 65 years or older, recovering from a trauma or elective surgery of the pelvis or lower extremity and being admitted for GR. Excluded from participation were individuals who were non-Dutch-speaking; those who did not consent or – as determined by the attending physician – lacked decisional capacity to provide informed consent or to comply with instructions; were not allowed to put full weight on their legs; had comorbidity that – in the opinion of the attending physician – precluded them from participation in the measurements (e.g. uncontrolled cardiac arrhythmia, decompensated heart failure [25]); had an expected stay at the ward of less than two weeks; and/or were admitted for rehabilitation after lower extremity amputation. All subjects received verbal and written information about the procedures and filled in an informed consent form before participating in this study. Data were collected from March 2017 until January 2019. The present study was conducted according to the declaration of Helsinki of the World Medical Association and Ethical Principles in the conduct of research with human participants. Furthermore, The

Medical Ethics Review Committee of the VU University confirmed that the Medical Research involving Human Subjects Act (WMO) does not apply to the present study (2017.067).

Talk Test

Set-up

All participants performed the Talk Test on similar ergometers available at the participating orthopedic GR wards (Thera Tigo 506 (THERAtrainer, Hochdorf, Germany). This cycle ergometer is specially designed for patients with low physical capacity as small increments in workload are possible. Further, the ergometer can be fitted with different seats, including a wheelchair, which is then placed in front of the cycle ergometer. Correct and comfortable cycling position was ensured for each participant by adjusting pedal height and distance between pedal and axis. To prevent the feet from slipping out of the cycle ergometer, straps were attached to the pedals.

Protocol

Figure 1 illustrates a schematic overview of the Talk Test. Each test started with a two-minute warm up at 0-5 Watt. Next, the resistance was gradually increased with 2-6 Watt every 2 minutes until test termination. Participants had to maintain a minimum cycle speed of 50 revolutions per minute throughout the test. During the last 30 seconds of each two-min stage, participants were asked to recite a standard paragraph. The test examiner then asked whether the participant was able to speak comfortably during this speech provoker. Besides, participants were asked to state their rating of perceived exertion (RPE) with a Dutch modified version (0-10) of the Borg scale, [26] a measure that is frequently used in clinical practice. In this study participants slowly recited a well-known part of the national anthem of The Netherlands, which is around 30 words and takes about 10-15 seconds to recite. Participants could respond with the following answer possibilities: “yes” (positive), “yes, but” or “not sure” (equivocal), or “no” (negative). In case of a positive or equivocal response, participants continued to cycle at the next stage. In case of a negative response, the test was finished and followed by a cooling down with cycling at a low resistance until the participant had recovered sufficiently. At the end of each test the reason for termination of the test was reported. These reasons for test termination were categorized in one of five categories (i.e. test completed, pain, motivation, fatigue or otherwise).

Safety precautions

Throughout the test, we measured heart rate responses and maintained a safe, submaximal exercise level by keeping the heart rate below ~80% of the age-predicted maximal HR. [27] In addition, in case of any signs of syncope, dizziness, seizures or the inability to provide feedback, the test would be terminated immediately.

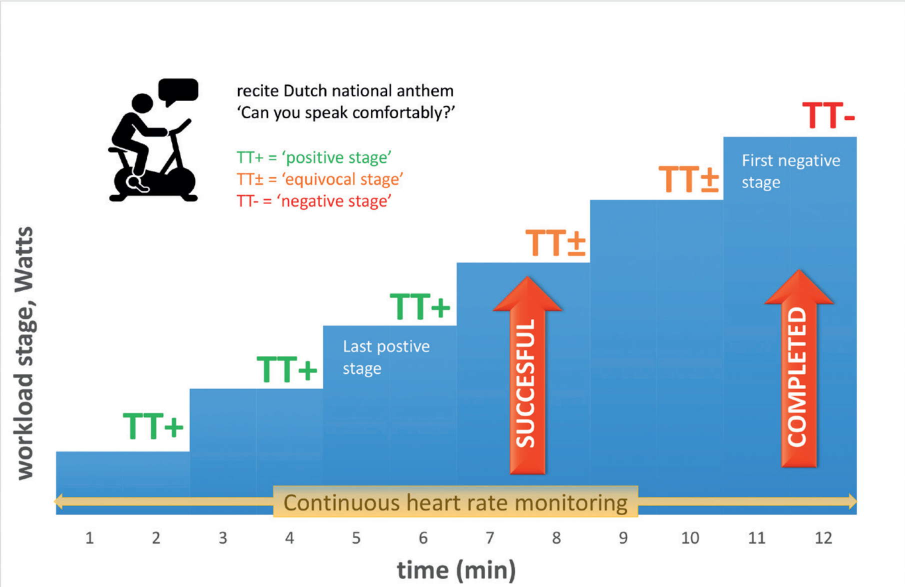

Figure 1. Schematic overview of the test protocol
The figure illustrates the stages after the Talk Test started. The test was considered 'successful' when the last positive stage could be determined and 'completed' when the whole test could be performed until a participant gave a negative answer.

Data collection, processing and analysis
Patient characteristics were collected from the individual patient records. From the Talk Test we collected the workload (Watts), RPE score and response to the speech provoker from each consecutive stage. The workload at the last positive stage was used as an estimation of VT and the first negative stage as an indication of the RCP. [28] We defined the Talk Test as 'successful' when at least the last positive stage could be determined (i.e. when a positive stage was followed by an equivocal answer or a negative answer) and as 'completed' when the participant gave a negative answer.

Feasibility
Feasibility was evaluated by the completion rate, success rate, and reported reasons for early test termination. Success rate and completion rate were respectively calculated as the number of successful and completed tests expressed as a percentage of the number of participants who started the test. With a completion rate and success rate of 70% or higher we considered the test as feasible. Reasons for stopping prematurely were evaluated with regard to safety of the test.

Statistics
Descriptive statistics were used to characterize the sample. We used medians and interquartile ranges for non-normally distributed continuous data and numbers and percentages for categorical data. Mann-Whitney U tests were performed to test differences between the study

cohorts for continuous data, while Chi-square tests were used for categorical data. The level of significance was set at an alpha of 0.05. Statistical analyses were performed with SPSS (version 29.0, SPSS Inc, Chicago, IL, USA).

Results

A total number of 93 frail older adults were included in the FIT4FRAIL study, see Figure 2 for the process of participant inclusion. The total cohort consisted of 48 participants in the longitudinal study (C1) and 45 participants in the cross-sectional study (C2). Baseline characteristics of the total group and the two different study cohorts are presented in Table 1. The two study cohorts were not significantly different for age nor gender, (P>0.05). In addition, the reasons for admission were relatively equally distributed across cohorts, except that C1 had a higher number of total knee arthroplasties (25%) and lower hip arthroplasties (21%) compared to C2 (9% knee, 40% hip).

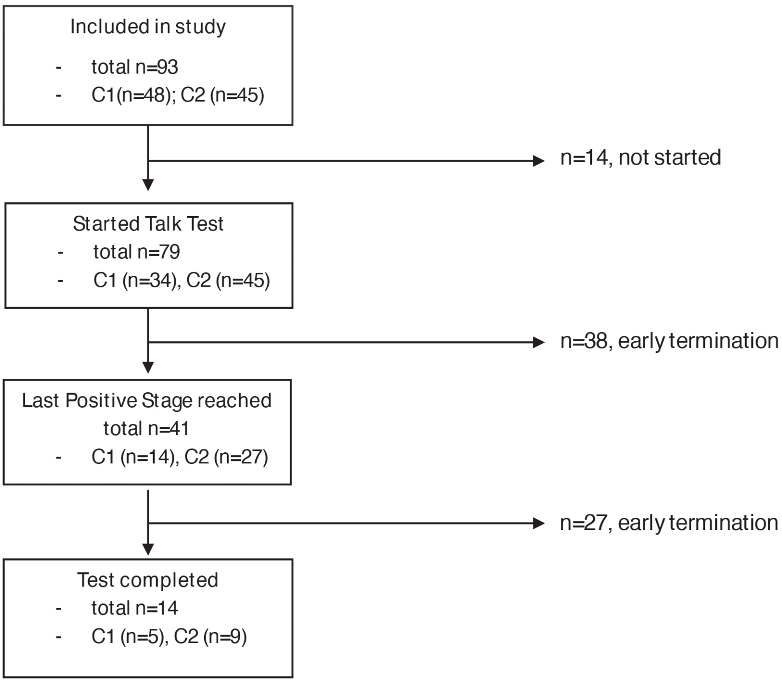

Figure 2 Inclusion and test performance of participants

Table 1. Baseline characteristics of participants in geriatric rehabilitation. Data represent the total study cohort (n=93) and the C1 cohort (n=48) and C2 cohort (n=45) separately.

	Total n=93	C1 n=48	C2 n=45
Age	83 (8)	83 (11)	83 (11)
Gender (m/f)	31/62	13/35	18/27
Reason for admission, n (%)			
• Hip fracture	38 (41%)	18 (38%)	20 (44%)
• Total hip arthroplasty	28 (30%)	10 (21%)	18 (40%)
• Total knee arthroplasty	16 (17%)	12 (25%)	4 (9%)
• Other fracture lower extremity	4 (4%)	4 (8%)	-
• Other	7 (8%)	4 (8%)	3 (7%)

Values are median (IQR). Age nor gender was significantly different between C1 and C2, P>0.05

Feasibility: completion rate and adverse events

Of all patients included in the study, 85% (79/93) actually started the Talk Test. In C2 all 45 subjects (100%) started the Talk test as they were specifically recruited for this purpose. In C1 this was only 70%. Reasons for not starting the test in C1 were only occasionally reported and varied from practical reasons (unavailable) to reasons related to their clinical status (too much pain).

From the 79 patients who started the Talk Test, 41 (52%) had a successful test result. These numbers differed somewhat between the C1 (14, 41%) and C2 (27, 60%). Furthermore, only 14 patients (18%) of the total cohort completed the Talk Test. Again, these numbers differed somewhat between C1 (15%, n=5) and C2 (20%, n=9).

Detailed information about available Talk Test data and reasons for early termination are presented in Table 2. Reported reasons to terminate the test other than test completion included insufficient strength (n=16), pain (n=14), motivation (n=8), fatigue (n=15) or other (n=13). Other reported reasons were cycling was too heavy (3), drop in cycling speed (5), failure to cycle (2), dizziness (1), dyspnea (1), difficulties with dual task and technical issues (2). Notably, while most stop reasons were equally reported among individuals with and without a successful test result, motivation and fatigue were more frequently reported as reasons to stop in those without successful Talk Test.

Table 2. Detailed descriptives of available Talk Test data and reasons to terminate the test.

	Total	C1	C2
Talk Test started	79	34	45
Unsuccessful test	38	20	18
Reasons to stop			
• Insufficient strength	8	1	7
• Pain	7	4	3
• Motivation	7	4	3
• Fatigue	10	10	0
• Other	6	1	5
Successful test	41	14	27
Reasons to stop			
• Insufficient strength	8	2	6
• Pain	7	0	7
• Motivation	1	0	1
• Fatigue	5	4	1
• Other	7	3	4
Completed test	7	5	2

Unsuccessful test: no last positive stage could be determined, Successful test: the last positive stage could be determined: Completed test: the whole test could be performed until a participant gave a negative answer.

Outcomes of the Talk Test

The median workload attained during the last positive, equivocal, and first negative stage ranged between 15 and 35 Watts. Results also show that the median workloads of the two different study cohorts were comparable for the last positive and equivocal stages of the Talk Test, P>0.05 (Table3). Furthermore, the median RPE values reported during these different stages of the Talk Test increased from 5 for the last positive stage to 7 for the first negative stage, without significant differences between C1 and C2.

Table 3. Outcomes of the Talk Test of participants in C1 and C2.

	stage	Total n=93	C1 n=48	C2 n=45
Work load (watt)	Last positive	15 (16), n=41	12 (20), n=14	16 (15), n=27
	Equivocal	20 (18), n=39	15 (20), n=12	20 (15), n=27
	First negative	34 (20), n=9	-	35 (20), n=9
RPE	Last positive	5 (2), n=40	5 (1), n=14	5 (2), n=26
	Equivocal	6 (3), n=38	5 (2), n=12	6 (2), n=26
	First negative	7 (1), n=8	-	7 (1), n=8

RPE: rating of perceived exertion. Values are median (IQR). None of the outcomes were significantly different between C1 and C2, p>0.05

Discussion

This study explored the feasibility of the Talk Test as a tool for prescribing aerobic exercise intensity in frail older adults undergoing orthopedic GR. Our findings suggest that while the

Talk Test is a promising, practical method, its application in this specific population presents unique challenges.

Key Findings
The majority (85%) of the participants started the Talk Test and 52% of participants performed a successful test by reaching the last positive stage. These results indicate a moderate feasibility for determining a marker that points at the transition from light to moderate exercise intensity. Notably, only 18% completed the entire protocol by reaching the negative stage, where speech was no longer comfortable. Therefore, its utility to determine exercise intensities up to vigorous intensity seems limited in frail orthopedic GR patients. This seems not problematic since we recently showed that lower intensities may be appropriate for aerobic exercise in frail older adults [5] highlighting the usability of the Talk Test to determine safe and adequate exercise intensity.

Importantly, the mean workload at the last positive stage (15 watts) and negative stage (25 watts) allowed for a rough estimation of peak exercise capacity, suggesting a group average of approximately 30–40 watts. This is markedly below the age-predicted maximum work rate for older adults, which, when extrapolated to age and composition of our sample is estimated to be around 120W. [29] The semi-recumbent cycling position, known to reduce performance compared to standard cycle ergometry, [30] may partly explain this low capacity. In addition, our study cohort represents a very vulnerable group of patients that has a low physical tolerance due to their age and multi-morbidities. [1] Likely and supported by our results, the orthopedic GR patient is characterized by limited joint mobility, weakness, and pain which is inherent to their medical condition. These results highlight the physiological and psychological barriers to exercise testing in frail older adults. Nevertheless, our findings in a very selected study cohort underscore that even within a highly vulnerable population, tailored exercise testing remains feasible for some participants, enabling evidence-based and more personalized training recommendations to promote safe and effective physical exercise.

Differences Between Cohorts
The two cohorts differed somewhat in terms of test feasibility. C2, including participants that were specifically recruited to test the feasibility of the Talk Test, demonstrated higher success rates (60% versus 41%) and completion rates (20% versus 15%) compared to C1. We used similar in- and exclusion criteria for the two study cohorts, but for C2, patients were only recruited if the health care practitioner (physiotherapist or physician) believed the person would be able to perform the test. Reasons for not including patients for C2 were not systematically noted by the health care practitioner but could relate to mobility problems of e.g. hip and knee joints. It could also be possible that practitioners in C2 more strictly selected patients. Although still inconclusive, our results suggest that differences in the inclusion procedure may have contributed to the different feasibility scores in the two study cohorts and underscore the importance of patient selection in determining the feasibility of the Talk Test. Obviously, muscle weakness and pain was apparent in both cohorts. In clinical practice, this suggests that for many orthopedic GR patients, particularly those with lower extremity impairments, alternative approaches or adaptations to the Talk Test may be necessary. Nevertheless, for those who can participate, the Talk Test can provide valuable input for safe and effective exercise prescription.

Methodological Considerations

In frail patients, it is critical to perform aerobic exercise at intensities just below or around the ventilatory thresholds to ensure safety while avoiding overexertion and exertional ischemia [17 18]. Consistent with this, the Talk Test was deemed successful even if the negative stage was not reached, provided that the last positive stage was determined. This approach reflects a pragmatic adaptation to the challenges of testing in frail populations and highlights the importance of individualizing exercise assessments.

It is attractive to adopt the suggestion that the Borg's RPE would be a more easily applicable tool than any exercise test to determine light to moderate or even vigorous exercise intensity. However, research showed its limited usability in physically deconditioned or cognitively impaired older adults [12]. In line with this, we occasionally observed that some patients tended to rate their RPE response linearly, with increasing the response with one scale point for each subsequent step during the incremental exercise. We, therefore, question the validity of this measure for exercise prescription in our participants.

Importantly, the interpretation of our results is based on the assumption that the Talk Test is valid to estimate the ventilatory threshold across populations with varying fitness levels, e.g. ranging from healthy athletes to patients with cardiovascular disease. [19-24] Because the Talk Test was never validated for our specific study population, results should be interpreted carefully. The primary focus of the present study was to evaluate whether such submaximal incremental exercise test would be feasible in older adults admitted to GR. While our results allow no conclusions about the validity of the Talk Test these results seem promising as more effective intensities of aerobic exercise prescription should be feasible in some orthopedic GR patients thereby meeting the guidelines for aerobic fitness improvement. [5] This supports the Talk Test as a tool for prescribing safe yet sufficiently challenging exercise intensities in frail populations. Further research is needed to establish how adequate the test actually is in identifying such personalized exercise intensities and how effective these training intensities are when applied in exercise programs for orthopedic GR patients.

Pain, a common characteristic of orthopedic (GR) patients, seemed to preclude the determination of the last positive stage in some of our participants. While it is unlikely that pain directly influenced the assessment of comfortable speech, its presence may have indirectly impacted participants' perception of effort or willingness to continue. Further research is needed to clarify the extent to which pain and other symptoms influence Talk Test outcomes.

Implications for practice and research

The simplicity and low-resource requirements of the Talk Test make it an attractive option for the orthopedic GR setting. However, careful pre-assessment of the patient should include absolute and relative contraindications for exercise testing, [25] with specific attention to e.g. musculoskeletal problems or physical intolerance. Such assessment is essential to identify those likely to benefit from the test, but also to avoid potential problems while performing the test. Since specific criteria are lacking for our study population, assessment guidelines need to be developed in future research. For patients unable to perform lower-extremity exercises, alternative methods of assessing aerobic capacity should be explored. One possibility may be arm crank ergometry testing, such as used before and after endurance training program of post-hip fracture patients. [31] Future studies should also investigate adaptations to the protocol, such as modified speech tasks or upper-body ergometry, to broaden its applicability.

Conclusion

The Talk Test seems a promising tool for prescribing safe and adequate aerobic exercise intensity in a select group of frail older adults in orthopedic GR. Its application, however, requires thoughtful consideration of individual patient characteristics and limitations. Further research and protocol refinements are needed before the Talk Test could become an integral component of personalized exercise prescription in geriatric rehabilitation.

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The content of physical fitness training and the changes in physical fitness and functioning in orthopedic geriatric rehabilitation.

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Abstract

Purpose: This explorative study investigates the content of physical fitness training and changes in physical fitness and functioning in the current practice of orthopedic geriatric rehabilitation (GR) in the Netherlands.

Materials and Methods: The content of physical fitness training was analyzed in 48 patients from 11 orthopedic GR wards, comparing it to general guidelines for older adults. Endurance, muscle strength and functioning were measured at admission and discharge. Correlations between training volume and change in endurance, knee-extensor muscle strength, and physical functioning were assessed.

Results: Training characteristics varied substantially among individuals. Compared to guidelines, endurance time and intensity were low, and muscle strength training volume was low to moderate. Significant improvements (17.7% to 41.4%) in muscle strength and all measures of physical functioning were observed. Pain highly affected endurance outcomes in the majority of the patients. Patients not limited by pain showed no change in endurance. Only resistance training volume of the affected leg moderately correlated with change in muscle strength.

Conclusions: Physical fitness training content varied and was generally low in intensity compared to guidelines. Its relation to fitness and functioning was limited. Future efforts should focus on improving training strategies and developing a valid measure of endurance.

Keywords: Geriatric rehabilitation; Physical fitness; Physical functioning; Resistance training; Endurance training

Implications for rehabilitation

- The content of the training of endurance and muscle strength in orthopedic geriatric rehabilitation (GR) varies and is generally of low intensity.
- Strategies for this training should improve, for example by increasing the physiotherapists' awareness of the guidelines and by the addition of arm crank ergometer training.
- A valid measure for endurance in orthopedic GR should be developed. In the meantime, if the 6MWT is used, pain should be assessed and considered to properly interpret the score and its changes over time.

Introduction

Aging is associated with an increase in morbidity and a decline in endurance and muscle strength (from here, defined as physical fitness), and frail older adults are vulnerable to developing disabilities and increased dependency. [1-3] When these older people undergo orthopedic surgery, such as for joint replacement or after a hip fracture, they can benefit from geriatric rehabilitation (GR). This orthopedic GR is a multidimensional intervention aiming for the recovery of physical activities and participation in the daily lives of older adults. [4] In practice, achieving functional goals such as rising from a chair or climbing stairs is often impeded by this older population's reduced muscle strength and reduced endurance (the ability to sustain a dynamic physical activity with large muscle groups for an extended period of time). [5, 6] Physical fitness training, including aerobic and strengthening exercises, has been shown to improve frail older adults' physical functioning, namely the ability to perform basic activities of daily living. [7-10] As a result, physical fitness training is an important part of the GR program.

Orthopedic GR programs show substantial variation concerning the amount of physiotherapy and physical activity. [11, 12] It is most likely that there is also substantial variation in the content of physical fitness training provided within this field. Several international guidelines provide exercise recommendations for healthy older adults. [13-15] These guidelines include recommendations for the key aspects of training, the so-called FITT characteristics. They cover the frequency (number of sessions per week), intensity, time (per session), and type of training needed to enhance older adults' health. In general, frailty and poor health are seen as the most significant barriers to physical fitness training in older adults. [16] However, exercise can be safe and beneficial for the frail and old. [9, 10, 17, 18] Training should be adjusted for older adults with one or more medical conditions in a manner that 'effectively and safely treats those conditions.' [13] However, it is unclear how this can be achieved since individuals in orthopedic GR after recent surgery or fall show substantial variety in frailty and (multi)morbidity. Additionally, their training goal is improving their physical fitness, rather than general health. Evidence suggests that the exercise characteristics from current existing guidelines are suitable for frail older adults with the goal of improving physical fitness, although lower frequencies and intensities might also be beneficial, however, concrete recommendations are lacking. [18] Moreover, patients in orthopedic GR are much less physically active than recommended in the guidelines. [19] Based on the lack of concrete recommendations for physical fitness training in orthopedic GR, expected variation in rehabilitation programs, and a patient group that infrequently engages in physical activity, current rehabilitation programs are likely sub-optimal, which may, in turn, result in sub-optimal physical fitness and physical functioning when patients return to their homes.

Besides training intensity, training volume as a product of total exercise time (endurance exercise) or the number of sessions and repetitions (resistance exercise) are important characteristics influencing training outcomes. Although lower training volumes than prescribed in the guidelines are expected in current practice, it is possible that this training is still beneficial for the frail population in orthopedic GR, just like for other frail groups. [18, 20] Assessing the actual content of physical fitness training in orthopedic GR in the Netherlands, as well as the changes in physical fitness and physical functioning, can, therefore, generate valuable knowledge to add to the current recommendations. This can help adjust physical fitness training to the needs of frail older adults in orthopedic geriatric rehabilitation, contributing to more effective rehabilitation programs.

This explorative study aims to investigate the content of physical fitness training and the changes in physical fitness and physical functioning in the current practice of inpatient orthopedic GR in the Netherlands. We seek to achieve this by answering the following specific questions:

1. What is the content of physical fitness training in the current practice of inpatient orthopedic GR and how does this relate to published guidelines for physical fitness training in older adults?
2. How does endurance, muscle strength, and physical functioning change between admission and discharge in the practice of inpatient orthopedic GR?
3. Are changes in physical fitness and physical functioning associated with the content of physical fitness training in the current practice of inpatient orthopedic GR?

Materials and methods

Study design

This is an explorative, observational study with measurements in the first and second week after admission and in the week of discharge, reported according to the 'Strengthening the reporting of observational studies in epidemiology' (STROBE) statement. [21]

Setting and participants

The study was conducted in inpatient GR wards, recruited from the University Network of Organizations of care for older adults of Amsterdam UMC (UNO Amsterdam). In the Netherlands, GR wards are part of nursing home organizations, being usually located in a nursing home or located in a separate building or in a hospital, and the staff are a dedicated multidisciplinary team of registered (assistant) nurses, physicians, physiotherapists, occupational therapists, and possibly others. The participating wards were located in urban and rural regions in the center and western parts of the Netherlands. Inclusion criteria for participants were being aged 65 years or older, recovering from a trauma or elective surgery of the pelvis or lower extremity, and being admitted for GR. Excluded from participation were individuals who were non-Dutch-speaking, those who did not consent or – as determined by the attending physician – were not mentally competent to provide informed consent nor to comply with instructions, were not allowed to put full weight on their legs, had comorbidity that – in the opinion of the attending physician – precluded them from participation in the measurements, had an expected stay at the ward of less than two weeks, and/or were admitted for rehabilitation after lower extremity amputation. Data were collected from November 2017 until January 2019.

The study procedures were reviewed and approved by the Medical Ethics Review Committee of the VU University Medical Center (number 2017.067, Amsterdam, The Netherlands).

Outcomes

Four types of data were gathered: patient characteristics, training characteristics and physical fitness and functioning outcomes. Appendices 1a and 1b (tables) provide an extensive description of the outcomes and measures used and their measurement properties. Here, we provide a brief overview.

Patient characteristics were age, gender, body mass index (BMI), degree of frailty (Tilburg Frailty Indicator (TFI)), [22] fear of falling (Falls Efficacy Scale International (FES-I)), [23] motivation for performing physical exercise (Intrinsic Motivation Inventory (IMI)), [24] and comorbidity (Functional Comorbidity Index (FCI)). [25] Detailed information about these measurements is provided in appendix 1a.

Training characteristics of each physiotherapy session were gathered in logbooks (FITT characteristics and participants' level of participation (Pittsburg Rehabilitation Participation Scale (PRPS)). [26] During our research, we aimed to align our data collection as closely as possible with common practice, for example in kilograms instead of in percentage of the one repetition maximum (%1RM). The logbook form is presented in appendix 2 (Logbook Form). In addition, the participants' activity pattern was measured with a trunk accelerometer (MoveMonitor, McRoberts, The Hague, The Netherlands), providing the number of minutes spent on lying, sitting, standing, shuffling, walking, cycling, and stair climbing. (See appendix 1a).

Measures of physical fitness were hand grip strength (HGS), [27] strength of knee extensors measured with a hand-held dynamometer (MicroFET 2, Hoggan scientific, Salt Lake City, USA), and maximum power during rising from sitting to standing with the accelerometer-instrumented Sit to Stand Test (STST) (Movetest, McRoberts, The Hague, Netherlands). Endurance was measured with two tests: the Talk Test (TT) and the Six Minute Walk test (6MWT). [28, 29] (See appendix 1a).

Physical functioning was measured with the Barthel Index (BI), [30] Timed Up and Go test (TUG), ([31] Elderly Mobility Scale (EMS) [32] and Functional Ambulation Categories (FAC), [33] and the activity pattern was measured with the trunk accelerometer (MoveMonitor, McRoberts, The Hague, The Netherlands), providing number of minutes spent on lying, sitting, standing, shuffling, walking, cycling and stair climbing. At the end of the rehabilitation period, participants rated their level of change in physical functioning experienced (Likert Global Rating Scale (GRS)). (See appendix 1a).

To determine if pain affected the test results, the patient was asked after the physical fitness and functioning tests whether they experienced any pain, and if so, whether this pain hindered their performance.

Procedure

A kick-off meeting was held in each participating ward, with two separate training sessions, one for the nursing staff and one for the physicians and physiotherapists. Both training sessions consisted of general information about the study protocol, local arrangements, specific training on the assessment of measurement instruments, and training in filling out the research forms. After the training sessions, all information was available in a procedures manual kept at the ward. The researcher and a research assistants were available for questions and regularly present at the participating wards. After admittance, new patients who met the inclusion criteria were invited by their physician to volunteer for the study. After participants had provided written informed consent, the researcher contacted them to complete the questionnaire concerning patient characteristics (T0). The physical fitness and functioning tests were conducted in the second week of admission (T1) and the week of discharge (T2). As soon as the discharge date was fixed, the T2 measurements were planned. Logbook data were recorded from admittance until discharge. The trunk accelerometer was worn on five consecutive full days at T1 and T2, assisted by the nursing staff. The responsible nurse filled in the BI, and physiotherapists administered the TUG, EMS, FAC, 6MWT, and the logbook data. The researchers administered the other tests, i.e., HGS, knee-extensor muscle strength, STST, TT, and GRS.

Statistical analyses
Logbook data were transformed into variables at the patient level. For the physiotherapy sessions as a whole, this concerned the number of training weeks, session frequency, and duration. For resistance training, this concerned the frequency, number of sets per session, and number of repetitions per set for the strengthening exercises, classified according to the following muscle groups: core, upper extremity muscles, and lower extremity muscles, with special attention to the knee extensor. For endurance training, this concerned the endurance exercises' frequency, duration and intensity.

The FITT characteristics were compared with the ACSM guideline for older adults, which recommends performing aerobic exercise of moderate intensity for 30 minutes at least 5 days a week. 6 For resistance training, this guideline recommends progressing from moderate intensity (at least 1 set of 10-15 repetitions per muscle group) to vigorous intensity (1 to 3 sets of 8-12 repetitions per muscle group) at least twice a week. [5]

For the measures of physical fitness and functioning, change scores were computed between T1 and T2. We computed descriptive variables for the first two research questions, i.e., means and standard deviations for normally distributed continuous data, medians and interquartile ranges for non-normally distributed continuous data, and numbers and percentages for categorical data. The change scores were tested with a paired t-test, Wilcoxon matched pairs test, or McNemar test, depending on the type and distribution of the data.

The associations between content and changes in physical fitness and between changes in physical fitness and physical functioning were investigated with Pearson's (r) or Spearman's (ρ) correlation coefficient, depending on the type and distribution of the data. Given that exercise intensity and exercise volume (the product of frequency and time) are both important determinants of the effectiveness of training, to investigate its association with outcomes of training the content of training is best described by the product of exercise volume and intensity. Unfortunately, the pragmatic intensity measures during strength training could not be systematically categorized, and those during endurance training were incomplete. Therefore, exercise volume was chosen to represent the content. For muscle strength, we investigated the associations between the volume (total number of knee-extension repetitions per week), the relative change in knee-extensor muscle strength, and the relative change in the EMS and TUG scores. For endurance, this concerned the volume (total number of minutes per week), the relative change in the 6MWT score, and TT score and the relative change in the EMS score and TUG score. Correlation coefficients were rated negligible ($\rho \leq 0.10$), weak ($0.10 < \rho \leq 0.40$), moderate ($0.40 < \rho \leq 0.70$), strong ($0.70 < \rho \leq 0.90$) or very strong ($0.90 < \rho \leq 1.00$). [34]

Regarding the handling of missing data, all available data were reported, and for each outcome, we specified the number of participants providing data. To explore the possibility of selective drop-out, we conducted Mann-Whitney U-tests for each outcome, comparing T1 scores between participants with missing T2 data and those with data available at both time points. For all tests, alpha was set at 0.05. All data were analyzed with SPSS (version 28).

Results

Participants

Out of 23 healthcare facilities, 13 GR wards participated in the study, of which 11 included at least one patient (range of 1 to 11 participants, median 3 participants), and the other two wards did not provide a participant. Out of 442 admitted participants recovering from a trauma or elective surgery of the pelvis or lower extremity, 48 (11%) participated in the study. Participants were excluded due to being non-Dutch speaking (n=6; 1%), not giving consent (or being unable to) (n=75; 17%), being unable to follow instructions (n=42; 10%), not being allowed to put full weight on their legs (n=96; 22%), having comorbidity limiting study participation (n=80; 18%), having an expected stay of less than two weeks (n=67; 15%) and being admitted after lower extremity amputation (n=28; 6%).

Baseline characteristics of the participants are presented in Table 1.

Table 1. Baseline characteristics of participants in geriatric rehabilitation (n=48)

Gender, Female, n (%)	35	(73%)
Age (yrs), median (IQR)	82.5	(79.2; 89.8)
BMI, median (IQR)	26.2	(23.5; 29.1)
Reason for admission, n (%)		
• Hip fracture	18	(38%)
• Total hip arthroplasty	10	(21%)
• Total knee arthroplasty	12	(25%)
• Other fracture lower extremity	4	(8%)
• Other	4	(8%)
Premorbid living situation, n (%)		
• Independent, alone	27	(57%)
• Independent, with partner	15	(31%)
• Independent, with child	3	(6%)
• Independent, other	1	(2%)
• Residential home	2	(4%)
Tilburg Frailty Indicator [0-15]*, median (IQR)	5.0	(3.0; 6.0)
Falls Efficacy Scale [16-64]*, median (IQR)	26.5	(22.0; 33.8)

Table 1. Continued.

Gender, Female, n (%)	35	(73%)
Intrinsic Motivation Inventory*, median (IQR)		
• Interest/enjoyment [7-49]	25	(20; 34)
• Perceived competence [6-42]	15	(11; 24)
• Effort/importance [5-35]	17	(17; 18)
• Perceived choice [7-49]	30	(24; 37)
• Value/usefulness [4-28]	4	(4; 6)
Functional Comorbidity Index [0-18], median (IQR)	3.0	(2.0; 4.0)

**Possible range of scores between square brackets, with most favorable score underlined.*
IQR= interquartile range

Content of physical fitness training and physical activity

In the logbooks, 34 physiotherapists recorded 647 physiotherapy sessions of 45 participants (94%), with a median number of 15 sessions per participant (IQR 9; 19) and a median time per session of 30 minutes (IQR 20; 30). The median number of training weeks per patient was 4.4 (IQR 3.7; 6.0). The median score on the PRPS was 6 (IQR 5; 6). Resistance training and endurance training was reported in 44 patients. Resistance training of the upper extremity or core was reported in only 15 sessions and was therefore not further analyzed. Some indication resistance training intensity was reported in 399 of the 736 (54%) reported exercises. The endurance training intensity (in RPE) was reported in 377 out of 528 training sessions (71%). The characteristics of frequency, intensity, and time of resistance training and endurance training are presented in Table 2.

The weekly mean volume of resistance training per patient ranged from 1.4 to 372 repetitions per week for the lower extremity and from 1.4 to 273 repetitions per week for the knee extensors. The weekly mean volume of endurance training per patient ranged from 3 to 100 minutes per week.

For resistance training, ACSM guidelines were met for frequency (sessions/week ≥ 2) by 15 participants (34%), for the number of sets per session ≥ 1) by 44 participants (100%), and the number of repetitions per set ≥ 8) by 29 participants (66%). Guidelines for the intensity were not evaluated since the reported intensities could not be expressed in terms of light/moderate/vigorous intensity. Only 9 participants (20%) complied with all three evaluated aspects of the guidelines for resistance training. For endurance training, the guidelines ≥ 5 sessions/week, ≥ 30 min/session) were not met for any participant. Guidelines for endurance training intensity were not evaluated at the participant level due to a large number of missing RPEs.

Twenty-six participants wore the trunk accelerometer at T1 and T2 for at least a whole day, with a mean of five days at T1 (IQR 4; 6) and four days at T2 (IQR 3; 4). The weighted mean time per day spent on activities is presented in appendix 3 (table). Participants spent about 1.5 hours per day on active activities (standing, shuffling, walking, cycling, or stair climbing), most of which was standing.

Table 2. FIT characteristics at the patient level

	N (%)	Frequency	Intensity	Time		
		Sessions/week Median (IQR)	RPE Median (IQR)	Minutes/ session Median (IQR)	Sets/ session Median (IQR)	Repetitions/ set Median (IQR)
Physiotherapy	45 (94)	2.9 (2.3; 4.0)	NR	29.3 (23.2; 30.9)	NA	NA
Resistance training LE	44 (92)	1.7 (1.0; 2.3)	NR	NA	3.7 (2.8; 5.7)	9.3 (7.3; 11.4)
• Knee extensors		1.7 (1.0; 2.2)	NR	NA	3.5 (2.8; 5.1)	9.1 (7.3; 11.5)
Endurance training, total of all sessions	44 (94)	2.3 (1.8; 3.0)		12.9 (10.5; 15.5)	NA	NA
Endurance training, sessions with RPE* scores only	36 (75)	2.2 (1.7; 2.6)	4.1 (3.4; 4.5)	12.6 (10.4; 15.6)	NA	NA
					NA	NA
• Light intensity				7.7 (3.5; 11.0)	NA	NA
• Moderate intensity				3.3 (0.3; 5.8)	NA	NA
• Vigorous intensity				0.0 (0.0; 1.0)		

LE = Lower extremity; N (%) = Number of patients and percentage of the 48 participants; NR = Not registered; NA = Not applicable
**Rate of Perceived Exertion (0-10): light intensity (<5); moderate intensity (5-6); vigorous intensity (>6).*

Physical fitness and physical functioning

Most participants (n=41, 85%) had missing data on at least one measurement after T0. This was due to several reasons, including time restraints of nurses and physiotherapists, the patient's inability to perform the test due to pain, tiredness, or unexpected discharge. The scores on tests for physical fitness and physical functioning are presented in Table 3.

Table 3. Tests for physical fitness and physical functioning: Scores and number of participants with limiting pain during test performance

	Score T1 median (IQR) [n]	Score T2 median (IQR) [n]	Score T2-T1 median (IQR) [n]	p*	Limiting pain at T1 N (%)	Limiting pain at T2 N (%)	p†
PHYSICAL FITNESS							
Hand grip strength (kg)	23 (18; 28) [44]	22 (17; 27) [37]	0 (-2; 1) [37]	0.062	0 (0%)	0 (0%)	NA
Knee-extensor strength (AS) (N)	97 (67; 142) [42]	109 (80; 166) [39]	14 (0; 47) [37]	<0.001	16 (38%)	12 (31%)	0.170
Knee-extensor strength (NAS) (N)	170 (120; 212) [45]	169 (117; 214) [39]	0 (0; 0) [39]	0.261	0 (0%)	0 (0%)	NA
6MWT (m)	139 (45; 238) [44]	241 (156; 293) [38]	90 (15; 130) [37]	<0.001	25 (57%)	9 (24%)	0.003
Power STST (with use of hands) (W)	318 (252; 483) [27]	353 (283; 510) [30]	91 (27; 143) [20]	0.011	3 (11%)	1 (3%)	1.000
Talk Test (W)	12 (8; 23) [29]	10 (8; 18) [27]	0 (-3; 9) [22]	0.256	1 (3%)	0 (0%)	NA
PHYSICAL FUNCTIONING							
BI	16 (14; 18) [35]	18 (16; 20) [32]	3 (0; 5) [28]	<0.001	NA	NA	NA
TUG	29 (20; 43) [43]	18 (16; 26) [38]	-11 (-19; -4) [37]	<0.001	18 (42%)	12 (32%)	0.423
EMS	15 (11; 17) [43]	18 (16; 19) [37]	3 (1; 7) [36]	<0.001	16 (37%)	11 (30%)	0.172
FAC	4 (3; 4) [43]	4 (4; 5) [38]	1 (1; 1) [37]	<0.001	NA	NA	NA
Passive activities‡	1355 (1314; 1388) [38]	1300 (1271; 1351) [28]	-50 (-69; -17) [26]	<0.001	NA	NA	NA
Active activities§	79 (52; 122) [38]	114 (79; 162) [28]	41 (12; 59) [26]	<0.001	NA	NA	NA

- AS = affected side; NAS=Non-affected side;
- 6MWT=6 Minute Walking Test; BI=Barthel Index, EMS=Elderly Mobility Scale, FAC = Functional Ambulation Categories, (kg) = kilogram, (m) = meter, (N) = Newton, , STST= Sit To Stand Test, TUG = Timed Up and Go test, (W) = Watt.
- IQR = inter-quartile range, n=number of participants with measurement, N=number of participants with measurement limited by pain, NA= not applicable.
- *Wilcoxon Signed Rank test
- † McNemar test
- ‡ Passive activities: time spent lying or sitting in mean number of minutes per day
- § Active activities: time spent standing, shuffling, walking, cycling or stair climbing in mean number of minutes per day

For physical fitness, participants showed a statistically significant improvement in knee-extensor strength of the affected side, power during the STS test (both 27%), and distance walked during 6MWT (45%). In the 6MWT, significantly fewer participants were limited by pain during the test at T2 (n=9, 24%) compared to T1 (n=25, 57%). This pain reduction was also reflected in the number of participants who stopped walking before the six minutes were over, with 18 participants at T1 and only four at T2.

For physical functioning, participants showed a statistically significant improvement on all measurements from T1 to T2 (18 to 21%), which exceeded the minimal clinically important difference, being 3 points for BI, 2 points for EMS, and 3.2 seconds for TUG. [30, 35, 36] There was no difference in the number of participants limited by pain in the performance of the tests. Of the 38 participants who judged their change in physical functioning during their stay at the GR ward, the majority found that they had improved a little (n=8; 17%) or a lot (n=27; 56%). Three participants stated that their physical functioning was unchanged.

The exploration of selective drop-out revealed that, for all outcomes, T1 scores of participants who did not have a T2 score were similar to those who did.

Associations between training volume, physical fitness, and physical functioning

Table 4 presents the results for association exploration. All explored associations were rated as weak or negligible, except for the association between the volume of resistance training and relative change in knee-extensor strength of the affected leg, which showed a moderately strong and statistically significant association. The only other statistically significant association was between the relative changes in 6MWT and TUG scores; however, this association was weak.

Table 4. Associations between training volume, physical fitness and physical functioning.

	Spearman ρ [n]		p
STRENGTH TRAINING			
Volume (reps per week) vs relative change in knee-extensor strength*	0.469 [36]	Moderate	0.004
Relative change in knee-extensor strength* vs relative change in EMS score	0.083 [37]	Negligible	0.648
Relative change in knee-extensor strength* vs relative change in TUG score	-0.144 [37]	Weak	0.440
ENDURANCE TRAINING			
Volume (minutes per week) vs relative change in 6MWT score	-0.197 [34]	Weak	0.263
Volume (minutes per week) vs relative change in TT score	-0.182 [21]	Weak	0.430
Relative change in 6MWT score vs relative change in EMS score	0.344 [33]	Weak	0.050
Relative change in 6MWT score vs relative change in TUG score	-0.382 [34]	Weak	0.026
Relative change in TT score vs relative change in EMS score	-0.052 [19]	Negligible	0.832
Relative change in TT score vs relative change in TUG score	0.074 [18]	Negligible	0.769

6MWT= 6 Minutes Walking Test; EMS = Elderly mobility scale, TT = Talk Test, TUG = Timed Up and Go test
**Knee-extensor strength of the affected leg.*

Discussion

This explorative, observational study aimed to investigate the content of physical fitness training and changes in physical fitness and functioning in orthopedic GR. The training characteristics strongly varied between participants. The degree of agreement with ACSM guidelines for training was somewhat better for resistance training than for endurance training, where none of the guideline recommendations were met for any patient. Muscle strength and physical functioning improved between admission and discharge, but changes in endurance were less clear. The associations investigated associations between training volume, physical fitness, and physical functioning were weak or negligible, except for the moderately strong association between the volume of knee-extensor training and the change in muscle strength of the affected leg.

It is important to note that we included participants who met the inclusion criteria regardless of whether their therapy goal was to improve their physical fitness. Moreover, the therapists were not asked whether they were aware of the existing guidelines for training, as this could interfere with their daily practice. As expected, the number of weekly physiotherapy sessions strongly varied, aligning with earlier observational studies in GR. [11, 12, 37] The expected improvement in physical functioning between admission and discharge was confirmed and exceeded the thresholds for clinical relevance.

Another point worth considering is the timing of the baseline assessment, which was conducted in the second week after admission. This was a deliberate choice for two reasons. First, early improvements in activities such as standing up or walking with crutches are often driven by patients adapting to the new setting and receiving practical tips, rather than actual gains in physical fitness or functioning. Second, the admission process is typically intense. Time was needed to confirm eligibility, obtain informed consent, and explain the study procedures, which made earlier testing unfeasible. Although we did not expect the overall change scores to be larger, this timing allowed us to capture improvements that more accurately reflect real changes in fitness and functioning.

Resistance training in orthopedic GR

In our study, the guidelines for resistance training volume were only met by one-fifth of the participants. In this study, we did not explore factors influencing compliance with guidelines as they are the subject of a related investigation. [38] Despite the low compliance with guidelines, knee-extensor muscle strength and power improved, in accordance with the findings of Freitas et al. and Mitchell al. in individuals receiving GR after hip fracture. [39, 40] We found a moderate association between resistance training volume and change in muscle strength. This association suggests a causal relationship between training volume and gain in muscle strength. However, it could also result from reverse causality, whereby a patient who tolerates higher training loads can undergo higher training volumes, resulting in more substantial changes in muscle strength. The relation between the increase in muscle strength and change in physical functioning was negligible. Studies comparing additional resistance training according to the guidelines with no resistance training have found a higher gain in muscle strength in the intervention group, [40, 41] as well as a stronger gain in functional scores (EMS, BI, and TUG). [40] Although we could not assess training intensities, it is reasonable to assume that a stronger adherence to the guidelines would further improve muscle strength and overall functioning. Our results suggest that there may be room for improving resistance training by increasing training intensity and/or volume in the current orthopedic GR.

Endurance training in orthopedic GR

For endurance training, it is unsurprising that none of the guidelines were met by any patient, as the recommended volume of endurance training of 150 minutes per week exceeds the weekly total amount of physiotherapy minutes in our study. These therapy sessions also focus on other aspects of rehabilitation, [42] leaving little time for endurance training. On the other hand, training effects can also be achieved outside of therapy sessions, and therefore, we used activity trackers that measured the total amount of physical activity per day. These data showed an average of 94 minutes of 'active' activities per day (standing, shuffling, walking, cycling, or stair climbing), which is comparable to other studies in orthopedic GR [19] or other inpatient GR. [43, 44] However, the vast majority of this activity is standing, which does not meet the criteria for endurance exercise, i.e., dynamic muscle actions with large muscle groups performed at (at least) moderate intensity.

The results for the change in endurance seemed inconclusive. Scores on the 6MWT improved statistically significantly, but the results for the TT remained unchanged. This improved score on the 6MWT will likely reflect the decrease in limiting pain between T1 and T2 instead of an increase in endurance. The TT scores are less influenced by pain because the pain that hindered the patient from proceeding to the next stage led to the abortion of the test and the exclusion of the score from the analysis. This implies that endurance did not improve in the participants who were not limited by pain, which aligns with the low compliance with the guidelines. Groen et al. also concluded that a valid and feasible test for orthopedic GR is lacking. [45]

We found weak correlations between endurance training volume and change in endurance, and between change in endurance and change in functioning. A promising endurance training intervention was tested by Mendelsohn et al., who found that adding extra arm crank ergometer training in post-hip fracture patients was feasible and improved peak oxygen uptake and scores on 2- and 10-minute walking tests. At discharge, peak oxygen uptake and scores on walking tests were strongly correlated. [46] This suggests that it is possible to test and improve aerobic fitness (endurance) in this target group and that it might affect physical functioning. However, time restraints and a lack of specialized equipment can be expected to hamper this testing and additional training in current inpatient GR. Another promising intervention is increasing the activity outside the therapy sessions, with serious gaming, for example. [47] Finally, Quick et al. found that daily feedback on walking time goals using an accelerometer is an effective intervention promoting physical activity in GR. [48] The effect of these interventions on compliance with the guidelines and the effect on endurance and physical functioning should be investigated in future research. In the current practice of orthopedic GR, the focus on quick discharge along with time restraints may hinder adequate inpatient endurance training. The TT and the 6MWT scores show very low endurance levels at discharge, which may hamper daily functioning at home. [49] Therefore, endurance training should be part of a post-discharge exercise program, especially since we expect that this frail population does not meet the recommendations in their daily life.

Strengths and limitations of the study

A first strength is that this study is an observational investigation of daily practice in orthopedic GR, which thus provides a realistic view of the current status of physical fitness training in GR, as well as changes in physical fitness and functioning. A second strength is the strong variety and level of detail of the data gathered, resulting in a comprehensive overview of fitness, functioning, and training parameters.

This study also has some limitations that need to be addressed. Only 11% of the admitted patients were included, limiting the generalizability of the results, which is also affected by the fact that we had to exclude individuals with cognitive disabilities. If we exclude the individuals who were physically unable to participate in endurance or resistance training (amputation or weight-bearing restrictions), the inclusion rate would still only be 15%. The excluded patients include patients with expected better fitness, such as patients with a shorter stay in GR, and also patients with an expected lower fitness, such as patients who had comorbidity that precluded them from participation. It is unclear in which direction this affects our results. Another limitation was the large amount of missing data, which fortunately did not result in selection bias. A third limitation is using logbook data of the therapy sessions filled in by physical therapists. This may have led to underestimating the frequency and total training volume. However, a consulted group of experienced Dutch GR professionals deemed the numbers for therapy volume and frequency found in our study realistic. A final limitation is that our data on resistance training intensity were unsuitable for comparison with established guidelines, as they could not be expressed in percentage of the one repetition maximum or in the rate of perceived exertion.

Conclusion

In this explorative, descriptive study, we found an increase in muscle strength and power. However, only a minority of the resistance training complied with the existing guidelines, and the relation between training volume and change in muscle strength was moderate. This suggests that there may be room for improvement, possibly by increasing physiotherapists' awareness of the ACSM guidelines emphasizing the training intensity and its documentation. Endurance training also seems sub-optimal. It was not in accordance with the guidelines in any patient, and we found no change in endurance, although a valid and responsive endurance test for orthopedic GR is lacking. Endurance training could be improved by additional arm crank ergometer training, serious gaming, evaluating walking time goals using accelerometers, and/or better post-discharge programs to develop endurance capacity in the community. The fact that the improvements in physical functioning were not related to changes in muscle strength or endurance is probably the result of a sub-optimal gain in physical fitness.

Future research should investigate the effect of these interventions on compliance with the guidelines, endurance, muscle strength and physical functioning.

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Declaration of interest
The authors report there are no competing interests to declare.

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Supplementary material

Appendix 1a. Outcomes

Outcome	Measure	Description *
PATIENT CHARACTERISTICS		
Age	Age in years	
Gender	Male/Female	
Over-/Under weight	Body mass index (BMI)	
Frailty	Tilburg Frailty Indicator (TFI) [1]	Measures physical, psychological and social components of frailty, [0-15].
Fear of falling	Falls Efficacy Scale International (FES-I) [2]	Measures the level of concern about falling during social and physical activities inside and outside the home, whether or not the person actually does the activity, [16-64].
Motivation for physical exercising	Intrinsic Motivation Inventory (IMI) [3]	Measures the subscales interest/ enjoyment [7-49], perceived competence [6-42], effort/importance [5-35], perceived choice [7-49], value/usefulness [4-28].
Comorbidity	Functional Comorbidity Index (FCI) [4]	Counts the number of predefined diagnoses a patient has [0-18]
CONTENT		
Characteristics of each PT-session		Logbooks filled in by physiotherapists. The logbook form is presented in Appendix B
	Duration of PT-session	Total duration of the session (in minutes)
	Characteristics of muscle strengthening exercises †	Intensity (I), number of sets and repetitions per set (T) of predefined types (T) of muscle strengthening exercises. Intensity is reported pragmatically, e.g. in kilograms, or number of strings.
	Characteristics of endurance training exercise †,	Rate of perceived exertion (I) and duration (T) of predefined types (T) of endurance training exercises. Rate of perceived exertion on a 0-10 scale: ≤4 (light), 5-6 (moderate), ≥7 (vigorous), duration in minutes.
	Duration of other types of exercises	Duration of other types of exercises. (in minutes)
	Pittsburg Rehabilitation Participation Scale (PRPS) [5]	Clinician-rated 6-point Likert-type item measuring patient participation in inpatient rehabilitation sessions [1-6]
Activity	Number of minutes spent on predefined activities.	Trunk accelerometer (MoveMonitor, McRoberts, The Hague, The Netherlands), providing number of minutes spent on lying, sitting, standing, shuffling, walking, cycling and stair climbing. Lying and sitting are classified 'passive activities', the others 'active activities',

Appendix 1a. Continued

Outcome	Measure	Description *
PHYSICAL FITNESS		
General fitness	Hand grip strength (HGS) in kg [6]	Tested by the Jamar hydraulic hand dynamometer (Jamar, Dulth MN, USA), according to the standard operating procedure proposed by Roberts et al., resulting in one maximum grip strength out of six measurements (three of each hand).
Strength of the knee extensors	Strength of affected and not-affected side in Newton.	Measured with a hand-held dynamometer (MicroFET 2, Hoggan scientific, Salt Lake City UT, USA). The test was performed in a sitting position, with the legs hanging freely, and hips and knees in 90 degrees flexion. For each leg the maximum isometric knee extensor strength was determined out of three attempts
Muscle power	Maximum power during rising from sit to stand in Watt.	Measured with the accelerometer-instrumented Sit to Stand Test (STST) (Movetest, McRoberts, The Hague, Netherlands), analyzing four cycles of getting up and sitting down. The highest peak power during the rise from sit to stand was determined out of the four cycles. The test was performed with and without the use of hands.
Endurance (1)	Talk Test (TT) [7]	Submaximal graded exercise test was used to determine the ventilatory threshold. The test was performed on a recurrent cycle ergometer (Thera Vital or Thera Trainer, Medica Medizinthechnik, Hochdorf, Germany). The power was increased every two minutes. The patient was asked to recite a standard paragraph at the end of each stage, and then answered to a simple question: "Can you speak comfortably?" If the answer was "yes", the stage was marked as a 'positive stage'. At a certain intensity, speech became somewhat uncomfortable, and the response to the "can you speak comfortably?" question was "yes, but" or "no". The power (Watts) at which the patient was cycling at the last 'positive stage', was used as the measure for endurance.
Endurance (2)	Six Minute Walk Test (6MWT) [8]	Operationalized by the maximum distance that a patient can walk in six minutes.

Appendix 1a. Continued

Outcome	Measure	Description *
PHYSICAL FUNCTIONING		
Independence in ADL	Barthel Index (BI) [9]	An observation list, that measures the patient's (in)dependence in activities of daily living. [0-20]
Basic mobility	Timed Up and Go test (TUG) [10]	Performance test that measures the timed needed to get up from a chair, walk three meters, return to the chair and sit down. A lower score indicates better basic mobility.
Basic mobility tasks	Elderly Mobility Scale (EMS) [11]	Performance test, consisting of seven tasks that measure basic mobility needed to perform activities of daily living. [0-20]
Independence in walking	Functional Ambulation Categories (FAC) [12]	Performance test that measures the level of independence in walking. [0-5].
Perceived change	Global Rating Scale (GRS)	At the end of the rehabilitation period, the patient was asked to indicate how much their level of physical functioning had changed during their rehabilitation on a 5-point Likert scale, consisting of the following options: much deteriorated, slightly deteriorated, unchanged, slightly improved, and much improved.
Activity	Number of minutes spent on predefined activities	Trunk accelerometer (MoveMonitor, McRoberts, The Hague, The Netherlands), giving insight into the number of minutes spent on lying, sitting, standing, shuffling, walking, cycling and stair climbing. Lying and sitting are classified 'passive activities', the others 'active activities',

*possible range of scores between square brackets, with favorable score underlined.
† (F)ITT-characteristics: Frequency, Intensity, Time and Type of exercises. Frequency is number of sessions divided by number of training weeks.

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Appendix 1b. Measurement properties

Outcome measure	Tested population	Reliability	Validity	Responsivity
PATIËNT CHARACTERISTICS				
TFI[1]	Older adults	Test-retest: good	Construct validity good Predictive validity good	NA
FES-I[2-4]	Older adults and GR (hip fracture) patients;	Test-retest: adequate to excellent	Criterion validity good	Adequate to good
IMI[5,6]	Adult rehabilitation	There is some evidence that it is reliable and valid in the context of exercise activities.		
FCI[7,8]	GR-patients; adults	Interrater: good-excellent	Criterion validity good	NA
PPRS[9]	Inpatient rehabilitation	Interrater: good to excellent	Criterion validity good	NA
PHYSICAL FITNESS				
HGS[10-13]	Older adults	Test-retest: excellent	Good criterion validity	Good
HHD[14,15]	Older adults	Good	Good	Good
Power in STS [16-18]	Older adults	Test-retest: excellent	Construct validity good	Unknown
Talk test[19,20]	Adults and patients with cardiovascular diseases	Good	Construct validity: good surrogate of ventilatory threshold	Not researched
6MWT[21-24]	Geriatrics	Test-retest: excellent	Construct validity adequate correlation with functional scores Criterion validity: adequate	Good
PHYSICAL FUNCTIONING				
BI[25,26]	GR	Interrater: excellent	Construct validity adequate to excellent correlations with DEMMI, 2MWT, TUG	Good
TUG[23,27-29]	Community dwelling older adults	Test-retest: excellent Interrater: good	Criterion validity excellent Construct validity adequate and excellent	Good
EMS[30]	Older adults	Interrater: excellent	Concurrent validity: excellent correlation with BI and FIM	Moderate
FAC[31-33]	Stroke patients GR patients	Test-retest and interrater excellent -	Construct validity good, for stroke adequate correlation with DEMMI	Good

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References 1b

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Appendix 2 (Logbook Form) (translated in English, original form is in Dutch)

Logbook physiotherapy FIT4FRAIL (fill-in instruction: see below)
Subject number: ……….
Name filler:…..
Date:
Time:

SESSION DURATION	Time in minutes			
Total session duration				
STRENGTH WITH WEIGHTS/DEVICES/ ELASTICS	Number of sets	Number of repetitions	Weight (kg)	
Knee extension				
Knee flexion				
Leg press				
Abductors				
Adductors				
Calf exercises				
Biceps				
Triceps				
Chest				
Abdomen				
Back				
FUNCTIONAL STRENGTH EXERCISES/ FUNCTIONAL EXERCISES WITH STRENGTH COMPONENT	Number of sets	Number of repetitions	Weight (kg)	
Squat (1-2 legged)				
Step exercise (step up/off)				
Lunges				
Stair climbing – one stair at a time[1]				
Stair climbing – step over step				
Getting up from a chair				
Transfer sitting-sitting/toilet transfer				
Not affected leg steps up first, affected leg lifts up to the same stair.				
AEROBIC /ENDURANCE TRAINING	Continuous /interval	Pause duration interval training (min)	Total duration (min)	RPE
Cycling				
Walking				
Swimming				
Wheelchair riding				
Ball game				

Appendix 2. Continued.

OTHER TYPES OF EXERCISES	Total duration (min)
Other transfers (bed transfers, incl. sitting-lying)	
Mobilising exercises	
Joint stabilising exercises	
Balance exercises	
PITTSBURGH REHABILITATION PARTICIPATION SCALE	Score (see explanatory note).
PRPS score	

Details /remarks:

Fill-in instruction
The subject number is entered at the top of the page. Furthermore, the logbook consists of 6 parts and space at the bottom for any comments or details. The log must also be completed if the patient does not show up for the session.

The six parts are:

- Total duration of the session: enter the duration of the session in minutes here. If the patient does not show up, please state 0 followed by the planned time.
- Strength with weights/devices/elastics: enter the number of sets, the number of repetitions and the weight/resistance in kilograms here.
- Functional strength exercises: enter the number of sets and the number of repetitions here. If any weights are used, also enter this.
- Aerobic/condition training: indicate whether it was continuous or interval training, how long the exercise lasted and the Rate of Perceived Exertion on a 10-point Borg Scale (see below). With interval training, the breaks and the total duration are listed separately.
- Other exercises: enter the total duration in minutes.
- Pittsburgh Rehabilitation Participation Scale: enter the score (see below for explanation).

Pittsburgh Rehabilitation Participation Scale
At each visit, record the patient's motivation for the examination/treatment

Score as follows:

1. None: Patient refused to come or did not participate in any exercise
2. Poor: Patient refused or did not participate in at least half of the exercises
3. Moderate: Patient participated in most exercises but did not try or did not complete the exercises or had to be prompted a lot
4. Good: Patient participated in all exercises and did reasonably well and completed almost all exercises and passively followed directions
5. Very good: patient participated in all exercises and did his best and completed all exercises, but passively followed directions

6. Excellent: Patient participated in all exercises with best efforts and completed all exercises, showed active interest in the exercises and/or future therapy sessions

1 - 10 Borg Rating of Perceived Exertion Scale

0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really Hard
10	Maximal: Just like my hardest race

Appendix 3. Time spent on activities in mean number of minutes per day (n=26; 54% of all participants).

	T1		T2		Weighted mean T1&T2		T2-T1		T2-T1
	Median (IQR)		Median (IQR)		Median (IQR)		Median (IQR)		p***
Lying	801	(640; 953)	731	(585; 854)	799	(608; 890)	-50	(-98; 19)	0.052
Sitting	542	(360; 687)	603	(448; 696)	583	(420; 722)	0	(-72; 75)	0.869
Standing	57	(40; 97)	71	(51; 126)	69	(48; 107)	23	(9; 37)	0.002
Shuffling	7	(3; 12)	11	(7; 16)	9	(6; 13)	3	(-1; 12)	0.009
Walking	6	(1; 18)	18	(5; 31)	12	(4; 20)	6	(-1; 15)	0.002
Cycling	0	(0; 2)	2	(0; 4)	1	(0; 3)	1	(0; 3)	0.013
Stair climbing	0	(0; 0)	0	(0; 0)	0	(0; 0)	0	(0; 0)	0.554
Passive activities*	1355	(1314; 1388)	1300	(1271; 1351)	1334	(1291; 1376)	-50	(-69; -17)	0.003
Active activities**	79	(52; 123)	115	(79; 162)	94	(63; 138)	41	(12; 59)	0.004

** Sum of lying and sitting*
*** Sum of standing, shuffling, walking, cycling and stair climbing*
**** Wilcoxon matched pairs*

06

Barriers and facilitators for physical fitness training in orthopedic geriatric rehabilitation. A qualitative study

Wattel EM, Meiland FJM, van der Wouden JC, de Groot AJ, Hertogh CMPM, Gerrits KHL. Barriers and facilitators for physical fitness training in orthopedic geriatric rehabilitation. A qualitative study. Disabil Rehabil. 2024 Dec;46(24):5845-5853. doi: 10.1080/09638288.2024.2314161.

Abstract

Purpose: The aim of this explorative, qualitative study is to identify factors that potentially influence the execution of physical fitness training in inpatient orthopedic geriatric rehabilitation (GR), from the perspectives of patients, their relatives and professionals.

Materials and methods: In GR wards of skilled nursing facilities in the Netherlands, semi-structured interviews were held with triads of patients, their relatives and responsible nurses, and focus groups with members of the multidisciplinary teams. Verbatim reports were analyzed according to the framework method.

Results: We found twelve categories of barriers and facilitators related to characteristics of the patients, their family, staff, training program and organization.

Conclusions: The barriers and facilitators found largely correspond with those found for participation in exercise in related settings, but also show important differences. This overview of barriers and facilitators enables multidisciplinary teams to design improvements at the level of the organization and interventions, as well as at the level of the individual training program, tailoring it to the patient's circumstances and needs. Further research should focus on weighing these barriers and facilitators to develop a feasible guidance for daily practice, as well as testing their effect on the adherence to existing physical fitness training guidelines.

Keywords: Geriatric rehabilitation; Physical fitness training; Orthopedic; Barriers; Facilitators

Implications for Rehabilitation.

- Physical fitness training is important in reaching functional goals in orthopedic GR.
- Practicing outside of therapy can be stimulated by clarity about expectations, proper training equipment and tailored stimulation/assistance.
- Training volume and intensity should meet the guidelines, but be tailored to the patient.
- Characteristics of the program, staff and organization need to be considered as they impact the physical fitness training.

Introduction

Geriatric rehabilitation (GR) is a multidimensional program of diagnostic and therapeutic interventions for older people with disabling impairments; for example, after hip fracture or elective orthopedic surgery. [1] The primary focus of GR is on restoring functional outcomes and social participation. [1-3] In practice, reduced physical fitness – such as aerobic capacity and muscle strength – is often a limiting factor in achieving functional outcomes in this aged target group. [4,5] Therefore, physical fitness should be an additional focus of the rehabilitation program. Despite the need for an increased focus on physical fitness training in GR, the implementation of evidence-based training guidelines is currently limited. [6,7] To facilitate such implementation, this study aims to understand the possible underlying factors that may influence the feasibility and effectiveness of physical fitness training in orthopedic GR programs.

General guidelines describe optimal training characteristics for improving physical fitness and recommend tailoring the training characteristics to the individual's tolerance and preference. [8,9] In addition to these training characteristics, a well-tailored training program also considers factors that affect adherence to them. Therefore, it is essential to understand what factors are barriers or facilitators for physical fitness training in GR. In the Netherlands, inpatient GR wards are generally located in nursing homes, where also long-term care is provided, such as care for patients with dementia. There is a growing body of literature concerning factors that influence participation in physical activity and exercise in older adults in various settings, such as community dwelling, in-hospital and institutionalized older adults. Studies have found that adherence is stimulated by – for example – the patients' willingness to exercise, support by others and the availability of exercise facilities. [10-13] Frequently mentioned barriers for exercise are limitations due to poor health status, heavy caregiver workloads and the layout of the (hospital) ward. [10-13] However, to date no research has focused on the specific facilitators and barriers for exercise adherence during inpatient GR.

Following a life event (fall or surgery), patients find themselves in a situation where they have to adapt to the consequences of e.g. the surgery and to a totally new setting where they reside during rehabilitation. For the majority of patients, participating in a structured rehabilitation program was a novel experience, so often they are not aware of what is expected from them concerning exercise programs, rehabilitation goals, improving their physical fitness and returning home. Therefore, the factors that influence exercise adherence might differ from those in the previously mentioned studies. Therefore, the factors that influence exercise adherence might differ from those in the previously mentioned studies. We expect to find specific factors for this setting, related for example to the fall and/or surgery, the return to their home, but also concerning the multidisciplinary collaboration.

In this explorative, qualitative study, we aim to identify factors that potentially influence the execution of physical fitness training in inpatient GR. Perspectives of patients, their relatives and GR professionals will be taken into account. To guide our exploration, we will take advantage of knowledge from implementation science, particularly the theoretical approach of determinant frameworks, that aim to understand and/or explain what influences implementation outcomes. Nilsen studied eight of the most commonly cited determinant frameworks and concluded that they are quite similar about the general types of determinants they account for. Therefore we used the general model of Nilsen, which distinguishes five types of determinants, such as characteristics of the intervention and characteristics of the user. [14]

Methods

Design

A qualitative, explorative, descriptive design was used with semi-structured interviews and focus groups. The interviews were held with triads of patients, their informal caregivers and responsible nurses, and the focus groups with professionals from multidisciplinary orthopedic GR teams. This triangulation of methods and sources was chosen to create the most diverse and rich dataset possible, in a limited timeframe. Interviews allow for more detail about specific cases, particularly considering that for each patient three different involved persons were interviewed. Focus groups provide the benefit of interdisciplinary interaction where ideas arise and concerns are discussed. We reported according to the COREQ checklist. [15]

Setting and participants

This study is part of the Fit4Frail project, which investigates physical fitness training in orthopedic GR. The study was proceeded by a quantitative observational study of the current training of physical fitness in GR, which was performed in eleven GR wards recruited by the University Network of Organizations of care for older adults of Amsterdam UMC (UNO Amsterdam). In the current study, we aimed to include patients comparable to the participants in the observational study. Therefore we used the same in- and exclusion criteria as in the observational study. Patients aged 65 years or older, recovering from a trauma or elective surgery of the lower extremity and admitted for GR were included. Exclusion criteria included patients who 1) were non-Dutch-speaking; 2) gave no consent or were not mentally competent on this matter; 3) were unable to follow instructions; 4) were admitted for rehabilitation after lower extremity amputation 5) were not allowed to fully put weight on their legs; 6) had comorbidity that precluded from participation in the observational study; and/or 7) had an expected length of stay at the ward of less than two weeks. The latter three exclusion criteria were established to select patients that could perform all necessary measurement tests (like the six minutes walking test and the talk test) in the week of admittance and the week of discharge.

For this explorative study, we intended to include a convenient sample of participants, and recruited professionals and patients from three GR wards of the observational study, which were located in the middle and western parts of the Netherlands. For the semi-structured interviews, we aimed for six triads of patients, their informal caregivers and responsible nurses. For the focus groups, we targeted professionals from the multidisciplinary orthopedic GR teams, such as physicians, therapists and nurses, from each of the three wards. We aimed for three focus groups, one at each participating ward. This number of interviews and focus groups was considered feasible within the time frame of the project.

Procedure

New patients were invited by their physician or therapist when they met the inclusion criteria. After obtaining the patient's consent, as well as the consent of the informal caregivers and the responsible nurse, the interviewer contacted them to make an appointment for the interviews. Each participant was interviewed individually. For the focus groups, the GR professionals gave informed consent prior to the start.

Ethical considerations

The study procedures were reviewed and approved by the Medical Ethics Review Committee of the VU University Medical Center (number 2019.345, Amsterdam, The Netherlands).

Data collection

One semi-structured interview guide was composed for all participant groups, based on the implementation model of Nilsen, which summarizes the most commonly cited frameworks in implementation science, and distinguishes characteristics of the intervention, users and end users, the context and the implementation process. [14] As a behavior change (training) is needed to reach the GR goals in physical fitness training, the end user (the patient) characteristics of the model were extended with behavior-related items, such as self-efficacy and motivation. These items are derived from the integrated change model, which states that covert or overt behaviors are determined by a person's motivation or intention to engage in a specific type of behavior. [16] The interview guide was tested in a pilot interview, and covered the topics of rehabilitation and exercising, persons involved in the rehabilitation and environmental factors. The interviewer was an elderly care physician who had recently followed a qualitative interview training, and had no professional or personal relations to the patients. Interviews were audio recorded.

For the focus groups, a topic list was based on the same model as the interview guide, covering the same topics. The focus groups were moderated by an experienced moderator and experienced elderly care physician (CH). The focus groups were audio recorded.

Data analysis

Data were analyzed according to the framework method, a stepwise procedure for analyzing qualitative data. [17] All interviews and focus groups were transcribed verbatim. The researchers started with open coding, after which the codes were grouped into categories of barriers and facilitators fitting the characteristics of the Nilsen model. These categories formed a dynamic analytical framework. Quotes were considered to refer to physical fitness training if the terms 'physical fitness training' or 'training' were mentioned by the participants or if they mentioned activities that could influence endurance capacity or muscle strength. [18] For endurance capacity, this concerned activities that involved major muscle groups and were continuous and rhythmic in nature, like walking and cycling. For muscle strength, this concerned activities that involved certain repetitions or sets of force exertion against any resistance, like repeatedly lifting a leg or repeatedly standing up from a chair. [18]

The interviews of the first triad (patient, informal caregiver, responsible nurse) and the first focus group were each coded independently by two researchers (DV en AM, in acknowledgements), after which any discrepancies were discussed until consensus was reached. All other transcripts were coded by one researcher each. New codes or adaptations to the codes were discussed. Categorization and the aggregation with the thematic model of Nilsen was undertaken in an iterative process. The codes were processed into Atlas.ti (version 22, Scientific Software Development GmbH, Berlin, Germany). For each category, the corresponding quotes were merged, summarized and classified as either barriers or facilitators for physical fitness training.

The resulting barriers and facilitators were presented to the members of the GR commission of the UNO Amsterdam in an online meeting. This commission comprises GR professionals of eighteen GR care organizations of the academic network (e.g. physicians, nurses and therapists). They were asked if the barriers and facilitators were recognizable and if other barriers and facilitators had been missed.

The level of experience of the professionals in the interviews and focus groups were rated according to their years of experience in GR: “junior” (0 through 5 years); “medior” (6 through 15 years) and “senior” (> 15 years). This information was adjusted to their quotes.

Results

A total of fifteen interviews and two focus groups were conducted, including five patients, five informal caregivers and eighteen GR professionals. Due to the limited timeframe, a sixth patient could not be included. Due to the high workload in the GR wards, the third focus group was not planned. Interviews took place face to face at the GR ward between August and December 2019, and lasted between 14 and 56 minutes. The patients were all living alone, and had been admitted for fractures of hip or femur or (revision of) total hip arthroplasty. The characteristics of the participants are presented in Table 1. The focus groups took place at the GR ward in January 2020, and lasted one hour

Facilitators and barriers were found for four of the five characteristics of Nilsen’s model: the innovation (the program), the users (staff), the end users (patients) and the context (family and organization). Overall, twelve underlying categories of facilitators and barriers were identified. The members of the GR committee of the UNO Amsterdam recognized the results and believed that there were no missing categories. The model of Nilsen, the related factors and the categories of facilitators and barriers including their description are presented in Figure 1. In the next section, we further elaborate on the factors, barriers and facilitators that were expressed by the participants. An extensive overview of barriers and facilitators is presented in Table 2. As all informal caregivers were sons or daughters of the patients, from here onwards we will refer to them as ‘relatives’, while the GR professionals are referred to as ‘professionals’.

Table 1. Characteristics of participants.

	Patients (n=5)	Informal caregivers (n=5)	GR professionals; nurses in interviews (n=5)	GR professionals in focus groups (n=13)
Median age (range)	86 (72-91)	53 (49-63)	48 (42-61)	47 (23-65)
Sex ratio (M:F)	0:5	1:4	0:5	0:13
Median length of stay at day of interview in days (range)	26 (21-29)			
Relation with patient				
• Son		1		
• Daughter		4		
Median professional experience in years (range)			29 (12-42)	18 (1-40)
Discipline				
• Nurse/certified assistant nurse			5	3
• Physiotherapist				3
• Occupational therapist				2
• Exercise therapist				1
• Social worker				1
• Elderly care physician				2
• Quality advisor				1

F=female; M=male; n=number.

Program factors

Goal

A relative stated that the absence of a proper goal hindered adequate training. *[Relative 03]: "It seems to run sort of improptu, like 'oh, she has to this today, so let's just do a quick climb up those stairs."* Professionals stated that goals are important to motivate patients for training. *[Moderator]: "For proper training, how important is it to set goals?" [Occupational therapist FG2; junior]: "It covers motivation. Yes, that also tells the client what to work towards."*

Assessment and evaluation

Professionals mentioned assessment and evaluation as factors influencing physical fitness training, such as the use of quick tests and formal tests to set and monitor fitness goals, as well as the use of visible progress that motivates the patient. *[Occupational therapist FG1; senior] "It sometimes may add encouragement for them to think 'this is where I got yesterday, I really want to be able to walk a bit further.'"*

Content and form of therapy

All participant groups considered the possibility of practicing outside of therapy influencing physical fitness training. Interestingly this possibility was influenced by other types of factors, such as patient and staff factors, which shows an interrelatedness between factors that can occur. For instance, patients mentioned (a lack of) own initiative and – if they needed help

– limited time of staff. *[Patient 01]: "And perhaps I should also have asked, like, 'guys, do you have time to walk?' Perhaps I'm slow in such things." [Patient 05] "And they just say 'busy, busy, busy, busy'." Another barrier, mentioned by* professionals is that patients often do not see that participating in daily tasks is also part of the rehabilitation program and can help to improve their fitness and functioning. Professionals state that 'everything is rehabilitation'. *[Occupational therapist FG1; senior]: "I say, 'yes you're talking about 30 minutes of therapies 2, 3 times a week, but this is also therapy, getting out of bed by yourself, standing by yourself, turning by yourself, walking.' And... those... those are things that you may have to try to instil in people at times."*

Some quotes concerned therapist-led training. According to patients, good training equipment encourages fitness training, while the absence of therapy at the weekend hinders training. Professionals discussed the optimal frequency of muscle strength training and stated that it should not be undertaken on consecutive days.

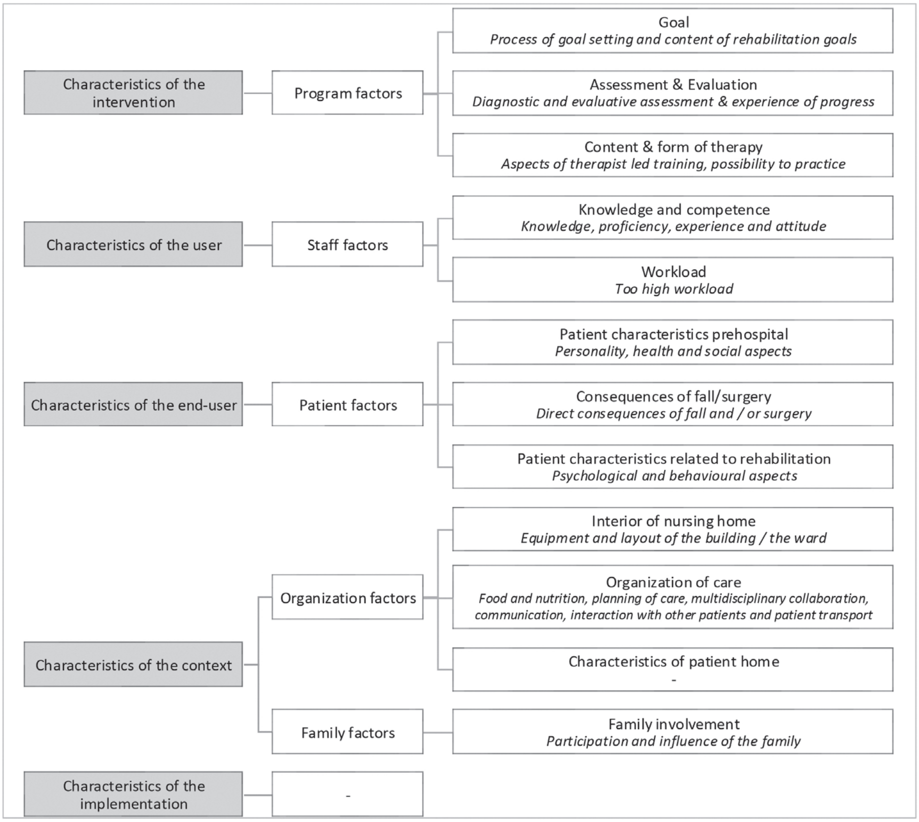

Figure 1. The Nilson model (left), the related factors (middle) and the categories of barriers and facilitators, including a brief description in italics (right).

Staff factors

Knowledge and competence

Professionals mentioned the proficiency in motivating and inviting for physical fitness training. They also mentioned the knowledge of how to assess the appropriate training level and the interpretation of pain in a patient, which they related this to the experience of professionals. Relatives experienced that the lacking professional attitude of a staff member hindered physical fitness training. They viewed proficiency in tailoring the training program to the patient's specific needs as a crucial enabling factor. *[Relative 05]: "So, look at each person's traits and go from there. Not treating everyone the same… no... just 'your need this, you need that.'"*

Workload

This factor concerned the lack of time of staff hindering physical fitness training, which was expressed by both patients and professionals.

Patient factors

Pre-hospital characteristics

The personality of the patient – named by patients and professionals – was mentioned as an influencing factor and was further specified; for example, such as being too easy-going. *[Responsible nurse 05; senior]: "I say, 'put your chair on the brake' and say 'you want to go for a nice walk'. But some people go for it, but some people think: 'well, nice try, but I'll let myself be driven in my chair, thank you very much.'"*

Both physical and cognitive comorbidity are seen as barriers for physical fitness training. *[Patient 03]: "Look, they [...] then found that I had a slightly murmuring heart, so maybe that's why I also get short of breath faster with that rowing exercise." [Occupational therapist FG2; junior]: "And if someone is cognitively just fine, then they often also go and do extra homework and exercises and they also understand the instructions they were given, so then they can also rehabilitate by themselves, [better] than if someone is hampered in that respect."*

Another factor named by professionals is general fitness prior to hospitalization. *[Occupational therapist FG1; senior]: "Look, sometimes someone still cycled 10 kilometres each day, […] they can take on a higher load than an old girl who more or less only walked to the front door to empty the letterbox and back again."*

Social aspects that professionals considered to influence physical fitness training include cultural differences in coping with pain, financial barriers for utilizing professional training after discharge home, and finally loneliness and its associated lacking incentive for training.

Consequences of fall/surgery

Professionals considered weight-bearing restrictions after surgery a barrier for muscle strength training. *[Physiotherapist FG2; senior]: "The use of strength training equipment is actually a contraindication for people with orthopedic rehabilitation, the first few weeks."* Professionals also mention the fear of falling as a barrier for physical fitness training. This can be directly associated with the fall but also have other causes, and is therefore also mentioned as a patient characteristic related to rehabilitation. Pain and loss of fitness after surgery are both mentioned as barriers for training by patients and professionals. *[Patient 03]: "I try, but I get short of breath, so it really does take me quite some effort."*

Patient characteristics related to rehabilitation
Professionals mention fear (of falling) as a barrier for physical fitness training, where fear of falling also fits under consequences of fall/surgery. Motivation is a facilitator mentioned by all participant groups, which can relate to motivation towards a specific rehabilitation goal or the more general motivation to recover. *[Relative 03]: "So, she tells herself, in her head, '[...] in a few months I'm going to do that again', well, I think that's going to help with rehabilitation." [Patient 03] "Then they say there's someone at the back, that you can always call if you can't manage. But then I won't give in, [...] I'll then keep working on that rowing machine."* Moreover, besides those more psychological characteristics, inactivity is seen as a behavioral barrier for physical fitness training, such as patients sitting all day in their room during their rehabilitation or after discharge at home, when the incentive for rehabilitation declines.

Organization factors

Interior of nursing home
Patients, relatives and professionals mentioned spaces that were inviting to exercise as facilitators for physical fitness training, such as spacious corridors, or a restaurant where lunch and dinner are served. However, if the walking distances are too long, they become a hindering factor for physical fitness training. *[Relative 03] "My mother was at the very end of the corridor and [...] when they say, 'well, come down to eat' and you don't have that much strength yet, you don't have a spot or a chair or something similar anywhere where you can take a breather."* Professionals mentioned the presence of equipment – like a home trainer or a hand rail in the corridors – as enablers for physical fitness training.

Organization of care
One of the topics in this category is that tasteful and nutritious food facilitates physical fitness training. *[Relative 02]: "She is also eating good regular protein again here and everyone says that is good for her, for her muscle building."* Both relatives and professionals highlight the importance of good communication; for example, about the possibility for the family to participate in exercise. *[Relative 03]: "Perhaps we can mean something in that respect, that maybe we can go and walk outside for an extra hour, so to speak. And, in fact, I now have absolutely no idea whether that is expected of us at all."* Other subtopics are only mentioned by professionals; for example, structural planning of walking with patients on the ward, such as at a fixed time of the day, or incorporating training in daily activities. Furthermore, professionals mention the importance of multidisciplinary collaboration. *[Occupational therapist FG2; junior]: "... Can the nursing staff mobilize a little more with the walker? When do we actually remove the wheelchair completely, that someone must mobilize freely. That's how you coordinate with each other, but also with the client".*

Characteristics of patient home

This topic is named by professionals, and concerns how therapy goals are determined by characteristics of the patient home, such as the need to climb stairs, as well as how these characteristics influence physical fitness training at home. *[Assisting Nurse FG1; senior]: "And that's of course here in Y, if you live on the 4th floor, [...] then you're just happy to be back in your chair on the 4th floor and then you think, like, 'yes, the kids will do the shopping.'"*

Family factors

Family involvement

Relatives believe that they can support physical fitness training by stimulating a patient to exercise or by practicing with the patient themselves. *[Relative 04]. "That's what I tell her too, like, 'even if it's only for 10 minutes, go for a bike ride, that will help your muscles in your thigh.'"* On the other hand, not knowing that you are allowed to help is seen as a barrier by others. *[Relative 01] "Yes, I don't know of that possibility at all. [...] no one says like, 'gosh, hey, if you want to, you can go and practice with madam in the room."* This aligns with professionals, who see a positive collaboration with the family as a facilitator for physical fitness training. By contrast, family can hinder physical fitness training by being too cautious, and by putting on the brakes; for example, due to the fear of a premature discharge. *[Physician FG2; senior]* "*They very often put on the brakes a little, because they are incredibly afraid that dad, mum will be sent home too early [...] so, to be frank, I see them as an inhibiting factor sometimes."*

Table 2. Overview of barriers and facilitators for physical fitness training in orthopedic GR.

The stakeholder group that mentioned barriers/facilitators is mentioned in parentheses: PT = patient, REL = relative, PRO = GR professional

1. Program factors	
Barriers	*Facilitators*
1.1 GOAL	
Lack of clarity about requirements to return home or perform a home visit. (REL)	• Goals that account for premorbid functioning and home environment. (PRO, PT) • Setting meaningful goals together with the patient, for both in- and outpatient rehabilitation. (PRO) • Subdivision of goals into smaller sub-goals. (PRO)
1.2 ASSESSMENT AND EVALUATION	
Insecurity about fracture healing. (PRO)	• X-ray if there is uncertainty about fracture healing. (PRO) • Rapid test to estimate level of functioning. (PRO) • Using professional view/knowledge. (PRO) • Using measurement instruments improves insight for both patient and GR professionals in: 1) prognosis of length of stay, 2) learning ability, 3) progression, 4) safety/fall risk, and 5) goal achievement. (PRO) • Visible progress like the use of a normal chair instead of a wheel chair, or positive evaluation by therapist. (REL, PRO)
1.3 CONTENT AND FORM OF THERAPY	
• (Too) little physiotherapy (PT, PRO)/no weekend therapy. (PT) • Limited space to exercise at home. (PRO) • Limited practicing outside of therapy due to • limited patient initiative, (PT, PRO) • limited time of staff, (PT, PRO) • restrictions for patient (not allowed to walk independently). (PT)	• Optimal therapy frequency and intensity, e.g. - High intensity and frequency for endurance training. (PRO) - Strength training not on two subsequent days. (PRO) • Good therapy content - Home visit to formulate therapy goals. (PRO) - For specific patient group (e.g. cognitively impaired) integration of training in ADLs. (PRO) • Practicing outside of therapy - Role of nursing staff: assisting/stimulating/slowing down, removing wheelchair/commode chair. (PRO) - Equipment on ward such as a home trainer. (REL) - Positive effect on self-efficacy. (PRO)

Table 2. Continued.

2. Staff factors	
Barriers	*Facilitators*
2.1 KNOWLEDGE AND COMPETENCE	
• Lack of professional attitude (e.g. in case of lacking chemistry between patient and GR professional/proper treatment of patient. (REL, PRO) • No insight into patient's progression. (PRO)	• Experienced GR professionals. (PRO) • Proficiency in: - Motivating/inviting and giving confidence: being able to adapt the treatment to the patient. (REL, PRO) - Accounting for patient diversity, and adjusting frequency and content of therapy to patient's needs. (PRO) • Knowledge of: - How to assess the appropriate training level. (PRO) - Interpreting pain in a patient: is something wrong or can we continue exercising? (PRO)
2.2 WORKLOAD	
• Lack of time/(experienced) staff to help patient practice outside of therapy. (PT, PRO) • Patients don't ask for help or to practice when they see that staff are busy. (PRO)	Patient tries to be self-supporting when there are not enough staff members. (PT)

Table 2. Continued.

3. Patient factors	
Barriers	*Facilitators*
3.1 PRE-HOSPITAL PATIENT CHARACTERISTICS	
• "Loneliness." (PRO) • Comorbidity that influences rehabilitation (e.g. cognitive impairment, pulmonary or cardiac problems (COPD, heart failure). (PT, PRO) • Character and temperament, e.g. externalization of locus of control, too polite to ask for help, too easy-going. (PT, PRO) • Cultural diversity, e.g. more worries about pain in non-Western background. (PRO)	• Good initial fitness (at home). (PT, PRO) • Character, e.g. initiative, flexibility. (PT, PRO) • Independence. (PRO)
3.2 CONSEQUENCES OF FALL/SURGERY	
• Pain and doubts whether pain is alarm signal. (PT, PRO) • Problems in in fixation of screws/position of the leg. (PT, PRO) • Restrictions to bear full weight on affected leg, including restrictions to perform strength training. (PRO)	
3.3 PATIENT CHARACTERISTICS RELATED TO REHABILITATION PERIOD	
• Anxiety, e.g. about falling (again). (PRO) • Insecurity, e.g. due to pain, or if a skill is not practiced enough. (PT, REL, PRO) • Inactivity, e.g. not asking to practice, sitting all day in one's room. (PRO)	• Self-confidence. (PT, REL) • Motivation, incentive. (PT, REL, PRO) • Adequate expectations and preparation concerning length of stay, level of functioning at discharge, do's and don'ts (generally better in elective patients). (PT, PRO) • Role of patient: desire and capability to keep control/responsibility, e.g. practicing outside of therapy, clarifying what is important and what one's own goals are. (P, PRO) • Social interaction with others. (PRO)

Table 2. Continued.

4. Organization factors	
Barriers	*Facilitators*
4.1 INTERIOR OF NURSING HOME	
• Twin rooms: little space to move around. (PRO) • Location of nurse's office: no insight into patients practicing outside of therapy. (PRO) • Too long corridors and walking distances, encouraging to take wheelchair. (REL, PRO)	• Private bathroom stimulates to do ADL oneself, and thereby walking short distances. (PRO) • Shared bathrooms: if occupied then walk to the next (PRO) • Rooms that are inviting to go to and to practice/exercise. (PRO) • Home trainer, leg press, hand rail in the corridors etc. in GR ward (PRO) • Preconditions: spacious corridors (REL, PRO)
4.2 ORGANIZATION OF CARE	
• Planning of care • Many not-patient-related tasks and activities, e.g. new patient files, meetings, education. (PRO) • Multidisciplinary collaboration • Lacking or contradictory transfer documents from hospital. (PRO) • Multidisciplinary meeting without patient. (PRO) • Communication between various stakeholders • Lacking communication with family about opportunities for family to participate in exercise. (REL) • Transport to group therapy meetings after discharge. (PRO)	• Food and nutrition - Tasty and nutritious (enough protein) food. (REL, PRO) • Planning of care - Planning for assistance practicing outside of therapy ("walking list"). (PRO) - Incorporate practicing in ADL (e.g. putting wheelchair further away). (PRO) • Multidisciplinary collaboration - Multidisciplinary team (where everyone is involved, not only physiotherapy, occupational therapy, doctor, nurses, dietician, speech therapist. (PRO) - Team meetings to align approach, therapy intensity, practicing outside of therapy. (PRO) • Communication between various stakeholders - Communication with patient and family about: - Functioning, progress, need for longer stay, possibility for family to join therapy sessions. (REL, PRO) - Clarity about what to expect in GR for patients and family, e.g. clear agreements, a plan towards discharge. (PRO) - Interaction with other patients: seeing other patients exercising. (PRO)
4.3 CHARACTERISTICS OF PATIENT'S HOME	
Poor accessibility (many stairs) discourages practicing outdoors. (PRO)	

Table 2. Continued.

5. Family factors	
Barriers	*Facilitators*
5.1 FAMILY INVOLVEMENT	
• Don’t know that they are allowed to help. (REL) • Put on the brakes. (PRO) • Fear of overexertion in case of pain. (PRO) • More nurturing than needed. (PRO)	• Family practicing with patient. (REL, PRO) • Collaboration between family and GR professionals: early involvement, providing information. (PRO) • Stimulus for patient. (REL)

Discussion

In this study, we have identified barriers and facilitators for physical fitness training in orthopedic GR, from the perspective of patients, their relatives and professionals. We found that the barriers and facilitators were multi-factorial, with five main themes of program, patient, family, staff and organization factors. These themes are sometimes interrelated, and some barriers fitted in more than one theme. Insights into these factors can help to develop strategies to improve physical fitness training in orthopedic GR and tailor physical fitness training to a patient's individual situation and needs.

Although research on barriers and facilitators has been conducted regarding the participation in self-care or self-management of older patients in the hospital, [12,19] as well as participation in physical exercise in home-dwelling or residential older adults, [10,11,13] no research has been conducted on barriers and facilitators of physical fitness training in orthopedic GR. In the abovementioned studies, the factors concerning the exercise program itself mainly concerned the content and form of the activity. For example, the studies of Gebhard and of Aro found group-based activities as being both motivating and hindering participation in physical activity. That can offer the opportunity to socialize, but it can also be confronting to see others performing better or worse. [11,13] The absence of factors related to goal setting, assessment and evaluation in the aforementioned studies can be explained by their settings, where the aim was not an improvement in functioning or participation as in GR.

All mentioned studies found patient factors as barriers and facilitators; for example, comorbidities [10,11,13], pain [10-12], good initial fitness [10,19] and self-efficacy. [10,11] In general, patient factors reported by other studies largely match those in our study, although we also found facilitators related to rehabilitation, such as adequate expectations and preparation for the rehabilitation process, as well as the patient taking on an active role and showing ownership.

Family factors are hardly mentioned in the aforementioned studies. Only Gebhard et al. found family support to be a motivating factor for the participation in physical activities among people with dementia in residential care settings. [11] A new topic found in our study is the relatives themselves practicing with the patient, as well as the factors influencing this.

All studies found staff factors such as motivating staff members who encourage physical activity [11-13,19] or – on the contrary – a physician who does not advise participating in it. [10] Only Chan et al. found heavy staff workload to be a barrier in their study on the participation of patients in self-care in a hospital setting, whereas the other studies did not report workload as a barrier. [12] A factor that we found that was not mentioned in other studies is staff knowledge and competence; for example, on how to assess the appropriate training level, and how to interpret pain in a patient.

Organization factors were also found in all studies. They concerned the layout of the house or the ward, the availability of equipment and the organization of care. For people with dementia, the feeling of being locked up is felt as a barrier for physical activity. [11] Hospitalized patients were hindered in their activities by the feeling of being a guest who is dependent on hospital procedures and not expected to take initiative in physical activities. [12,19] An interesting facilitator that the study of Schutzer et al. [10] reported – but was not found in our study – is the use of prompts such as telephone calls and emails as a nudge to participate in a program. The use of prompts – adapted to the GR setting – could be considered to enhance the performance of physical fitness training. Novel factors in our study are the topics related to multidisciplinary collaboration and communication between various stakeholders, such as family and GR professionals. Good collaboration and communication can contribute to the alignment of activities, resulting in a coherent training program in which all stakeholders play their role in the execution of physical fitness training.

Although our results are generally consistent with findings of studies in other settings, we also found barriers and facilitators that are unique for the setting of training physical fitness in GR. Patients recovering from a sudden decline in functioning have a targeted goal of improvement and wish to return home, which involves a multidisciplinary team and treatment program. Another difference of our study with the existing literature is that the other studies solely used the patients' perspective, whereas we added the perspectives of their relatives and professionals. These differences explain – for example – the different program factors (like setting goals and factors for assessment and evaluation, as well as practicing outside of therapy) and factors concerning the organization of care (with a strong role of multidisciplinary collaboration), as well as the family factors that we found, which were absent in most other studies.

This exploration found no factors related to implementation. This is in accordance with our expectations because we investigated the current practice and not the implementation (strategy) of a specific intervention.

It was remarkable that one of the interviews lasted only 14 minutes, much shorter than the other interviews which lasted roughly between 30 and 60 minutes. This interview was conducted with a relative who had little time to visit the patient and had little knowledge of the patient's rehabilitation trajectory.

Strengths and limitations of the study

A first strength of our study is the fact that we used the contribution of patients, their relatives and GR professionals, thus providing a broad perspective on barriers and facilitators for physical fitness training and the process of GR. A second strength of our study is the triangulation of methods, which – combined with the aforementioned triangulation of viewpoints – enabled developing the most diverse and rich dataset possible in a limited timeframe. The interviews were held in triads around a patient (patient, informal caregiver and responsible nurse) and allowed exploring barriers and facilitators in an individual rehabilitation process in greater depth. The focus groups with GR professionals have the advantage of offering the broader scope of professionals who have experienced multiple rehabilitation trajectories. Moreover, the interaction between various participants enables complementing each other and prompting discussion. A third strength is the fact that the interviews took place during the inpatient rehabilitation trajectory of the participating patients, which minimized recall bias. Finally, the use of an implementation model covering the evaluation of barriers and facilitators appeared to be very helpful to develop an interview guide and build the preliminary framework for our results.

Limitations of our study include the fact that we did not recruit participants until saturation, and that we did not reach the desired number of interviews and focus groups. Hence, this may not provide a complete picture of the relevant factors. The included patients are probably not representative of the study population, being all female, living alone and their informal caregivers being their children. Initially, we intended to perform targeted sampling, for example to include both men and women, or to include patients with different kinds of (co) morbidity. As the inclusion appeared to be very difficult, we were happy with all included patients. Moreover, we did not systematically survey comorbidities and probably patients with cognitive problems are under-represented. This might limit the generalizability of the results as it comes to the patient perspective. Another limitation of our study is that for patients and their relatives the isolated focus on physical fitness training seemed difficult, as it is an integrated part of the overall rehabilitation process. In the focus groups, physical fitness training (or muscle strength and endurance training) was a known concept. For this reason, we chose to code all quotes that referred to activities that could influence physical fitness as 'physical fitness training', such as all quotes about walking, climbing stairs and cycling. However, it is possible that some of these quotes were not strictly related to the training of physical fitness. A last potential limitation is that both the interviewer and the moderator are elderly care physicians with professional experience in GR, which could have influenced the findings of the (focus group) interviews. However, as physicians, neither of them was involved in physical fitness training in GR and their experience with the setting was also an advantage. The two main coders were never involved in GR.

The resulting barriers and facilitators of this study reflect experiences and opinions of the participants. Further research should focus on weighing the found barriers and facilitators for their impact on the execution of physical fitness training quantitatively in a larger group of participants, developing a feasible guidance for daily practice, and testing the effect of this guidance in terms of adherence to the existing physical fitness training guidelines.

Conclusions

To conclude, in this study we have offered insights into the barriers and facilitators of physical fitness training from the perspective of patients, their relatives and GR professionals. This overview of barriers and facilitators enables multidisciplinary teams to develop strategies to improve physical fitness training in two ways. First, the knowledge about barriers and facilitators at the level of the program, staff and organization can be used to design improvements within their organization and their interventions; for example, by implementing person-centered goal setting, taking care of well-trained staff, critically evaluating the training volume within the rehabilitation program, and improving the communication with patients and family about the GR process. Second, individual training programs can be better tailored to a patient's circumstances and needs, taking into account the barriers and facilitators found at the patient and family level. Future research should focus on the development and testing of a feasible guidance for daily practice.

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Declaration of interest statement
The authors report there are no competing interests to declare.

Data availability statement
The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research supporting data is not available.

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07

Development of a practical guideline for person centred goal setting in geriatric rehabilitation – a participatory action research.

Wattel EM, de Groot AJ, Deetman-van der Breggen S, Bonthuis R, Jongejan N, Tol-Schilder MMR, van der Wouden JC, Gobbens R. Development of a practical guideline for person centred goal setting in geriatric rehabilitation: a participatory action research. Eur Geriatr Med. 2023 Oct;14(5):1011-1019. Doi: 10.1007/s41999-023-00830-w.

Abstract

Purpose: To improve goal setting in Geriatric Rehabilitation (GR), by developing an evidence based practical guideline for patient-centred goal setting.

Methods: Participatory action research (PAR) in a cyclical process, with GR professionals as co-researchers. Each cycle consisted of five phases: problem analysis, literature review, development, practical experience, feedback & evaluation. The evaluation was based on video recordings of goal setting conversations, and on oral and written feedback of the GR professionals who tested the guideline.

Results: In two PAR-cycles the guideline was developed, consisting of eight recommendations for setting and using goals, and of practical advices elaborating three of the recommendations, concerning conversational skills specific for goal setting conversations. After the second cycle the research team concluded that the guideline was feasible in daily practice and effective when used consciously.

Conclusion: In this study, a practical guideline for setting and using goals in GR was developed. GR teams can improve their patient centred working with goals by discussing the recommendations in their team and choosing the recommendations to work on. This can be supported by the development of an interdisciplinary training. The effect on quality of care should be subject to further investigation.

Keywords: Geriatric Rehabilitation, Patient Centeredness, Goal setting, Practical Guideline.

Key summary points

- Aim: Developing an evidence based practical guideline for patient-centred goal setting in geriatric rehabilitation.
- Findings: The guideline consists of eight recommendations, including three recommendations concerning conversational skills. Those three are further elaborated into practical advices.
- Message: Geriatric rehabilitation teams can improve their patient centred working with goals by discussing the recommendations in their team and choosing the recommendations to work on.

Introduction

Older people with a (sub)acute deterioration in functioning, caused by for example stroke or hip fracture, can benefit from geriatric rehabilitation (GR). [1] GR is a multidimensional approach consisting of diagnostic and therapeutic interventions, the purpose of which is to optimize functioning and participation, [2,3] GR starts off with a comprehensive geriatric assessment, that aims to identify the specific problems and needs of a patient. Subsequently, rehabilitation goals are drawn up, which form the basis of the patient specific multidisciplinary rehabilitation plan. [3] In the Netherlands, every year about 45,000 older persons are admitted to GR after hospitalization. [4]

Ideally the rehabilitation goals are set in dialogue with the patient. This process of establishing or negotiating rehabilitation goals is called 'goal setting'. [5] Research in adult rehabilitation patients, who suffer less from geriatric syndromes and comorbidity, shows low quality evidence that goal setting leads to better psychosocial outcomes. [5] These findings are not yet confirmed in GR literature, where the research mainly focusses on effects on length of stay and functioning at GR discharge. [6] Possibly goal setting in GR merely improves other outcomes such as patient satisfaction and self-efficacy. [7] Goal setting fits in the modern standards of good care that concerns the whole person, including preferences, experiences, and the right to make decisions about one's own treatment. [8]. This is consistent with the fact that person centred care and goal setting are key elements in Dutch governmental documents on good care and the Dutch research agenda for GR. [9,10]

Although both professionals and patients think it is important to genuinely involve GR patients and their informal caregivers in goal setting, in daily practice it appears to be difficult. [11-13] Patients feel that goals are mainly set by professionals and rehabilitation professionals have doubts about the capability of GR patients to formulate realistic goals, although even in patients with mild to moderate dementia collaborative goal setting appears to be feasible. [11-14] Complicating factors are the fact that not all patients aspire the same active role in the goal setting process and the desired role can change over time. [15] Another aspect that hinders the enhancement of goal setting is that goal setting is generally new to patients in GR and that they have difficulties in understanding what is expected from them. [16] Finally, GR professionals tend to overestimate the patient's influence in their own goal setting, and at the same time, many patients rate their involvement in the establishment of their goals as insufficient. [11,16,17]

Within the University Network of Care for Older People Amsterdam (UNO Amsterdam), researchers of Amsterdam UMC and health care professionals collaborate to connect research and daily practice. In the GR working group of UNO Amsterdam, GR professionals of the network (e.g. physicians, nurses and therapists) and researchers have chosen goal setting as a topic where research can help to improve their daily GR practice, and thereby improve the quality of care.

In order to improve goal setting in GR, we aimed to develop a practical guideline for patient-centred goal setting. To target the problems that GR professionals experience in the performance of goal setting, this study was conducted in co-creation with GR professionals connected to UNO Amsterdam.

Methods

Design

We chose a participatory action research (PAR) design, [18,19] in which a practical guideline was developed, tested and evaluated in collaboration with professionals involved in GR. We reported according to the recommendations of Smith et al.. [20]

Participants

UNO is a network in which 23 care organizations throughout the Netherlands collaborate to connect scientific research and daily practice in the field of care for older adults with vulnerability. Members of the GR commission of UNO Amsterdam (both GR professionals and researchers) initiated this study and participated in it as the PAR research team. The testing of the guideline was performed by the GR professionals (e.g. physicians, nurses and therapists) of the research team, and / or by their colleagues in their GR organization.

Participatory Action Research (PAR)

PAR is an approach that is suited to improve practice in co-creation between researchers and professionals. [18] We used the definition of Van Buul et al.: “Participatory action research aims to bring about change in social situations by both *improving practice* (i.e. taking action) and *creating knowledge or theory* (i.e. reflecting on action).”[…] “It works through a *cyclical process* of planning, action and reflection. This process is *collaborative*: it requires substantial involvement of relevant stakeholders, which facilitates empowerment. The persons under study are considered ‘co-researchers’ who test practices and gather evidence in action phases, and evaluate this action and plan further action in reflection phases.” [19]

In the current study, the cyclical process started with addressing the challenges of goal setting in GR as an important problem. Each cycle consists of five phases, each representing an element of the cyclical process of planning, action and reflection that is typical of PAR (Figure 1). Depending on the evaluation in the fifth phase a new cycle started or the cyclical process was terminated.

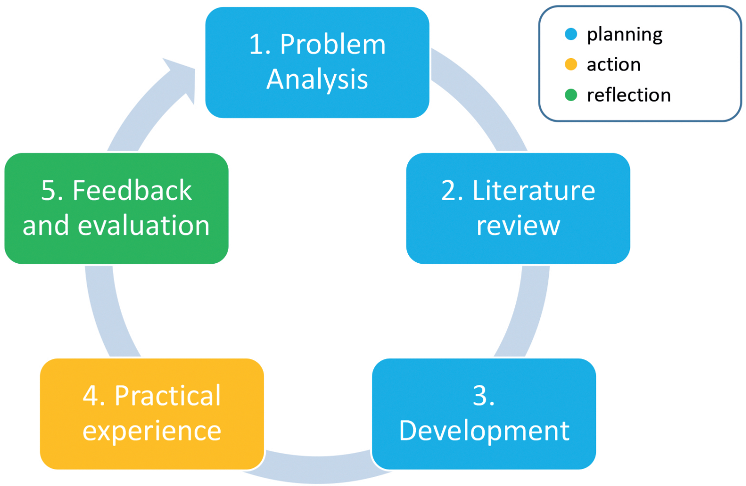

Figure 1. Cyclical process of PAR

An extensive description of the PAR-phases is presented in Online Resource A. In summary the phases include:

Phase 1: Problem analysis
Members of the research team analysed the goal setting process combining both practical experience and literature research, and formulated the problems that had to be solved.

Phase 2: Literature review
Members of the research team searched scientific literature to solve the problems found in phase 1.

Phase 3: Development
Members of the research team discussed the scientific literature in order to develop and subsequently adapt the guideline for goal setting in GR.

Phase 4 Practical experience
GR professionals (members of the research team and their colleagues in the GR organization) tested the guideline in their daily practice and provided feedback.

Phase 5 Feedback and evaluation
Members of the research team reviewed the feedback and judged if the guideline was ready for dissemination and implementation in GR without further adjustments.

Ethics approval
The study procedures were reviewed and approved by the Medical Ethics Review Committee of the VU University Medical Center (number 2020.492, Amsterdam, The Netherlands). The study was performed in line with the principles of the Declaration of Helsinki. [21]

Consent
Written informed consent was obtained from all individual participants included in the study.

Results

The guideline was created during the course of two cycles. In the first cycle, seven goal setting recommendations were developed and tested from February 2017 to February 2018. In the second cycle, practical advices for implementing three of the recommendations were developed from November 2019 to February 2022.

Participants and their roles
The research team consisted of members of the GR commission of the UNO network: two elderly care physicians, a nurse practitioner, a nurse / professor, an occupational therapist/ policy officer, a physiotherapist, and a researcher. Two elderly care physicians temporarily joined the team but had to quit due to time constraints. All members had extensive experience in GR and / or GR research (five to thirty five years). Five out of these nine participants were female. The members of the research team initiated the project, defined the research question, actively participated in all PAR-phases and in the writing of the research paper. The team was advised by a second researcher.

Colleagues of the research team members participated in the phase of practical experience, by testing the guideline and providing feedback. All were GR professionals. In the first cycle the professional background of the colleagues was not registered, in the second cycle they were three elderly care physicians, a resident, a nurse, a speech therapist, and three physiotherapists. Seven of them were female.

Cycle 1: recommendations for goal setting
The problem analysis revealed that the rehabilitation plans are not adequately 'owned' by the patients and their relatives, and that this is due to a lack of tailored information, a lack of patient involvement in goal setting decision making and a lack of follow-up of the goals throughout the rehabilitation process, by the involved disciplines, the patients and their informal caregivers. This broadened the scope of the project to both goal setting and a visible role of the goals throughout the rehabilitation process. Based on the findings of Smit et al. [11] the research team concluded that developing recommendations, rather than a strict step-wise method, is preferred for enhancing goal setting practice. This allows GR teams to examine their performance on each recommendation, and only change their working method where improvement can be expected. The research team discussed Smit's other findings, as well as studies on shared decision making within goal setting [16] and patient experiences of goal setting in post-acute stroke rehabilitation. [15] The discussion led to seven recommendations for goal setting in GR, that were extended with an eighth recommendation in the second cycle. The recommendations are presented in Box 1.

Box 1. Recommendations for goal setting-dialogue in geriatric rehabilitation.

1. Most patients are unaccustomed to working with goals and simply want to get better. The language used by GR professionals is frequently perceived as jargon. It is critical to **match the patient's language** during the discussion of treatment goals.
2. The **way a patient wants to participate in goal setting varies** from patient to patient and can change over time. This should be a **recurring theme** in discussions with the patient.
3. The multidisciplinary team of GR professionals, patients and their relatives work together to negotiate and set meaningful rehabilitation goals. A balance is sought in this **interplay** between the goals of the patient and his relatives, the expertise of the care providers, and the frameworks established by, for example, financing.
4. The multidisciplinary team's GR professionals **commit to** the goals and tailor their treatment and supervision accordingly.
5. The goals that are set are **evaluated** in multidisciplinary team meetings.
6. The goals that are set are **evaluated with the patient and their relatives**.
7. The question of **who discusses and evaluates the treatment goals with the patient and their relatives** should be addressed.
8. Attention should be paid to both short-term functional goals, which must be met before discharge home, and long-term goals, which include goals related to social roles and participation.*

* *This recommendation was added in the second cycle.*

The testing of the recommendations revealed that, in general, the recommendations were deemed useful. The first three recommendations were thought to be more difficult to fulfil and needed practical elaboration. They concerned conversational skills that are specific for goal setting, for example on the topic how to match the patient's language and avoid using the word 'goal'. The other four recommendations of the first cycle were thought to be more straightforward, because they only needed procedural adaptations. These recommendations concerned the key role of goals throughout the rehabilitation process. The first three recommendations were chosen to be addressed in the next cycle.

Cycle 2: practical advices for implementing three of the recommendations.
This cycle began by making video recordings of five real-life goal setting conversations with three female and two male patients: in all conversations a patient and a GR professional were present, the presence of other GR team members and relatives varied. In one conversation the goal setting process was structured by the Canadian Occupational Performance Measure (COPM). [22]

The scientific literature that was analysed in this cycle concerned research on shared decision making in frail older adults, [23-26] shared decision making within goal setting in rehabilitation, [27] comprehensible communication, [28] barriers and facilitators for goal setting, [16] types of set goals [12,13,29-31] and the course of goal setting conversation and the interaction between patient and therapist. [17,30,32-38] Findings of these scientific publications were used to evaluate the video recordings. This resulted in the addition of an eighth recommendation to the set of recommendations and it resulted in practical advices for the goal setting conversation. The extra recommendation concerned the type of goals: not only functional goals that are needed for discharge, but also goals that focus on physical, functional and psychosocial aspects of life after discharge. The advices for the goal setting conversation were divided over three main elements: an introduction, the actual goal setting conversation and a summary and clarification of what has been discussed. The advices and the considerations that led to them are presented in Box 2.

Seven GR professionals put the practical advices to test and video recorded their goal setting conversations with five female and two male patients. In the assessment of the recordings it became clear that in three of them the GR professional obviously used the structure and practical advices. These conversations began with the proposed introduction, the use of the majority of the advices was identifiable and the professionals visibly checked the paper with the advices. The other four recordings did not show that the advices were used, the research team assumed this was, in retrospect, due to unclear instructions for the professionals. The research team decided to evaluate the feasibility and effect in the conversations where the advices were obviously used. These three professionals reported that the structuring effect of the advices supported them to have a successful goal setting conversation, despite the unnatural setting of the video recording. According to the GR professionals, two of the conversations resulted in clear rehabilitation goals for the patients. The third professional reported that the patient was unsure what to expect from her recovery and thus did not express her rehabilitation goals. This conversation was complicated by the fact that the GR professional was not the patient's actual therapist and thus could not contribute her professional perspective to the goal setting process. Based on the feedback of the GR professionals the research team concluded that the guideline (recommendations and practical advices) was feasible in daily practice and effective when used consciously.

Box 2. Practical advices for implementing recommendations 1, 2 and 3

Components of the goal setting conversation	Recommendation number, source and considerations
Preparation questions for exploring the patient's starting position: • Have you previously received rehabilitation? (Are you familiar with the concept of goal setting?) • What did they tell you? • What do you require to recover?	**Recommendation:** 1,2 and 3 **Source:** video recordings, experience of research team and publications [7,22,24-26,32,36] **Considerations:** 'Is this patient familiar with the concept of goal setting and emotionally ready for this conversation' are important questions, entering this conversation. This is done by exploring expectations, knowledge, prior experience with rehabilitation and goal setting, and issues that distract from a goal setting conversation.
Explanation of the conversation's purpose: "This conversation is intended to cover two topics: What do you need to be able to perform, in order to return home? What else is necessary for you to be able to live at home again and to get your life back on track?"	**Recommendation:** 1 and 3 (matching the patient's language & the interplay between participants leads to meaningful goals). **Source:** experience of research team and literature [11,12,15,28,36] **Considerations:** The distinction between functional goals that focus on discharge home and 'other' goals (e.g. participation goals, patient's dreams, goals on cognition or mood) makes the goals more meaningful for the patients, and prevents from therapist-led choice of just 'privileged goals'.[27]
Explanation of the patient's role (patient is an expert on himself): Briefly name options, e.g. "There are various ways to determine those rehabilitation goals. One way is for you to say what the goals are, another is for the doctors and therapists (that is "we") to say what the goals are and a third way is for us to talk about it and decide together. Which do you prefer if I put it that way?"	**Recommendation:** 2 (opening the conversation about the patient's desire to participate in decision making: how do you do that?) **Source:** video recordings and publications [22,32,36] **Considerations:** -

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Box 2. Continued.

Components of the goal setting conversation	Recommendation number, source and considerations
Goal setting conversation, either COPM or other type	**Recommendation:** 1, 2 and 3. **Source:** Publications [11,12,15,17,22,24,26,28,30,31,33-36] **Considerations:** The purpose of this cycle is not to choose the best goal setting intervention. For the Recommendation 'the interplay between participants leads to meaningful goals' interesting insights were found that can help the GR professionals improve the interplay between the goal setting participants. - Use of a decision aid. - For some patients it is helping to break down goals into smaller parts. - Professionals prefer goals ('privileged goals') characterized by short timeframes, conservative estimation of outcomes, and physical function. The selection of other types of goals is unlikely. - Patients goals deemed unattainable by the rehabilitation team are never agreed on. - When professionals cannot agree on a patient's goals, they employ strategies such as: 1. Focusing on the admission rather than the long term if the possibility of success is uncertain; 2. Presenting information in a step-by-step manner in order to elicit agreement; 3. Indicating that the goal is essentially non-negotiable, for example, by writing it down, 4. Collaborating with other team members to formulate goals 5. Making use of the authority implicit in the professional role; 6. Moving on to the next goal despite signs of patient resistance - When patients use words like "Well…." or "I think …." They might doubt if they are able to articulate goals.
Summary and clarification • Summarize the goals and explain what disciplines are involved to reach the goals • Ask back if it is clear • Ask 'What other questions do you have?'	**Recommendation:** 1. (matching the patient's language) **Source:** video recordings, experience of research team and publications [17,27] **Considerations:** The Pharos factsheet [26] emphasized the significance of these points in transferring the plan from the therapist's head to the patient's. The final point ("What other questions do you have?") proved to be far more inviting than "Do you have any questions?". Instead of being expected to understand everything, the patient is expected to have questions.

Next steps

The research team proposed to develop a training for the application of this guideline as a next step, and then perform a pilot study to test the effect of this training on patient involvement in goal setting and patient ownership of the rehabilitation process.

The PAR process

Participatory action research in itself has a greater yield than just the results of the PAR-cycles. This is for example personal outcomes for the participants and learning points from challenges in the PAR process. The co-researchers experienced that their participation in this project raised their awareness of goal setting challenges. Their involvement made them aware of difficulties in choosing the right language, and of the fact that patients are not aware how the goals affect their rehabilitation trajectory.

An important challenge was the transparency and clarity of appointments for the research team members, due to the collective approach and the shared responsibility of the team members. An illustration of this was the preparation of the practical experience (phase 4) in the second cycle, where the advices for the goal setting conversation would be tested. As a team we thought that all team members knew what to do, but in the end, we had to conclude that four out of seven professionals that tested the goal setting conversation advices, got insufficient instructions.

What we learned from this challenge, is that appointments, goals and expectations have to be clear and unambiguous, and well-documented. And besides that, a clear training program is necessary for proper application of the practical guideline.

Discussion

In this PAR-project, we aimed to develop a practical guideline for goal setting in GR. The resulting guideline consists of eight recommendations and a further practical elaboration of three of them, concerning conversational skills that are specific for goal setting. Multidisciplinary teams of GR professionals could use these recommendations for a tailored improvement of their patient centred goal setting practice.

An important choice in this study is the development of a practical guideline built on recommendations instead of an extensive step-by-step method for goal setting. This choice was based on the feasibility study of Smit et al., that showed that professionals failed to implement all parts of the planned intervention. [11] This finding is consistent with that of Scobbie et al., who studied the implementation of a step-by-step intervention for goal setting, and concluded that the new and unfamiliar steps were not routinely implemented. [7] This is supported by the key findings of Peryer et al. about implementation of complex interventions. They concluded that the compatibility of a new intervention with the existing work routine was the most prevalent contextual factor in the implementation of new interventions. They stated "Some interventions were also perceived to be incongruent with habitual care routines and others were not deemed significantly different from existing practice to deserve a behavioral change". [39] The guideline with recommendations enables GR teams to make a tailored plan for improvement, and only change their working method where it doesn't align with the recommendations. [39] The implementation of our recommendations and advices can be supported by the development of an interdisciplinary training in which the GR teams undergo a critical self-reflection on the way their practice aligns to the recommendations, and in which they are trained in the goal setting conversation. Reflection on barriers and facilitators for the application of patient-centred goal setting should be a third component of the training. The review of Crawford et al., provides an extensive overview of this topic. [40]

Rather than choosing the best goal setting instrument, the guideline is built to solve the problems that hinder setting and achieving of proper goals. Most research only focusses on establishing goals together with the patients, and not on the role of the goals during rehabilitation. [14,17,30,35,36] Besides the study of Smit et al., we found a study in stroke rehabilitation about integration of goal setting all through the rehabilitation process, and the integration turned out to be poor. [37] Another study on this topic, is a pilot study that did not report results yet. [41] Our guideline strives for a central role for goals throughout the rehabilitation program, as this gives the patient control and ownership over his own rehabilitation, which is an important motivator according to professionals. [35]

This study's PAR approach, developing an evidence based guideline through collaboration between research and practice, is one of its strongest points. The collaboration between researchers and professionals within the GR committee of the UNO Amsterdam is an important facilitator for quality improvement by the development of evidence based products for GR with a high feasibility. A second strength of this study is the choice for development of recommendations instead of a totally new method, thereby increasing the chance of successful implementation. A final strength of this study is the interdisciplinary focus on goals throughout the rehabilitation, by regularly and explicitly evaluating them with the patient and their relatives, and by explaining how each discipline contributes to the achievement of the goals.

A limitation of the study is the fact that the feasibility and the effect of the practical advices in the second cycle of PAR, are based on the analysis of a limited number of goal setting conversations.

Another weakness of this study is the fact that no patients were involved as co-researchers. The patient perspective was derived from scientific studies that reported on this perspective in the goal setting process. Besides, the participation of patients in the development of a goal setting intervention in adult and child rehabilitation resulted in similar topics for improvement as we found in our study. [41] The involvement of patients in the PAR would have further refined the recommendations.

Although the recommendations were developed in close contact with GR professionals and tested in daily practice, the effect on the quality of care has not been established yet. Future research should be conducted in co-creation with patients and their relatives. For example, relevant outcomes should be established in this co-creation process. In our opinion, studies should primarily focus on the effect on patient involvement in goal setting and patient ownership of the rehabilitation process. [42] Patient related outcomes, such as improvements in physical functioning and quality of life, would be important secondary outcomes.

In conclusion, the practical guideline for goal setting in GR that was developed in this study, consists of eight recommendations and a further practical elaboration of three of them, concerning conversational skills that are specific for goal setting conversations. Multidisciplinary teams of GR professionals can use these recommendations for a tailored improvement of their patient centred goal setting practice. This can be supported by the development of an interdisciplinary training in which the GR teams undergo a critical self-reflection on the way their practice aligns to the recommendations, and in which they are trained in the goal setting conversation. The effect on quality of care should be subject to further investigation. Both the training and the research should be developed and conducted in co-creation with patients and their relatives.

Declarations

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No funding was received for conducting this study.

Competing interests

The authors have no relevant financial or non-financial interests to disclose.

Ethics approval

The study procedures were reviewed and approved by the Medical Ethics Review Committee of the VU University Medical Center (number 2020.492, Amsterdam, The Netherlands). The study was performed in line with the principles of the Declaration of Helsinki.

Consent

Written informed consent was obtained from all individual participants included in the study.

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Elizabeth M. Wattel, Aafke J. de Groot, Sacha Deetman - van der Breggen, Robin Bonthuis, Niels Jongejan, Marina M.R. Tol - Schilder and Robbert Gobbens. The first draft of the manuscript was written by Elizabeth M. Wattel and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Appendix

Online Resource A. Extensive description of the PAR-phases.

Phase	General	Cycle 1	Cycle 2
1	Problem analysis Members of the research team analysed the goal setting process combining both practical experience and literature research, and formulated the problem(s) that had to be solved.	No addition to general text.	Based on de outcome of Cycle 1, the research team decided to further elaborate the first three recommendations.
2	Literature review Members of the research team searched scientific literature to solve the problem(s) found in phase 1. The members stopped searching for new publications if they judged the new insights appropriate for solving the problems. The outcome of this phase were insights and ideas that can be used to solve the problems of phase 1	The literature search was meant to gain insights in the process of goal setting and to find new ideas to solve the problem(s) found in phase 1.	The research team gathered video recordings of goal setting conversation and searched for scientific literature on the following topics: • Matching the patient's language; • Shared decision making, and discussing the patient's role; • Interaction between patients and professionals in goal setting conversations.
3	Development Members of the research team discussed the scientific literature in order to develop and subsequently adapt the guideline for goal setting in GR.	The research team discussed the scientific literature and developed recommendations for goal setting.	The research team discussed the literature and the video recordings and formulated practical advices for goal setting conversation skills.
4	Practical experience GR professionals (members of the research team and their colleagues in the GR organization) tested the guideline in their daily practice and provided feedback. The outcome of this phase was information on the feasibility and helpfulness of (a specific part of) the guideline to perform client centred goal setting, in terms of video recordings and / or the verbal or written feedback by the GR professionals.	GR professionals (members of the research team and their colleagues in the GR organization) tested the recommendations with the patients that were admitted to their GR ward. They received a brief instruction and recommendations for goal setting on paper. They gave verbal feedback to the research team.	GR professionals (members of the research team and their colleagues in the GR organization) tested the practical advices in a goal setting conversation with the patients that were admitted to their GR ward. They received a brief instruction and they received the practical advices presented in Box 2 on paper (without the comments in the right column). Feedback was gathered by video recordings of the goal setting conversation and a short questionnaire on feasibility and helpfulness of the guideline for the GR professionals to perform client centred goal setting.
5	Feedback and evaluation Members of the research team reviewed the feedback and judged if the guideline was ready for dissemination and implementation in GR without further adjustments. This judgement was based on the feedback of the professionals (that tested the guideline). If the outcome of phase 5 was that further adjustments to the guideline were necessary, a new cycle was started. Otherwise, the cyclical process was terminated.	The verbal feedback was discussed.	The video recordings of the patient interviews were assessed using a topic list checking if 1) the GR professionals applied the practical advices of Box 2 and 2) if they succeeded to comply to the first three recommendations of box 1. The outcomes of the questionnaires for professionals were summarized. All outcomes were discussed.

08

General Discussion

General discussion

This thesis concerns two aims: 1) developing recommendations for the training of physical fitness (muscle strength and endurance) in orthopedic GR, studied in the Fit4Frail project, and 2) developing an evidence-based practical guideline for patient-centered goal setting. Both research projects were performed in the UNO Amsterdam 'living lab.' We will begin this general discussion with a brief summary of the findings from the sub-studies, before discussing the major themes of this thesis in further detail.

The literature review of endurance training (chapter 2) showed that it can be effective for vulnerable older adults. Exercise characteristics from existing guidelines — such as the guideline of the American College of Sports Medicine (ACSM) — are widely applicable to older adults, although lower frequencies and intensities also appear to be beneficial. In the Delphi study (chapter 3), experts in the field of orthopedic GR agreed that testing of endurance and muscle strength should be pragmatic, and that this is preferably performed in functional activities. The experts agreed that the training characteristics of the ACSM guidelines can be strived towards for endurance training, and adapted as necessary. For muscle strength training, consensus only was reached on characteristics for lower intensity training. In chapter 4, the talk test was described as a promising test for endurance capacity, although unfortunately it appeared to be infeasible in this population. Chapter 5 describes the current practice of orthopedic GR, highlighting that the content of physical fitness training substantially varies and is of low intensity compared to guidelines for older adults. The relation between the volume of this training and fitness and functioning is limited. Another finding is that a reliable measure of endurance capacity is lacking for this population.

The barriers and facilitators of physical fitness training found in the interview study (chapter 6) largely correspond with those found for participation in exercise in related settings, although they also show important differences. Similarities with other settings include comorbidities and pain hindering participation, whereas differences were found such as relatives enabling participation by practicing with the patient themselves. This overview of barriers and facilitators enables multidisciplinary teams to design improvements at the level of the organization and interventions, as well as at the individual training program level, tailoring it to the patient's circumstances and needs.

After analyzing the sub-studies (as described in chapters 2-6), a national expert meeting was held to create recommendations for the practice of orthopedic geriatric rehabilitation. This aligns with UNO Amsterdam's goal of making research findings practically applicable and thereby achieving societal impact. A report of this meeting is included as appendix A at the end of this thesis.

Chapter 7 describes the development of a practical guideline for patient-centered goal setting, comprising eight recommendations. The recommendations related to conversational skills were elaborated into practical advice concerning these skills.

Testing physical fitness

The findings of the Delphi study (chapter 3) serve as the foundation for recommendations for physical fitness testing for various purposes, such as assessing the safety of endurance training, determining the appropriate training intensity, or evaluating the training's effect. In the Delphi study, the experts deemed a pragmatic approach appropriate to assess exercise intensity by observing how well people performed in functional activities. For muscle strength, they reached consensus on using a derived 1 repetition maximum (1RM) test — for example, based on the weight that a patient can lift a maximum of eight times (8RM) — to determine the appropriate training intensity and evaluate the training. A pragmatic alternative was seen in performance on a functional test, provided that it has a significant strength component, such as standing up from a treatment table. In the other sub-studies of this thesis, we found no reason to further discuss these choices, which somewhat differs for testing endurance. In order to determine training intensity, expert consensus was reached on the Åstrand test, provided that the patient can cycle on an ergometer and is not limited by pain. This test is probably only suitable for a small minority of the patients in orthopedic GR. This assumption is supported by the limited feasibility of performing the talk test on a bicycle ergometer, mainly due to the inability to cycle on an ergometer, as discussed in chapters 4 and 5. Another problem is that about half of the participants in our study used beta blockers, which are known to limit the feasibility of the Åstrand test.[1] Accordingly, it might be the most suitable test to determine training intensity, albeit only for a minority of the participants. The research team expressed doubts over the choice of the Åstrand test, given that training intensities based on a percentage of maximal heart rate — like the Åstrand test — overlook physiological and metabolic responses to exercise, such as blood lactate accumulation.[2,3] Individual differences in lactate response can lead to varied training outcomes, with some individuals responding positively and others not at all. If a patient can cycle on an ergometer, a test based on a metabolic threshold — like the talk test — might be more appropriate for identifying an effective training stimulus.[2] The talk test involves a submaximal graded exercise test where patients recite a paragraph at each step until they can no longer speak comfortably. The last stage where they can speak comfortably indicates the first ventilatory threshold, marking the lower limit of moderate exercise intensity. Training at this intensity is considered safe and effective,[2] although the dual task of cycling and talking might be challenging for some patients. The Delphi panel likely chose the Åstrand test because the talk test is less commonly known, rather than because its mechanism is less valued. However, both the Åstrand test and the talk test are only feasible for a minority of patients.

The six-meter walking test (6MWT) was chosen in the Delphi study to evaluate the training effect. However, the results in the observational study were often influenced by pain at the time of admission to GR. The 6MWT might be more suitable at discharge, providing useful information for the physiotherapist at home. A known disadvantage of the 6MWT is its limited validity in measuring aerobic capacity, as the test score is influenced by many factors such as pain, walking technique, and muscle strength. The talk test was not a viable alternative, mainly because using a cycle ergometer after hip or knee surgery was often not feasible. This implies that a feasible and valid endurance test for inpatient GR is still lacking. Earlier research suggests that arm crank ergometry might be useful in this population. In future research, a test protocol for arm crank ergometry could be developed for and/or tested in this population.

It could also be argued that testing endurance at admission to determine training intensity is not essential. The training intensity can be monitored during exercise using the Borg scale and observing the patient's ventilation. This might be a pragmatic solution to the lack of a valid instrument, although it has the disadvantage of not allowing proper evaluation of the training effect.

Training physical fitness

Like for the testing of physical fitness, the Delphi study's findings (chapter 3) serve as the foundation for recommendations for physical fitness training characteristics. However, first we will address the results of the observational study (chapter 4), where we compared the training characteristics in the current practice of orthopedic GR to the ACSM guideline's recommendations. In the majority of the patients, the guideline's recommendations were not met, and the results were somewhat better for muscle strength training than endurance training. In the Delphi study, participants agreed on characteristics for resistance training that slightly deviated from the ACSM guidelines. They agreed on relatively low intensities, corresponding with a higher number of repetitions per set than the ACSM guideline's recommendations. When comparing the data of the observational study with these Delphi recommendations, the results are even worse than when compared with the ACSM guidelines. None of the participants complied with all three evaluated aspects: number of sessions per week, number of sets per session, and number of repetitions per set. Although we have no data about the training intensity in the observational study, we can conclude that the recommendations for muscle strength training are not met in this population. This apparent undertraining was discussed in the expert meeting, in which the experts suggested that the low training volumes were likely due to patient characteristics, such as pain or restrictions on certain exercises. They also mentioned that a lack of knowledge about exercise physiology among physiotherapists who have not received additional training could be a relevant factor. The Delphi study's recommendations enable tailoring the training characteristics, such as training at a lower intensity in case of pain, or varying the interplay between the FITT characteristics, such as shorter and more frequent sessions. Therefore, if patient-related factors are a barrier to higher training volumes, the Delphi study's recommendations fit and remain valid for muscle strength training.

For endurance training, the Delphi study participants agreed on training characteristics based on ACSM recommendations (chapter 3), which depend on the training intensity: moderate (≥5 sessions per week of 30-60 minutes at a perceived intensity of 5-6 on a Borg 0-10 scale) or vigorous (≥3 sessions per week of 20-30 minutes at a perceived intensity of 7-8 on a Borg 0-10 scale). The systematic review (chapter 2) included older adults with various health conditions and diseases, and concluded that while the ACSM guidelines are generally applicable, vulnerable older adults also benefited from lower frequencies such as two to three sessions per week at lower intensities. In practice, time spent on endurance training is often low compared to the guidelines, as also observed in other research projects.[4] The limited therapy time in GR is a barrier as therapists must carefully decide how they best use this time. With a focus on quick discharge to home, they often prioritize other aspects over endurance training. Despite this limited therapy time, the experts in the meeting concluded that physiotherapists in GR should strive to follow the ACSM guidelines, with a minimum of three sessions per week for endurance training. Earlier research has suggested promising interventions to achieve this — including arm crank training[5], exergaming[6] and using daily feedback on walking time goals with accelerometers[7] — which the experts found feasible. These interventions can help to increase the frequency and duration of endurance training and provide opportunities to raise exercise intensity. Additionally, measures such as participation in group therapy or using cheaper staff such as therapy assistants can support these efforts. For individual patients, the Delphi study's recommendations enable tailoring the training characteristics, such as starting at a lower intensity and employing a shorter session duration or varying the interplay between the FITT characteristics, such as shorter and more frequent sessions. These adjustments aim to improve patients' fitness levels at discharge, enhancing their ability to function at home and reducing the risk of readmission. Endurance training should also be part of post-discharge treatment, although there are practical barriers to its organization and funding.

Based on these findings and considerations, the recommendations of the Delphi study for endurance training remain valid.

Barriers and facilitators of physical fitness training in orthopedic GR
The interview study (chapter 6) provided 78 factors that positively or negatively influenced physical fitness training in orthopedic GR. This concerned factors at the level of 1) the patient, e.g. weight-bearing restrictions related to surgery or motivation for training; 2) the patient's family, e.g. family members practicing with the patient; 3) staff members, e.g. proficiency in adjusting to patient diversity or limited time due to a high workload; 4) the rehabilitation program, e.g. high intensity and frequency of endurance training; and 5) the organization, e.g. the availability of exercise equipment at the ward. These factors were discussed in the expert meeting, and those that are easy to address and achieve high impact were identified as 'low hanging fruit.' This led to agreement on 27 factors influencing physical fitness training, which are presented in appendix B. These 27 factors can be summarized into four overarching topics. One main topic is the ability of GR professionals to coach the patients in a way that increases their self-confidence and motivation, reduces insecurity and inactivity, and sets realistic expectations. A well-researched method to achieve this is motivational interviewing, which has been shown to improve motivation for rehabilitation and related behaviors. A second key topic is family participation in GR, with earlier research showing that family involvement can positively affect the rehabilitation process by increasing therapy time, better preparing both the family and the patient for discharge, resulting in a shorter length of stay, better participation in the community, and improved quality of life for both patients and caregivers. [8] A third key topic is ensuring that the content of testing and training is adequate and personalized, and that staff are knowledgeable and proficient. The studies in this thesis provide practical recommendations for GR professionals, both for therapy sessions and training outside of therapy. Having training equipment available at the wards is essential for the latter. The final overarching topic is person-centered goal setting, which leads to personalized, meaningful goals that guide the rehabilitation process. Recommendations for this topic are detailed in the next section.

Goal setting
Setting and achieving goals with patients is a vital part of GR, although it can be challenging in practice. In the participatory action research (PAR) project (chapter 7), we developed a

practical guideline for goal setting together with GR professionals. We formulated eight recommendations for setting and using goals, three of which were expanded into practical advice on conversational skills specific to goal setting. The recommendations focused on 1) tailoring the information to patients and their relatives, 2) improving their participation in goal setting decision-making, and 3) enhancing the follow-up of goals throughout the rehabilitation process by all involved disciplines, patients, and their relatives. We concluded that creating recommendations is preferable for improving goal-setting practice, rather than following a rigid step-by-step process. This approach allows GR teams to evaluate their performance on each recommendation and only adjust their method if improvement is expected.

For this project, we used literature to include the patient perspective, although patients (and their family) were not actively involved. Fortunately, a recent study in the Netherlands by Drenth et al. describes the experiences, wishes and needs of patients regarding participation during GR.[9] The themes from this study closely relate to those in the PAR project, whereby patients prefer active patient participation and expect clinicians to actively support them. Different methods and approaches are necessary, requiring a flexible strategy that considers the patient's needs and environment. Based on Drenth et al.'s study, ten recommendations for practice were formulated,[9] which largely overlap with our findings. However, their study adds the advice to always invite patients or their family to multidisciplinary team meetings, while in our project we do not specify whether the patient should be present at these meetings, leaving it to the GR wards' procedures.

The PAR project on patient-centered goal setting is an example of how close collaboration between science and practice can lead to practical, evidence-based products for current practice. The UNO Amsterdam 'living lab' where academic researchers and LTC staff collaborate on research offers excellent opportunities to further strengthen this collaboration.

Methodological considerations

One concern in the Fit4Frail study is the generalizability of the results. In the observational study, only fifteen percent of the admitted patients who could benefit from physical fitness training were included. It is plausible that these included patients were not representative, possibly having fewer cognitive problems and comorbidities, and thus being less vulnerable than their peers. Moreover, the data were gathered from 2017 to 2019, and experts in the meeting noted that the GR population has since become even more vulnerable. This might be reflected in the length of stay in orthopedic GR, which declined in 2014 and 2015 following the introduction of activity-based funding, but started to increase again in 2019.[10,11] This highlights the study's second drawback, namely the dynamic setting in which it was conducted, reflecting a common issue with empirical studies. In this study, it concerns the changing population and the increasing focus on a quick discharge to the patient's home. Therefore, the results of the observational study likely apply to only a small selection of the current orthopedic GR patients. However, the results of the Delphi study — which serve as the basis for our recommendations — reflect the consensus of experts about all orthopedic GR patients. The systematic review (chapter 2) has an even wider scope, as acknowledged by the experts, who believed that the outcomes of Fit4Frail are also applicable to non-orthopedic GR patients. One possible question is whether goal setting is possible in an increasingly vulnerable population, although it has been proven feasible even in patients with dementia in GR.[12] A third limitation is the large amount of missing data in the observational study. Although the participants and local staff were motivated to gather data and reminders were sent, many measurements were still lacking. Future research could improve by including fewer wards, allowing researchers to be more present at each ward. This could enhance personal relationships and increase the likelihood of performing discharge measurements in case of unexpected quick discharges. Another limitation is the limited patient involvement in the setup of both the Fit4Frail study and the goal-setting project. Patients were only involved as study subjects rather than co-researchers. In recent years, research in the care for older adults in the Netherlands has significantly developed in this area, with older people and their relatives becoming more actively involved in all phases of research. Future projects could benefit from active patient involvement to better tailor the study and its results to their needs.

One strength of the Fit4Frail study is the fact that it involved relatively fundamental research in exercise physiology, which has major implications for the daily practice of GR. This translation of fundamental knowledge into practical recommendations and related products was undertaken in close collaboration with GR professionals in the UNO Amsterdam 'living lab,' reflecting a second strength of this research project. The 'living lab' fosters the collaboration between scientific researchers and professionals. In the Fit4Frail project, GR professionals were involved in the design of the study, the study was conducted in care organizations participating in the 'living lab,' and the results were discussed with GR professionals of UNO Amsterdam and — in the expert meeting — with GR professionals of sister 'living labs' in other parts of the Netherlands. The goal-setting study was a co-creation project involving GR professionals and researchers of the UNO Amsterdam 'living lab.' Another strength of the Fit4Frail project is the use of multiple research methods, including a literature review, expert consensus in the Delphi study, quantitative observational data, and qualitative interview data. This combination of data provides a comprehensive view of physical fitness testing and training.

Recommendations for practice

Based on this thesis, four topics can be identified for possible changes in GR practice. First, increased focus should be placed on physical fitness during and after inpatient orthopedic GR. Patients are often discharged to their home with very low physical fitness, increasing the risk of impaired recovery and readmissions. Raising awareness about the importance of physical fitness in this vulnerable population — in both inpatient GR and at home — can enhance long-term rehabilitation outcomes. Second, if improving endurance or muscle strength is a rehabilitation goal, therapists should follow the recommendations for testing and training endurance and muscle strength of this thesis. A fact sheet will be developed for this purpose. As a follow-up to this study, educational materials will be developed to help physiotherapists to educate their less experienced colleagues, patients and patients' families. Third, GR teams should discuss the 'high impact and easy to address' barriers and facilitators for physical fitness training in their organization. Addressing these factors will help to improve patients' rehabilitation trajectories.

Finally, GR teams can enhance their patient-centered goal-setting and achieving processes. In a follow-up to our PAR project, a self-scan and a training will be developed. The self-scan is designed for GR teams to review their working procedures in relation to the recommendations, allowing them to identify areas for improvement. The training will focus on conversational skills that are specific to goal setting in GR. Both the self-scan and the training will be developed in collaboration with GR professionals and patients.

Recommendations for future research

During the Fit4Frail project, we developed recommendations for testing and training physical fitness, although we did not test their effect in practice. Future research should develop and test an intervention based on these recommendations for inpatient orthopedic GR. Given the focus on quick discharge to home, it is also necessary to develop and test home-based therapy programs to further improve patients' physical fitness. Interventions should consider the organizational and financial barriers and should also be tested in other GR populations, such as patients with acute physical deterioration after an illness or non-orthopedic surgery. We conclude that an outcome measure for endurance capacity in orthopedic GR is lacking and thus future research should focus on developing such an instrument to establish suitable training intensity and evaluate the training effectiveness. The use of a talk test protocol in arm crank ergometry is a promising opportunity, and the quality of this instrument should be assessed. Another area for future research is the increasingly vulnerable population in orthopedic GR, which might require adjustments to current GR programs. This population should be followed after discharge to measure physical, functional and participation outcomes, as well as healthcare consumption, including readmissions. Finally, we have developed recommendations for improving patient-centered goal setting and achievements, testing the feasibility of the recommendations and the usefulness of the guideline for patient-centered goal setting. Future research should focus on the effects of this intervention on patient involvement in the rehabilitation process.

In all of these studies, we recommend that both GR professionals and patients and their family members are involved as co-researchers.

General conclusions

In the Fit4Frail study, we established recommendations for testing and training physical fitness in orthopedic GR based on scientific literature and expert opinion. We also studied the actual training of physical fitness, changes in physical fitness and functioning, and barriers and facilitators of this training. We conclude that there is undertraining of physical fitness in orthopedic GR and have formulated recommendations for improving this type of training.

Finally, collaboratively working towards patient-centered goals should be a key focus in geriatric rehabilitation. This thesis provides practical guidance to enhance collaboration between patients and their families, as well as interdisciplinary collaboration.

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09

Appendices

Supplementary material

Appendix A. Towards recommendations for testing and training physical fitness in orthopedic geriatric rehabilitation: Report of a national expert meeting

After analyzing the five sub-studies (as described in chapters 2 to 7), a national expert meeting was held to discuss recommendations for the practice of orthopedic geriatric rehabilitation with the research team. This descriptive report presents the outcomes of the expert meeting.

Participants

The expert meeting was held with participants with broad experience in physical fitness training in orthopedic GR. We aimed for a meeting with eight to ten Dutch experts and tried to find twelve to thirteen applicants to account for possible cancellations. Dutch physiotherapists and exercise physiologists who had registered themselves for participation in the previous Delphi study (chapter 3) were invited by email. As a second step, we recruited participants via the collaborating academic networks of care for older persons in the Netherlands (SANO). Fifteen experts applied for the meeting, and after a cancellation by five of them, the meeting was held with ten experts. Nine of them were physiotherapists, representing six care organizations spread over the country, and one was an exercise physiologist and experienced lecturer in the field of training. Five members of the Fit4Frail research team and an implementation expert also attended the meeting. One of the researchers — an expert moderator — presided over the meeting. The other researchers participated in and facilitated the discussions.

Preparation

Participants received a summary of the four sub-studies in Dutch one month prior to the meeting. Following a brief participant introduction, the four sub-studies were presented to the group, whereby the participants were then given the opportunity to express their opinions about the outcomes.

Discussion 1: Participants reflected on the study results

The use and viability of measuring tools was the first topic of discussion. The participants acknowledged that pain made it difficult to administer the six-minute walk test (6MWT) at admission. This test can be used at discharge and in the transfer to a primary care therapist. A shorter walking test was considered, although it was agreed that it would not be suitable for determining aerobic capacity. Participants voiced skepticism over the Åstrand test's feasibility and validity in a population recovering from surgery on a lower leg and frequently using beta blockers. The application of the potentially out-of-date ACSM rules was a second theme. The 2019 NSCA recommendation advises exercising at 60–80% of 1RM to increase muscle strength. Additionally, strength can increase at lower intensities (30% of 1RM, for example). The population being studied was addressed as a third theme. The participants noted that the GR population in general has deteriorated since the data was collected in 2018–2019. Due to their premature discharge and increased frailty, patients with highly burdened informal caregivers experience crisis readmissions and thus the population studied might not be representative of the current GR population. As a result, the study results might not be relevant and generalizable to current GR patients. As a final question, the researchers asked the participants why they thought the protocol for muscle strength training was not adhered to in the observational study. Were patient-related considerations involved in this? Alternatively, did they believe that the physiotherapists were not aware of the guidelines? Participants thought that geriatric physiotherapists would be familiar with training requirements as these are part of their master's degree program, although this might be different for physiotherapists who did not follow this program. In general, the participants thought that pain was the limiting factor concerning the lack of adherence to the protocol in the frail population studied.

Discussion 2: Specific topics
The next step was to hold a more structured discussion based on three specific topics that puzzled the research team.

The first topic concerned the *characteristics of endurance training*. In the Delphi study (chapter 3), consensus was reached on these characteristics according to the guidelines of the American College of Sports Medicine. However, our systematic review (chapter 2) showed that improved endurance could be reached with lower intensities and frequencies in the majority of older adults. What does this mean for daily practice in orthopedic GR?

The participants stated that the amount of therapy is determined by activity-based funding, the so-called 'DBCs' that define established combinations of diagnostic and care activities and the associated fixed price. Each care organization chooses how the funding is used, such as using therapy assistants and other less expensive professionals (e.g. "movement agoge"), supervised by a physiotherapist. Higher frequencies and longer training durations can also be achieved with groupwise training, although this is not suitable for all patients. One participant – an experienced lecturer in exercise physiology for geriatrics physiotherapists –reported that 50 percent of the physiotherapists in his courses experience that they have been "too kind" regarding endurance training. According to this lecturer, students in this course consistently achieve better than expected outcomes when they follow the guidelines for endurance training. The participants in our meeting concluded that physiotherapists in GR should strive to follow the guidelines, and that three sessions a week is the minimal frequency necessary for endurance training. This could be accomplished by group therapy, using — for example — a therapy assistant, exercising outside of therapy (e.g. with family), combining wearables such as an accelerometer or Fitbit with goals, arm-crank training, or exergaming.

The second topic was measuring endurance with the 6MWT. In the Delphi study, it was suggested that this test could be used to assess the impact of endurance training. The test appears to be excessively affected by pain in the observational study, making it seem worthless as a means of evaluating endurance.

Earlier in the discussion, the participants explored the 6MWT's viability and concluded that it can be helpful when a patient is discharged from inpatient rehabilitation and transferred to a primary care therapist. The main topic of debate concerned what to measure while assessing endurance, which mainly refers to "how long a patient can maintain an activity." A test with constant effort would be suitable, although pain would have an equivalent impact when walking. The two-minute walk test, two-minute step test, and fatigue resistance test were among the other tests proposed, although they were all determined to be ineffective for assessing endurance in the population in question. A promising option for developing a measure of endurance in inpatient GR was arm-crank ergometry. The participants expected that patients were not hindered by pain during arm-cranking, and they stated that arm-crank ergometers were available in their institutions.

The third item related to the observational study's conclusion that endurance training falls short of the prescribed guidelines for this kind of training. The literature offers several methods to enhance this training, including using accelerometers and related physical activity goals, arm-crank ergometry, exergaming, and the potential to begin endurance training following release home. The research team asked the professionals' thoughts about the feasibility and effectiveness of these training approaches in orthopedic GR.

Although the participants were generally in favor of the aforementioned methods, they noted that endurance training is only undertaken after discharge. A 6MWT endurance discharge measurement and home training recommendations were considered appropriate. The GR therapist might be able to help with this post-discharge endurance training.

Barriers and facilitators

Following the discussions mentioned, the meeting's main topic was the interview study's findings regarding the facilitators and barriers to physical fitness training in orthopedic GR (chapter 6). Five categories containing 78 barriers and facilitators (factors) were identified in this study. Participants in the expert discussion identified the 'low-hanging fruit' factors, namely those that have a high impact and are easy to address. Before the meeting, each element was listed on a sticky note. Additionally, flip charts with two axes — a vertical axis for difficulty to improve and a horizontal axis for level of impact — were developed. There were four flipcharts: one for each of the categories of "program factors," "patient factors," and "organization factors," while the other two categories of "staff factors" and "family factors" were combined into a single flipchart because they contained fewer obstacles. Four groups of two to three participants each were formed, and each group began at a different flipchart with their assignment. The group had to collaboratively arrange the sticky notes into the grid based on their assessment of the level of impact and difficulty of enhancing each barrier or facilitator. At the end of each round, a photo of the flipcharts was taken. After moving to the next flipchart, the groups rearranged the sticky notes originally positioned by their peers to reflect their own opinions. A new photo of the flipcharts was created after each round (three rounds in total).

What is needed to put this knowledge into practice?

The meeting ended with a brief discussion about applying the findings in everyday practice. A course called "Exercise Physiology and Physical Training in Older Adults" already exists. It was considered not necessary to develop a new course or organize a webinar, as this might be an overly passive way of sharing the results. The participants expressed that a PowerPoint presentation would be helpful to facilitate physiotherapists in educating their less experienced colleagues, their patients, and the patients' families. The 'low-hanging fruit' of the barriers and facilitators should be summarized and — if possible — adjusted for the altered population in GR since the study was conducted. Other aspects mentioned were sharing the findings with physical therapy schools and insurance companies.

Additionally, despite the fact that the studies focused on orthopedic GR, the participants stated that the outcomes are also conveniently applicable for non-orthopedic GR patients.

Finally, the development of an effective measurement instrument for endurance would be a golden opportunity in terms of helping to improve physical fitness training.

Analysis of barriers and facilitators flipcharts
Following the meeting, an analysis was conducted on the flipchart photos. The grid was divided into four quadrants for each photo, and the sticky notes were categorized based on the quadrant in which they were placed. Sticky notes that were positioned between two quadrants were labeled as being on the border of — for instance — quadrants one and two: '1/2.' Consequently, each sticky note (and therefore each barrier and facilitator) had a maximum of three scores (from the three rounds), and their overall score was descriptive; for example, '2' or '2, 2/4, and 4.' Subsequently, every barrier and facilitator was categorized based on their overall score. The low-hanging fruit —high impact and easily improvable — were the barriers and facilitators, receiving an overall score of '4.' They are presented in Appendix B.

Appendix B. Barriers and facilitators, identified of having high impact and being easy to address

	B	F
Lack of clarity about requirements to return home or to perform a home visit.	X	
Goals that account for premorbid functioning and home environment.		X
Setting meaningful goals with the patient for inpatient and home-based rehabilitation.		X
Subdivision of goals into smaller sub-goals.		X
Using measurement instruments.		X
High intensity and frequency of endurance training.		X
Home visit to formulate therapy goals.		X
Integration of training in ADLs for specific patient groups (e.g. cognitively impaired).		X
Training outside of therapy as a result of equipment on ward, such as a home trainer.		X
Proficiency in adjusting the therapy frequency and content to the individual's needs.		X
Knowledge of assessing the appropriate training level.		X
Knowledge of interpreting pain in a patient (alarming or not?).		X

Appendix B. Continued.

	B	F
Pain and doubts concerning whether pain is an alarm signal.	X	
Insecurity, e.g. due to pain, or if a skill is not sufficiently practiced.	X	
Inactivity, e.g. not asking to practice, sitting all day in one's room.	X	
Self-confidence.		X
Motivation, incentive.		X
Adequate expectations concerning length of stay/level of functioning at discharge.		X
Home trainer, leg press, hand rail in the corridors, etc. in GR ward.		X
Lacking communication with family about opportunities to participate in exercise.	X	
Incorporate practicing in ADL (e.g. putting wheelchair further away).		X
Team meetings to align approach, therapy intensity, practicing outside of therapy.		X
Communication with patient and family about the course of the rehabilitation.		X
Communication with patient and family managing expectations.		X
Interaction with other patients: seeing other patients exercising.		X
Don't know that they are allowed to help.	X	
Stimulus for patient.		X

B: Barrier; F: Facilitator;

: Program factor; *: Staff factor;* *: Patient factor;* *: Organization factor;* *: Family factor*

Summary

This thesis addresses two aims: 1) developing recommendations for the training of physical fitness (muscle strength and endurance) in orthopedic geriatric rehabilitation (GR), as studied in the Fit4Frail project, and 2) developing an evidence-based practical guideline for patient-centered goal setting.

After the introduction, the following three chapters of the study focus on the characteristics of physical fitness training that should be taken into account to improve muscle strength and endurance in patients admitted to orthopedic GR. These concerned the so-called FITT characteristics of training, namely the frequency (how often?), intensity (how hard?), time (how long?), and type (what?) of training.

Chapter 2 presents the results of a systematic review of the literature concerning these characteristics in relation to the effectiveness of endurance training in older adults with various health statuses. Given that multiple systematic reviews have been published, we performed a systematic review of systematic reviews. We included 51 papers on 49 reviews. Thirty-three reviews reported a positive effect of training on endurance capacity, 11 remained inconclusive, and 5 reported no effect. The training characteristics varied largely. The frequency of interventions ranged from one session per week to five sessions per day. The intensity ranged from light to vigorous, and the duration of the training sessions ranged from a few minutes to 120 minutes per session. The most common type of intervention was a mixed aerobics exercise program, combining different aerobic exercises or these with other forms of training, such as strength training. The methodological quality of the studies was most often low. Information on adverse events was frequently lacking, but their occurrence seemed rare. Subgroup analyses revealed positive effects for all health conditions, except for patients after hip fracture, who underwent a moderate-intensity training program of one to two sessions per week. We concluded that exercise characteristics from existing guidelines, such as the American College of Sports Medicine (ACSM) guideline, are widely applicable for improving aerobic fitness. For vulnerable older adults, lower intensities and lower frequencies also seem beneficial. Some health conditions require specific adjustments.

Chapter 3 presents the results of an online international Delphi study conducted to reach an expert consensus about exercise testing and training in frail older adults in orthopedic GR. The participants were clinicians or researchers with expertise in the field of exercise testing and training in frail older patients with an orthopedic impairment. The majority of them were physical therapists. Thirty participants completed the first round. Twenty-eight (93%) completed the second round and 25 (83%) the third. Consensus was reached on a total of 34 statements. The statements and comments reflected the need for a pragmatic and tailored approach to testing and training in this population. For example, to evaluate changes in endurance capacity, a six-minute walk test (6MWT) was recommended. For testing muscle strength, it was suggested to assess performance on a functional task, provided that the task has a significant strength component. Furthermore, a functional approach to exercise training is preferred. For endurance training, the participants agreed on training characteristics based on ACSM recommendations, which depend on the training intensity: moderate (≥5 sessions per week of 30-60 minutes at a perceived intensity of 5-6 on the Borg 0-10 scale) or vigorous (≥3

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sessions per week of 20-30 minutes at a perceived intensity of 7-8 on the Borg 0-10 scale). For resistance training, the participants only agreed on relatively low intensities, and did not reach consensus on higher intensities. Consequently they advised 2 sessions per week, performing 2 to 3 sets of at least 15 repetitions at 40 to 60% of their one-repetition maximum (1RM). Both endurance and muscle strength training can be tailored by varying the interplay between the FITT characteristics, for example, shorter and more frequent sessions. Ratings of perceived exertion were promoted to monitor the intensity of training in patients without cognitive impairment. Furthermore, they both should be continued after GR to further increase the effects or to help limit further age-related deterioration.

The Delphi study suggested several tests for measuring endurance capacity, but they have limitations. For example, factors like leg muscle strength and walking technique can influence the 6-minute walk test (6MWT) score. In **chapter 4**, we explored the feasibility of using the talk test to determine training intensity and assess the impact of aerobic fitness training. The talk test is a submaximal, incremental cycle ergometer test that estimates the power output and heart rate at the first ventilatory threshold, indicating the lower limit of moderate exercise intensity. Training at this level is considered safe and effective, although combining cycling and talking may be difficult for vulnerable older patients. We included 93 patients from two different cohorts of patients in orthopedic GR. The first cohort consisted of 48 patients from the observational study. More details about this cohort can be found in chapter 5 (C1). The second cohort concerned 45 patients (C2), specifically recruited to test the talk test's feasibility. Out of these, 79 patients started the test (34 from C1 and 45 from C2), but only 41 patients (51%) reached a valid result (14 from C1 and 27 of C2). The main reasons for the termination of the test were pain and fatigue. The low success rate is notable, considering that the selected patients were expected to be able to complete the test. Therefore, we concluded that the talk test is not a feasible alternative for testing endurance capacity in orthopedic GR.

The following two chapters examine current practices in orthopedic rehabilitation, focusing on how physical fitness training is conducted and what factors influence it. **Chapter 5** details an observational study on the content of physical fitness training for patients in orthopedic rehabilitation, as well as changes in their physical fitness and functioning. We included 48 patients and found significant variation in training characteristics among them. For instance, the average amount of endurance training per patient ranged from 3 to 100 minutes per week, and the average amount of knee extensor training varied from 1 to 273 repetitions per week.

Compared to the ACSM guidelines for older adults, adherence was somewhat better for resistance training than for endurance training, where none of the patients met the guideline recommendations. Despite the low adherence to guidelines, muscle strength improved, however, the relationship between training volume and muscle strength gain was only moderate. As expected, there was no improvement in endurance capacity, resulting in very low fitness levels at discharge. Physical functioning also improved from admission to discharge, but this improvement was unrelated to endurance or muscle strength changes, possibly due to suboptimal fitness gains.

Chapter 6 describes the findings of an interview study into the barriers and facilitators of physical fitness training in orthopedic GR. In this study, individual interviews were held with five patients, their relatives, and their responsible nurses, and two focus group interviews were held with multidisciplinary GR teams. We found 78 factors that positively or negatively influenced physical fitness training. This involved factors at the level of 1) the patient, such as restrictions on weight-bearing after surgery or their motivation for training; 2) the patient's family, like family members practicing with the patient; 3) staff members, including their ability to adapt to patient diversity or their limited time due to a heavy workload; 4) the rehabilitation program, such as the intensity and frequency of endurance training; and 5) the organization, like the availability of exercise equipment in the ward. This comprehensive overview can help multidisciplinary teams improve physical fitness training in orthopedic GR in two ways. First, they can use insights on barriers and facilitators at the program, staff, and organizational levels to improve interventions. These include setting person-centered goals, ensuring well-trained staff, evaluating training volume, and enhancing communication with patients and families about the rehabilitation process. Second, they can tailor individual training programs to each patient's needs, considering the barriers and facilitators found at the patient and family level.

Chapter 7 describes the development of an evidence-based practical guideline for patient-centered goal setting in GR using participatory action research. Participants included GR professionals (e.g., physicians, nurses, and therapists) and researchers who picked goal setting as a topic for research to help them improve their daily GR practices. The project began with a problem analysis, which revealed that the rehabilitation plans were not adequately 'owned' by the patients and their relatives, owing to a lack of tailored information, a lack of patient involvement in goal-setting decision-making, and a lack of goal follow-up throughout the rehabilitation process by the involved disciplines, patients, and informal caregivers. The study revealed that developing recommendations rather than a strict step-by-step method was more feasible for GR teams. Instead of being required to implement a complete step-by-step intervention, a team can assess how well they meet each of the recommendations, prioritize areas with the most potential for improvement and create a customized improvement plan. This approach allows teams to tailor improvements to their specific needs and practices. The resulting guideline includes eight recommendations and practical advice for three of these, focusing on conversational skills specific to goal setting. The guideline emphasizes the importance of involving patients and their families in goal-setting, ensuring that goals are meaningful and tailored to individual needs. It also stresses the need for multidisciplinary collaboration and regular evaluation of goals throughout the rehabilitation process with the team members, patients, and their families.

In the **general discussion**, we reviewed the findings of the Delphi study in the context of the results of the other Fit4Frail studies. We concluded that the Delphi study's recommendations for training both muscle strength and endurance capacity align with the results of the other studies. We concluded the same for testing muscle strength. However, we concluded that a good test for endurance capacity is lacking and should be developed. In practice, increased focus should be placed on physical fitness training. If increasing endurance or muscle strength is a rehabilitation goal, therapists should follow the recommendations for testing and training.

Out of the 78 barriers and facilitators for physical fitness training, we identified 27 as easy to address and having a high impact, the so-called 'low hanging fruit'. Addressing these factors will help GR teams improve patients' rehabilitation trajectories. Finally, we concluded that

GR teams can enhance their patient-centered goal-setting and goal-achieving process by evaluating their performance on our eight recommendations and only adjusting their method if improvement is expected.

We discussed future research directions, including the involvement of GR professionals and patients in this research. We suggest developing and testing a fitness training program for inpatient and home-based orthopedic GR. Additionally, we propose developing a test to measure endurance capacity for this group. Lastly, future research should examine how the practical guideline for patient-centered goal-setting affects patient involvement.

Samenvatting

Dit proefschrift heeft twee doelen: Ten eerste, het ontwikkelen van aanbevelingen voor de training van spierkracht en uithoudingsvermogen bij oudere mensen die revalideren na een operatie aan hun bekken of been binnen de orthopedische geriatrische revalidatie. Dit deden we binnen het Fit4Frail-project. Ten tweede, het opstellen van een praktische richtlijn voor het samen met de patiënt werken met revalidatiedoelen.

Na de inleiding gaan drie hoofdstukken over hoe je zou moeten trainen om spierkracht en uithoudingsvermogen te verbeteren bij oudere mensen die revalideren in de orthopedische geriatrische revalidatie. Dit gaat over de kenmerken van de training, dat wil zeggen hoe vaak, hoe zwaar, hoe lang en welk type training nodig is.

Hoofdstuk 2 gaat over de kenmerken en de effectiviteit van training van het uithoudingsvermogen bij ouderen met verschillende soorten aandoeningen. We bekeken daarvoor 51 artikelen over 49 literatuuronderzoeken, die eerder door andere onderzoekers waren uitgevoerd, en we maakten een totaaloverzicht. De meeste artikelen lieten zien dat training een positief effect heeft op het uithoudingsvermogen. De kenmerken van de onderzochte trainingen varieerden sterk in frequentie, intensiteit en duur. Het meest voorkomende type training was een combinatie van verschillende aerobe oefeningen, zoals lopen en fietsen, soms gecombineerd met bijvoorbeeld krachttraining. De kwaliteit van de studies was vaak laag. Informatie over bijwerkingen ontbrak vaak, maar ze leken weinig voor te komen. We concludeerden dat de richtlijn van het American College of Sports Medicine (ACSM), breed toepasbaar is voor het verbeteren van het uithoudingsvermogen, maar dat voor kwetsbare ouderen trainen op een lagere intensiteit of frequentie ook gunstig kan zijn. Voor sommige groepen ouderen worden specifieke aanpassingen aan het trainingsprogramma geadviseerd.

In **hoofdstuk 3** presenteren we de resultaten van een online internationale Delphi-studie. Deze studie was bedoeld om consensus onder deskundigen te bereiken over de beste methode voor het testen en trainen van ouderen in de orthopedische geriatrische revalidatie. De deelnemers waren expert op dit gebied, als revalidatieprofessional of als onderzoeker. De meerderheid was fysiotherapeut. Dertig deelnemers voltooiden de eerste ronde, 28 de tweede ronde en 25 de derde. Er werd consensus bereikt over in totaal 34 stellingen. Uit deze stellingen bleek dat de deelnemers de voorkeur gaven aan een pragmatische en op maat gemaakte benadering van testen en trainen in deze patiëntengroep. Ze kwamen bijvoorbeeld overeen dat een zes minuten wandeltest (6MWT) geschikt is voor het evalueren van uithoudingsvermogen, en dat prestaties tijdens een functionele activiteit geschikt zijn voor het evalueren van spierkracht. Voor de training van het uithoudingsvermogen bereikten de deelnemers overeenstemming over de trainingskenmerken op basis van de ACSM-aanbevelingen. Daarbij geldt dat een training op een matige intensiteit tenminste 5 keer per week moet plaatsvinden, gedurende 30-60 minuten. Als je zwaarder traint, dan kan het korter en minder vaak: minimaal 3 keer per week, gedurende 20-30 minuten. De intensiteit kan bepaald worden door de ervaren mate van inspanning te scoren op een 0-10 schaal. Een score van 5-6 is matig intensief, een score van 7-8 is zwaar. Voor de training van spierkracht werden de deelnemers het alleen eens over relatief lage intensiteiten en niet over trainen op hogere intensiteiten. Daarbij adviseerden ze 2 sessies per week, waarbij 2 tot 3 sets van minimaal 15 herhalingen worden uitgevoerd met 40 tot 60% van het maximale gewicht dat iemand één keer kan tillen of verplaatsen binnen een bepaalde oefening (1RM).De training van zowel uithoudingsvermogen als spierkracht kan worden aangepast door het samenspel tussen de trainingskenmerken te variëren, bijvoorbeeld frequentere sessies van kortere duur. Tenslotte moeten beide trainingen na de revalidatie worden volgehouden om de effecten verder te vergroten of om verdere leeftijdsgerelateerde achteruitgang te helpen beperken.

De tests die werden gekozen voor het meten van uithoudingsvermogen hebben beperkingen. Zo kunnen factoren zoals beenspierkracht en looptechniek de score van bijvoorbeeld de zes minuten wandeltest (6MWT) beïnvloeden. In **hoofdstuk 4** onderzochten we de haalbaarheid van het gebruik van een relatief onbekende test, de talk test, om de trainingsintensiteit te bepalen en de impact van aerobe fitheidstraining te beoordelen. We includeerden 93 patiënten uit twee verschillende cohorten: 48 patiënten uit een longitudinale studie (in detail beschreven in hoofdstuk 5), waar de talk test een van de verschillende tests was, en 45 patiënten uit een tweede cohort, die specifiek waren geselecteerd om de haalbaarheid van de talk test te onderzoeken. Van deze patiënten begonnen 79 aan de test, maar slechts 41 patiënten (52%) voltooiden de test met een geldige score (14 uit C1 en 27 van C2). De belangrijkste redenen voor het voortijdig beëindigen van de test waren pijn en vermoeidheid. Dit lage percentage voltooide tests is opvallend, omdat de patiënten door hun arts of fysiotherapeut waren geselecteerd met de verwachting dat ze de test zouden kunnen voltooien. Daarom concludeerden we dat de talk test geen bruikbaar alternatief is voor het testen van uithoudingsvermogen in orthopedische geriatrische revalidatie.

De volgende twee hoofdstukken onderzoeken de huidige praktijk van orthopedische geriatrische revalidatie, met de nadruk op hoe fysieke fitheidstraining wordt uitgevoerd en welke factoren hierop van invloed zijn.

In **hoofdstuk 5** beschrijven we een observationele studie over de inhoud van fysieke fitheidstraining voor patiënten in orthopedische geriatrische revalidatie, evenals veranderingen in hun fysieke fitheid en functioneren. We includeerden 48 patiënten en vonden hierbij een aanzienlijke variatie in trainingskenmerken. Zo varieerde de gemiddelde trainingsduur van het uithoudingsvermogen van 3 tot 100 minuten per week, en de gemiddelde hoeveelheid krachttraining van de bovenbeenspieren varieerde van 1 tot 273 herhalingen per week.

De training van spierkracht voldeed iets beter aan de ACSM-aanbevelingen dan de training van uithoudingsvermogen. Bij de training van uithoudingsvermogen voldeed geen enkele patiënt aan de aanbevelingen voor frequentie, intensiteit, duur of type training. Bij de training van spierkracht waren er enkele patiënten die, voor een deel van de trainingskenmerken, wel aan de aanbevelingen voldeden, bijvoorbeeld het aantal herhalingen of sets van de oefeningen. Desondanks verbeterde de spierkracht, maar de relatie tussen trainingsvolume en spierkrachttoename was slechts matig. Zoals verwacht was er geen verbetering in uithoudingsvermogen, wat resulteerde in zeer lage fitheidsniveaus bij het ontslag van de patiënten naar huis. Hun fysieke functioneren verbeterde van opname tot ontslag, maar deze verbetering was niet gerelateerd aan veranderingen in uithoudingsvermogen of spierkracht, mogelijk omdat deze veranderingen te klein waren om impact te hebben.

In **hoofdstuk 6** beschrijven we de bevindingen van een interviewstudie naar factoren die fysieke fitheidstraining positief of negatief beïnvloeden. We hielden individuele interviews met vijf patiënten, hun familieleden en hun eerst verantwoordelijke verzorgenden of verpleegkundigen. Daarnaast hielden we twee focusgroepinterviews met multidisciplinaire revalidatieteams. We vonden 78 factoren op het niveau van 1) de patiënt, zoals het nog niet volledig mogen belasten na een operatie of niet gemotiveerd zijn om te trainen; 2) de familie van de patiënt, zoals familieleden die met de patiënt oefenen; 3) stafleden, bijvoorbeeld hun vermogen om zich aan te passen aan de diversiteit van patiënten of juist hun beperkte tijd bij een hoge werkdruk; 4) het revalidatieprogramma, zoals de intensiteit en frequentie van training van het uithoudingsvermogen; en 5) de organisatie, zoals communicatie tussen professionals en de beschikbaarheid van oefenapparatuur op de afdeling. Dit overzicht kan multidisciplinaire teams helpen om de training van fysieke fitheid te verbeteren. Ten eerste kunnen ze hun eigen interventies verbeteren door gebruik te maken van de inzichten op het niveau van het programma, de staf en de organisatie. Dit kan bijvoorbeeld door het stellen van persoonsgerichte doelen, het zorgen voor goed opgeleid personeel, het evalueren van het trainingsvolume en het verbeteren van de communicatie met patiënten en familie over het revalidatieproces. Ten tweede kunnen ze individuele trainingsprogramma's aanpassen aan de behoeften van elke patiënt, rekening houdend met de factoren die we vonden op het niveau van de patiënt en de familie.

In **hoofdstuk 7** beschrijven we de ontwikkeling van een evidence-based praktische richtlijn voor het patiëntgericht werken met revalidatiedoelen in de geriatrische revalidatie. We deden dit in een participatief actie-onderzoek, waaraan zowel professionals (zoals artsen, verpleegkundigen en therapeuten) deelnamen als onderzoekers. We startten met een probleemanalyse. Hieruit bleek dat de revalidatieplannen en -doelen niet voldoende 'eigendom' waren van de patiënten en hun familieleden. Dit kwam door een gebrek aan op maat gemaakte informatie en een gebrek aan patiëntbetrokkenheid bij de besluitvorming over doelstellingen. Daarnaast ontbrak het aan opvolging van doelen gedurende het revalidatieproces door de betrokken professionals, patiënten en hun naasten. Uit het onderzoek bleek dat het ontwikkelen van aanbevelingen beter past bij de geriatrische revalidatie dan een strikte stapsgewijze methode. In plaats van het verplicht invoeren van een complete interventie, kan een team onderzoeken hoe goed ze voldoen aan elk van de aanbevelingen, en vervolgens een verbeterplan op te stellen voor onderdelen waar in hun team de meeste verbetering te verwachten is. De resulterende praktische richtlijn bevat acht aanbevelingen. Drie aanbevelingen zijn verder uitgewerkt in praktische adviezen, met de nadruk op gespreksvaardigheden specifiek voor het voeren van een doelengesprek. De richtlijn benadrukt het belang van het betrekken van patiënten en hun families bij het stellen van revalidatiedoelen en het belang dat deze doelen betekenisvol zijn en afgestemd op individuele behoeften. Het benadrukt ook de noodzaak van multidisciplinaire samenwerking en regelmatige evaluatie van doelen gedurende het revalidatieproces met de teamleden, patiënten en hun families.

In de **algemene discussie** reflecteren we op de onderzoeksresultaten en doen we suggesties voor toekomstig onderzoek. We bespreken de uitkomsten van de Delphi-studie in het licht van de resultaten van de andere Fit4Frail-studies. We concluderen dat de aanbevelingen van de Delphi-studie voor *training* in lijn zijn met de resultaten van de andere studies. We concluderen hetzelfde voor het *testen* van spierkracht. Maar een goede test voor uithoudingsvermogen ontbreekt en moet ontwikkeld worden. In de praktijk moet er meer aandacht zijn voor het training van fysieke fitheid. Als het verhogen van uithoudingsvermogen of spierkracht een revalidatiedoel is, dan moeten therapeuten de aanbevelingen voor testen en trainen volgen.

Daarnaast identificeren we 27 factoren die impactvol zijn en gemakkelijk te beïnvloeden: het ‘laaghangend fruit’, waarmee revalidatieteams de trajecten van hun patiënten kunnen verbeteren. Tot slot concluderen we dat revalidatieteams het werken met revalidatiedoelen kunnen verbeteren door hun prestaties op onze acht aanbevelingen te evalueren en hun methode daar aan te passen waar verbetering wordt verwacht.

Toekomstig onderzoek zou zich moeten richten op het ontwikkelen en evalueren van een trainingsprogramma voor fysieke fitheid voor intramurale en ambulante orthopedische GR. Daarnaast stellen we voor om een test te ontwikkelen voor het meten van het uithoudingsvermogen, die bruikbaar is bij deze doelgroep. Tot slot zou toekomstig onderzoek moeten evalueren hoe de praktische richtlijn voor patiëntgericht werken met doelen de betrokkenheid van patiënten beïnvloedt. Bij al dit onderzoek moeten GR-professionals en patiënten worden betrokken.

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Een promotietraject doe je nooit alleen. Hoewel mijn naam uiteindelijk op de voorkant van dit proefschrift staat, zijn er verschillende mensen, zowel uit mijn professionele als privé-omgeving, zonder wie dit hele proefschrift niet mogelijk was geweest. Ik ben ontzettend dankbaar voor hun begeleiding, steun en vriendschap. Het is niet mogelijk om iedereen persoonlijk te noemen, maar een aantal mensen wil ik in het bijzonder bedanken.

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Aafke de Groot, niet als lid van de projectgroep maar wel heel nauw betrokken bij dit project. Beste Aafke, als een van de grondleggers van de geriatrische revalidatie in Nederland ken jij alle ins en outs ervan. Samen met Karin sta jij aan de basis van het Fit4Frail-project. Omdat jullie samen dachten dat we misschien wel te voorzichtig waren met het trainen binnen de geriatrische revalidatie, introduceerde je Karin op onze afdeling, en jullie beschreven de eerste contouren van het project. Daarnaast was je ook vanaf het begin betrokken bij de goal-setting studie. We vullen elkaar heel goed aan: waar ik soms wel erg recht op mijn doel afga, ben jij meer beschouwend. Je doet graag af en toe een stapje achteruit om te bekijken of we wel het goede doen. Ik heb je leren kennen als een heel deskundige en bescheiden collega, waar ik veel van kan leren. En daarnaast waardeer ik je bereidheid om altijd mee te denken of bij te dragen en niet te vergeten je onderkoelde humor, die voor mij soms heel onverwacht opkomt. Ik hoop dat je ook snel zover bent dat je je proefschrift mag verdedigen!

Dit onderzoek was nooit gelukt zonder de inzet en het uithoudingsvermogen van de deelnemers aan het Fit4Frail-onderzoek: behandelaren, verpleegkundigen, verzorgenden en revalidanten van Amaris, Amstelring, AxionContinu, Cordaan, Noorderbreedte, Omring, Vivium Zorggroep, Zonnehuisgroep Amstelland, Zonnehuisgroep IJssel-Vecht, Zorggroep Almere, Zorggroep Apeldoorn en Zorggroep Solis. Mijn dank is ook groot voor de grote hoeveelheid werk die binnen het Fit4Frailonderzoek is verzet door Dennis Visser. Hij speelde een belangrijke rol in de review, de observationele studie en de interviewstudie. Dennis werd daarin bijgestaan door onderzoekers Ewout Smit en Annelie Monnier, en door onderzoeksassistenten Ellen Koeman, Myrenka Bik en Lisanne van Zijl. Tenslotte hebben de deelnemers aan de Fit4Frail-expertsessie geholpen om de resultaten van het onderzoek te toetsen aan hun praktijkervaring, waardoor we onze conclusies nog beter konden formuleren.

De goal-setting studie was een project van de themagroep ‘goede zorg voor revalidanten’ van UNO Amsterdam. Dit project was nooit succesvol geweest zonder de inzet van de leden van deze themagroep, en hun collega’s, die de aanbevelingen uittestten in de praktijk. In het bijzonder wil ik hier de volgende mensen bedanken voor de samenwerking: Sacha Deetman, Robin Bonthuis, Marina Tol, Robbert Gobbens en Niels Jongejan.

De leden van de leescommissie, prof. dr. W.P. (Wilco) Achterberg, prof. dr. R. (Rienk) Dekker, prof. dr M. (Majon) Muller, prof. dr. M (Mirjam) Pijnappels, dr. M.C. (Margriet) Pol, prof. dr. N. (Nathalie) van der Velde en prof. dr. B. (Bart) Visser, dank ik voor de tijd die zij hebben gestoken in de kritische beoordeling van mijn proefschrift.

Mijn paranimfen Ruth Veenhuizen en Laura van Buul. Jarenlang vormden wij een stevig team en daarom vind ik het geweldig dat jullie naast mij willen staan op deze spannende dag. Ruth, je bent mijn maatje bij het UNO sinds 2011, en wat ben je een fantastische collega! Je bent altijd positief en je denkt erover na hoe jij zelf nieuwe kennis kunt toepassen of uitproberen in de praktijk. Veel mensen binnen én buiten de zorg zouden daar een voorbeeld aan moeten nemen. Daarnaast stimuleer je de mensen om je heen om zichzelf verder te ontwikkelen, en heb je oog voor kansen die ze zelf nog niet hebben gezien. Je weet dan woorden te vinden die mensen sterken, of die tenminste een nieuwe blik geven op hun situatie. Ik heb daar bewondering voor. Voor professioneel en privé-advies kan ik altijd bij je terecht, en, heel belangrijk, we kunnen ontzettend lachen samen. Ik hoop dat jij ook blijft groeien, zodat je je 'hobby' die Huntington heet de aandacht kunt geven die het verdient.

Laura, begin 2015 kwam je ons team versterken en dat heeft ons veel gebracht. Naast dat je een leuke en proactieve collega bent, heb jij een enorme kracht om zaken voor elkaar te krijgen. Je kunt ontzettend goed plannen maken, activiteiten plannen en heel efficiënt werken. En daarnaast ben je heel goed in het vertalen van wetenschappelijke kennis naar de praktijk. Daar hebben we veel aan gehad in je rol als coördinator bij het UNO en dat helpt je ook bij de ontwikkeling van je eigen onderzoekslijn. Het is jouw missie om antibiotica resistentie een halt toe te roepen, en de preventie, diagnostiek en behandeling van infectieziekten bij ouderen te verbeteren. En met dat in je achterhoofd heb je een onderzoeksagenda opgesteld, én uitgevoerd. Daar kan ik alleen maar met bewondering naar kijken. Ik ben benieuwd wat jij de wereld verder nog gaat brengen.

Collega's van de afdeling Ouderengeneeskunde, ik kan niet iedereen noemen maar door jullie ga ik elke dag met plezier naar mijn werk. Ik noem hier de collega's van mijn eigen team: Gaby, Maike, Josien, Paulien, Patricia, Tineke, Chadia en Joy, het is een plezier om met jullie te kunnen werken aan de verbinding tussen wetenschap en praktijk. Postdocs en senior onderzoekers, voor zover nog niet eerder genoemd: Anouk, Daisy, Eefje, Fenne, Jeanine, Karlijn, Marike en Marjon, samen met de junior onderzoekers en promovendi werken we elke dag aan de ontwikkeling van nieuwe kennis over de zorg voor ouderen met een kwetsbare gezondheid. Collega MT-leden, Ariadne, Bianca, Maaike en Martin, fijn dat we zo'n goed team vormen. En niet te vergeten Bernadette en Esther, die als management assistent de afdeling draaiend hielden en houden.

En dan wil ik natuurlijk mijn lieve familie en vrienden bedanken. Bedankt voor het meeleven de afgelopen jaren, maar vooral ook voor alle gezellige momenten, vakanties, feestjes, etentjes en andere activiteiten, die laten zien dat werk misschien wel belangrijk is, maar dat fijne mensen om je heen het leven echt de moeite waard maken.

Lieve mama, jij en papa gaven me een veilige basis. Samen zorgden jullie ervoor dat ik zorgeloos kon opgroeien in een liefdevolle omgeving, en jullie stimuleerden me om me daarna te blijven ontwikkelen. Jullie zijn een voorbeeld voor een leven met aandacht voor de mensen om je heen, en voor de mensen buiten de eigen kring, die hulp of ondersteuning nodig hebben. Mama, ik hoop dat je erbij kunt zijn en kunt genieten van deze bijzondere dag. Papa zou het ook prachtig gevonden hebben, en in onze gedachten is hij er natuurlijk ook gewoon bij.

Lieve Koen, Meike en Bas, ik geniet ervan jullie te zien opgroeien tot volwassen mensen met een eigen leven. Door nieuwe kennis en ervaringen op te doen vinden jullie je eigen pad in het leven. Soms is het nu stil in huis, maar het is geweldig om jullie te zien uitvliegen. Jullie geven plezier in mijn leven en vertrouwen in een mooie toekomst.

En als laatste mijn geliefde, Jan-Paul. Lieve Jan-Paul, zonder jouw steun was ik niet aan dit promotietraject begonnen. Je nuchtere “Als je dit wilt, dan moet je het gaan doen. Ik denk dat het bij je past,” hielp me over de twijfel heen en ik heb er geen spijt van. Geduldig volgde je mijn vorderingen, en intussen zette je zelf ook allerlei nieuwe stappen in je loopbaan. We zijn een goed team en ik hou van je!

Curriculum Vitae

Lizette Wattel werd geboren op 7 februari 1969 in Voorburg en groeide op in Emmeloord. Na het behalen van haar vwo-diploma aan de Christelijke Scholen Gemeenschap begon ze in 1987 aan een studie Farmacie aan de Rijksuniversiteit Groningen. In 1989 stapte ze over naar de opleiding Fysiotherapie aan de Rijkhogeschool Groningen, waar ze haar diploma behaalde.

In 1994 ging Lizette als fysiotherapeut aan de slag bij Verpleeghuis Naarderheem in Naarden, tegenwoordig onderdeel van Vivium Zorggroep. Ze werkte daar op afdelingen voor psychogeriatrie, somatiek en revalidatie. Van 1997 tot 2005 combineerde ze deze functie met een deeltijdstudie Bewegingswetenschappen aan de Vrije Universiteit Amsterdam.

In 2006 werd het Universitair Netwerk Ouderenzorg (UNO-VUmc) opgericht, een samenwerking tussen het VU medisch centrum en veertien verpleeghuizen. Lizette werd aangesteld als coördinator van het netwerk en kwam in dienst van VUmc. Van 2012 tot 2015 volgde ze daarnaast een masteropleiding epidemiologie bij EpidM.

In 2016 startten het goal-setting project en het Fit4Frail-project welke samen leidden tot haar promotie bij de Vrije Universiteit. Lizette is momenteel manager van het UNO, nu bekend als UNO Amsterdam, en onderzoeker bij de afdeling Ouderengeneeskunde van Amsterdam UMC.

Lizette woont in Hilversum met haar partner Jan-Paul Bakker. Ze hebben samen drie kinderen, Koen, Meike en Bas.

Author contributions

Chapter 1
General Introduction

Concept and design	Elizabeth M Wattel
Data collection	Not applicable
Statistical analysis	Not applicable
Interpretation of data	Not applicable
Drafting the manuscript	Elizabeth M Wattel
Critical revision of the manuscript	Johannes C van der Wouden, Karin HL Gerrits, Wim G Groen, Franka JM Meiland, Cees MPM Hertogh

Chapter 2
Effectiveness and characteristics of physical fitness training on aerobic fitness in vulnerable older adults: an umbrella review of systematic reviews.

Concept and design	Dennis Visser, Johannes C van der Wouden, Karin HL Gerrits, Elizabeth M Wattel, Franka JM Meiland, Aafke J de Groot, Cees MPM Hertogh, Ewout B Smit.
Data collection	Dennis Visser, Karin HL Gerrits, Elizabeth M Wattel, Elize P Jansma, Ewout B Smit.
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Critical revision of the manuscript	Johannes C van der Wouden, Karin HL Gerrits, Franka JM Meiland, Aafke J de Groot, Elize P Jansma, Cees MPM Hertogh, Ewout B Smit.

Chapter 3
Exercise testing and training in frail older adults with an orthopedic impairment participating in a geriatric rehabilitation program: an international Delphi study.

Concept and design	Wim G Groen, Elizabeth M Wattel, Karin HL Gerrits, Johannes C. van der Wouden, Franka JM Meiland, Aafke J de Groot, Cees MPM Hertogh
Data collection	Wim G Groen, Elizabeth M Wattel, Karin HL Gerrits
Statistical analysis	Not applicable
Interpretation of data	Wim G Groen, Elizabeth M Wattel, Karin HL Gerrits
Drafting the manuscript	Wim G Groen
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Chapter 4

Aerobic exercise in frail patients admitted to orthopedic geriatric rehabilitation: a pilot study on the feasibility of the talk test to prescribe adequate exercise intensity.

Concept and design	Karin HL Gerrits, Elizabeth M Wattel, Cees MPM Hertogh.
Data collection	Non-authors
Statistical analysis	Karin HL Gerrits
Interpretation of data	Karin HL Gerrits, Elizabeth M Wattel, Wim G Groen, Cees MPM Hertogh
Drafting the manuscript	Karin HL Gerrits
Critical revision of the manuscript	Karin HL Gerrits, Elizabeth M Wattel, Wim G Groen, Cees MPM Hertogh

Chapter 5

The content of physical fitness training and the changes in physical fitness and functioning in orthopedic geriatric rehabilitation: an explorative observational study.

Concept and design	Elizabeth M Wattel, Karin HL Gerrits, Dennis Visser, Johannes C. van der Wouden, Franka JM Meiland, Cees MPM Hertogh.
Data collection	Dennis Visser
Statistical analysis	Elizabeth M Wattel
Interpretation of data	Elizabeth M Wattel, Wim G Groen, Karin HL Gerrits, Johannes C. van der Wouden, Franka JM Meiland, Cees MPM Hertogh.
Drafting the manuscript	Elizabeth M Wattel
Critical revision of the manuscript	Wim G Groen, Karin HL Gerrits, Dennis Visser, Johannes C. van der Wouden, Franka JM Meiland, Cees MPM Hertogh.

Chapter 6

Wattel EM, Meiland FJM, van der Wouden JC, de Groot AJ, Hertogh CMPM, Gerrits KHL. Barriers and facilitators for physical fitness training in orthopedic geriatric rehabilitation. A qualitative study.

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Drafting the manuscript	Elizabeth M Wattel
Critical revision of the manuscript	Franka JM Meiland, Johannes C van der Wouden, Aafke J de Groot, Cees MPM Hertogh, Karin HL Gerrits

Chapter 7
Development of a practical guideline for person centred goal setting in geriatric rehabilitation: a participatory action research.

Concept and design	Elizabeth M Wattel, Aafke J de Groot, Sacha Deetman-van der Breggen, Robin Bonthuis, Niels Jongejan, Marina MR Schilder, Robbert Gobbens.
Data collection	Sacha Deetman-van der Breggen, Robin Bonthuis, Niels Jongejan, Marina MR Schilder, Robbert Gobbens.
Statistical analysis	Not applicable
Interpretation of data	Elizabeth M Wattel, Aafke J de Groot, Sacha Deetman-van der Breggen, Robin Bonthuis, Niels Jongejan, Marina MR Schilder, Robbert Gobbens.
Drafting the manuscript	Elizabeth M Wattel
Critical revision of the manuscript	Aafke J de Groot, Sacha Deetman-van der Breggen, Robin Bonthuis, Niels Jongejan, Marina MR Schilder, Robbert Gobbens.

Chapter 8
General Discussion

Concept and design	Elizabeth M Wattel
Data collection	Not applicable
Statistical analysis	Not applicable
Interpretation of data	Not applicable
Drafting the manuscript	Elizabeth M Wattel
Critical revision of the manuscript	Johannes C van der Wouden, Karin HL Gerrits, Wim G Groen, Franka JM Meiland, Cees MPM Hertogh

Portfolio & Publications

Portfolio

NAME	DATE ACHIEVED	EC
EXTERNAL COURSES		
GNK - APH -elective mandatory- Courses on advanced methodological research skills	15-12-2014	15.00
GNK - APH -mandatory- BROK	27-05-2016	1.50
Brok herregistratie1	20-12-2019	0.50
BROK Herregistratie 2	23-11-2023	0.50
GNK - AMS -mandatory- Course focused on scientific integrity	28-10-2024	2.00
RESEARCH RELATED		
Nursing home research conference	11-11-2016	2.00
Nursing home research conference	14-09-2018	1.00
Jaarcongres Studio GRZ	25-01-2019	1.00
AMDA conference	11-03-2021	2.00
SANO Wetenschapsdag	11-03-2021	1.00
EuGMS	20-09-2024	2.00
SANO Wetenschapsdag	31-10-2024	1.00
Research department meetings etc	31-12-2024	6.00
OTHER ACADEMIC ACTIVITIES		
UNO Symposium	05-06-2016	1.00
Expert meeting Fit4Frail	26-02-2024	1.00
Consortium GRZ (member)	31-12-2024	3.00
Valorisation - Theme group UNO Amsterdam	31-12-2024	1.00
TEACHING/STUDENT SUPERVISION		
Supervision of MSc Students	31-12-2019	6.00
Teaching Kaderopleiding GRZ	25-11-2021	1.50
Course Topics in Rehabilitation	26-09-2022	1.00
Total number of ECTS credits	-	**50.00**

Publications

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In this thesis

Visser D*, **Wattel EM***, Gerrits KHL, van der Wouden JC, Meiland FJM, de Groot AJ, Jansma EP, Hertogh CMPM, Smit EB. Effectiveness and characteristics of physical fitness training on aerobic fitness in vulnerable older adults: an umbrella review of systematic reviews. BMJ Open. 2022 May 31;12(5):e058056.
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Submitted

Wattel EM, Groen WG, Visser D, van der Wouden JC, Meiland FJM, Hertogh CMPM, Gerrits KHL. The content of physical fitness training and the changes in physical fitness and functioning in orthopedic geriatric rehabilitation: an explorative observational study. Disabil Rehabil. 2025 May 19:1-8.

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Dit proefschrift gaat over het verbeteren van de geriatrische revalidatie. Het onderzoek richtte zich op twee thema's: het trainen van kracht en uithoudingsvermogen na een operatie aan het bekken of been, en het stellen van revalidatiedoelen. Dit proefschrift biedt zowel wetenschappelijke inzichten als praktische handvatten voor het verbeteren van geriatrische revalidatie.

Voor fysieke fitheidstraining werden aanbevelingen opgesteld op basis van literatuuronderzoek en praktijkervaring. De aanbevelingen benadrukken het belang van op maat gemaakte programma's. Voor uithoudingsvermogen wordt een matige intensiteit (5x per week, 30-60 minuten) of een hogere intensiteit (3x per week, 20-30 minuten) aanbevolen. Voor krachttraining zijn twee sessies per week met 2-3 sets van 15 herhalingen (40-60% 1RM) effectief. De aanbevelingen bieden concrete handvatten voor het opstellen van haalbare trainingsprogramma's, zelfs bij kwetsbare ouderen. Het onderzoek toont echter aan dat de huidige praktijk vaak niet voldoet aan deze richtlijnen, wat resulteert in lage fitheidsniveaus bij ontslag.

Naast het onderzoek naar fysieke training ontwikkelden we een praktische richtlijn voor het stellen van revalidatiedoelen. Deze richtlijn bevat acht aanbevelingen, waaronder het stellen van betekenisvolle, haalbare doelen en het regelmatig evalueren van deze doelen. De praktische richtlijn ondersteunt een multidisciplinaire aanpak en helpt zorgprofessionals om patiëntgerichte zorg te bieden.

Toekomstig onderzoek richt zich op het ontwikkelen van een geschikte test voor uithoudingsvermogen en het evalueren van de aanbevelingen uit dit proefschrift in de praktijk. Dit proefschrift biedt een waardevolle basis voor het verbeteren van zowel de wetenschap als de praktijk van geriatrische revalidatie.