Sarcopenia in Older Adults

Towards better assessment, lifestyle interventions, and interprofessional care

Sabien H van Exter

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Chapter 1

General introduction

The impact of aging on health

The global population is aging both in absolute numbers and as a proportion of the total population. The percentage of people aged 65 and older is expected to increase from 10% in 2022 to 16% by 2050 [1]. This demographic transition is also seen in the Netherlands, where the ratio of people aged 65 and over to people of working age has grown from 22% in 2003 to 34% in 2023 [2]. The shift puts increasing pressure on healthcare systems, requiring adaptations to meet the evolving needs of an aging population [3].

Among the challenges faced by aging populations is the progressive loss of muscle strength and mass. As people age, this decline often occurs due to multiple factors that disturb the balance between muscle protein synthesis and breakdown [4-6]. While the rate of muscle loss in older adults depends on both genetic and environmental factors, the aging process itself compounds these effects [7].

Muscle protein synthesis is stimulated by adequate nutrition and exercise [8, 9]. Nutrition provides proteins that contain (essential) amino acids, the most crucial building blocks for skeletal muscle. However, older adults frequently struggle to consume sufficient protein due to reduced appetite, known as anorexia of aging [10, 11]. This issue is particularly pronounced among hospitalized older adults, who often experience more severe nutritional challenges compared to their counterparts in care homes or private residences. These challenges include nutritional impact symptoms like pain, nausea, and a loss of taste and smell [12, 13]. Community-dwelling older adults may also face practical barriers such as difficulties with grocery shopping and meal preparation, hindering adequate protein intake [14]. This may also lead to malnutrition, a state that arises from a lack of nutritional intake of uptake [15].

While adequate nutrition is crucial for maintaining muscle mass, physical activity is equally important in stimulating muscle protein synthesis and preventing muscle loss [16]. Exercise, particularly resistance training, enhances muscle strength and function by promoting muscle protein synthesis [17]. Guidelines recommend that adults and older adults engage in at least 150 minutes of moderately intensive weekly exercise. Additionally, they emphasize the importance of muscle and bone-strengthening activities for all adults and highlight the need for balance exercises specifically for older adults [18]. In the Netherlands, just 39.8% of adults aged 65 or older meet the weekly exercise guidelines [19]. The average level of exercise and physical activity declines with age and is associated with the progression of physical limitations and the loss of muscle strength and muscle mass [16, 20].

Additionally, aging reduces the muscle's responsiveness to anabolic stimuli like exercise and nutrition, a phenomenon known as anabolic resistance [21, 22]. Low protein intake and physical inactivity increase the risk of sarcopenia, a progressive skeletal muscle disease that involves a decrease in muscle strength and muscle mass and which prevalence increases with age [23, 24]. Malnutrition is a condition that shares numerous risk factors with sarcopenia and is itself a risk factor for the condition [25, 26].

Aging is one of the processes that causes an increase in muscle protein breakdown, disrupting muscle homeostasis. Aging leads to a change in muscle composition [27-29], decrease of neuromuscular motor units [30], decrease of satellite cells [31], and accompanied reduced regenerative capacity of the muscle [32, 33]. At the intracellular level, there is a shift toward increased proteolysis, impaired mitochondrial function, and heightened susceptibility to oxidative stress [30, 34]. On a systemic level, aging is associated with chronic inflammation [35] and reduced levels of anabolic hormones [36]. The full molecular mechanism is not yet clear, but it is hypothesized that a combination of these components and lack of physical activity and malnutrition leads to the development of sarcopenia [4, 6].

Impact of sarcopenia

Sarcopenia has a profound impact on older adults, increasing the risk of falls and fractures, among others [37]. This risk stems from the impaired balance brought on by the loss of muscle strength [38] and high prevalence of osteoporosis in this population [39]. The susceptibility of fractures with falls can lead to hospitalization, which is associated with sarcopenia [40]. The ensuing inactivity during hospitalization exacerbates muscle loss, perpetuating a vicious cycle of increased fall risk and hospital readmissions [41]. This inactivity is further increased by fatigue associated with sarcopenia and aging in general [42, 43]. (Figure 1) The progressive functional decline is linked to higher all-cause mortality rates in individuals with sarcopenia compared to those without the condition [44]. Furthermore, sarcopenia leads to a loss of physical independence, making tasks such as walking, cycling, cooking, and grocery shopping increasingly challenging [45, 46]. As living independently becomes more challenging, these individuals may require external support or move to a nursing home. The large impact sarcopenia can have on an individual and population level stresses the need for effective interventions.

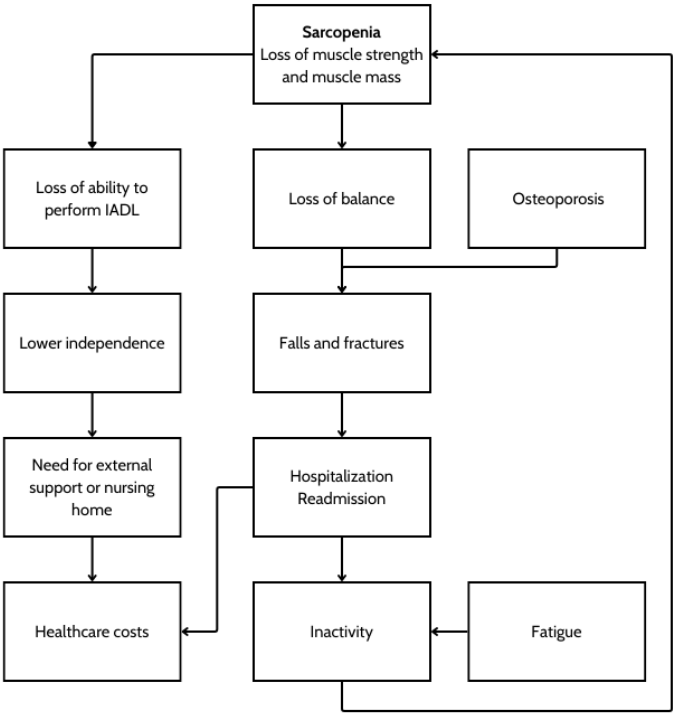

Figure 1 The impact of sarcopenia on hospitalization and the need for healthcare support

Diagnosis, assessment, and evaluation of sarcopenia

Sarcopenia has been recognized as a disease with an International Classification of Diseases-10 code since 2016 [47], and was further defined in Europe by the updated European Working Group on Sarcopenia in Older People (EWGSOP2) in 2019 [26]. This updated framework introduced a structured diagnostic approach, employing the Find-Assess-Confirm-Severity (FACS) model to guide clinicians and researchers (Figure 2). The FACS approach begins with a risk assessment screening using a brief questionnaire (SARC-F). This is followed by evaluations of muscle strength, muscle quantity or quality, and physical performance to establish a probable or final diagnosis and assess the severity of sarcopenia. However, international discrepancies remain, as Asian and American working groups use distinct criteria with different outcome measures and cut-off points [48, 49]. Currently, efforts are being made to establish a globally accepted definition of sarcopenia to enhance its recognition in research settings and clinical practice by the Global Leadership Initiative in Sarcopenia (GLIS).

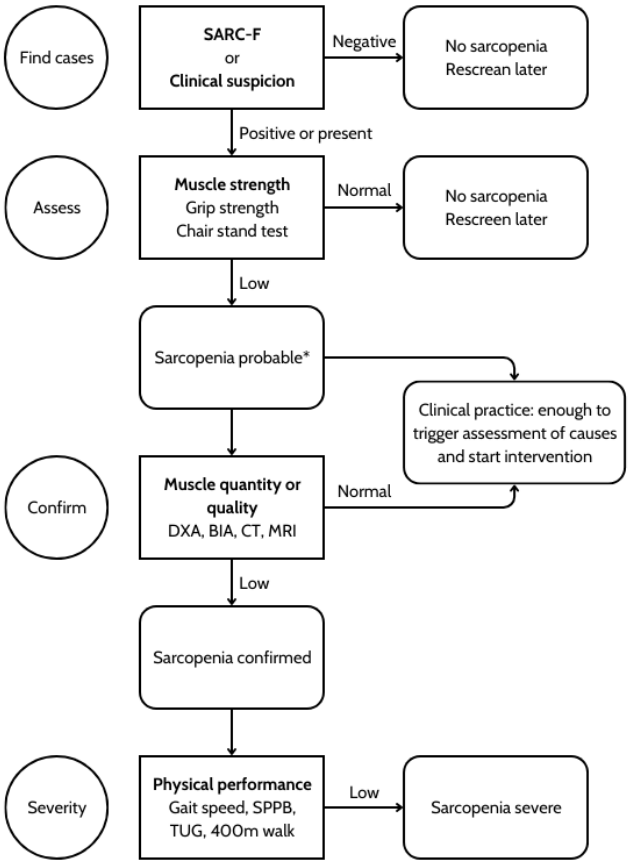

Figure 2 European Working Group on Sarcopenia in Older People (EWGSOP2) algorithm for case-finding, making a diagnosis and quantifying severity of sarcopenia in practice. Steps of the pathway are represented as Find-Assess-Confirm-Severity or FACS. *Consider other reasons for low muscle strength (e.g. depression, stroke, balance disorders, peripheral vascular disorders). Adapted from Cruz-Jentoft et al. (2019)

The current GLIS conceptual definition of sarcopenia includes three key components: muscle strength, muscle mass, and muscle-specific strength, defined as muscle strength relative to muscle mass. Declines in these components result in diminished physical performance, a hallmark feature of sarcopenia [50]. Monitoring these components and outcomes is crucial for those at risk to effectively prevent, reserve, and intervene sarcopenia progression. Older people should therefore not only be measured once for diagnosis but be routinely evaluated to stay ahead of development or progression of sarcopenia. GLIS working groups are currently investigating the standardization of assessments for muscle strength, muscle mass, muscle-specific

strength, and physical performance. This thesis presents a systematic review of the psychometric properties of outcome measures used to assess physical performance in community-dwelling older adults (**Chapter 2**). Additionally, the diagnostic accuracy of the SARC-F questionnaire used to assess the risk for sarcopenia has been studied in hospitalized adults aged 50 or above (**Chapter 3**).

Interventions for sarcopenia

The multifactorial nature of sarcopenia necessitates a comprehensive approach to its management. Currently, no medications have been approved for sarcopenia, and relying solely on pharmaceutical interventions seems counterintuitive given the complex physiological pathways involved [17, 51, 52]. However, the use of exercise and proper nutrition has emerged as an effective strategy, particularly for community-dwelling older adults [53].

Exercise is a cornerstone of sarcopenia management. Regular physical activity stimulates muscle protein synthesis, prevents frailty, and improves physical performance in older adults with sarcopenia [54, 55]. Exercise regimens should address the underlying mechanisms, clinical manifestations, and functional outcomes associated with sarcopenia. New guidelines recommend a combination of progressive resistance-based exercise and aerobic physical activity to maintain and build muscle mass and strength while improving physical performance and mitigate the decline in physical capacity associated with aging [17]. Evidence from recent studies underscores the benefits of resistance training in enhancing both muscle strength and muscle mass [56]. Furthermore, aerobic exercise can ameliorate the mitochondrial disfunction that drives sarcopenia development and progression [57]. Personalization of exercise regimens seems critical to ensure safety and efficacy, considering factors such as age, illness, and physical limitations.

While exercise plays a crucial role, nutrition is equally important for preventing and treating sarcopenia. Adequate protein intake is a prerequisite for muscle protein synthesis [58]. Inadequate protein intake is associated with sarcopenia in older adults [24]. International guidelines recommend a daily protein intake of 1.2-1.5 grams per kilogram of body weight for individuals with sarcopenia [59-62]. High-protein diets enriched with leucine—a critical amino acid for muscle protein synthesis—have been shown to enhance muscle strength in older adults with sarcopenia [63, 64]. Along with the protein intake, adequate energy intake is crucial because dietary protein will be used for energy production when energy is

lacking [65, 66]. However, participant adherence to these interventions, particularly nutritional regimens, is a critical determinant of success. This thesis evaluated the adherence to and efficacy of a nutritional intervention as part of a multimodal prehabilitation trial (**Chapter 4**).

The synergistic effects of combined exercise and nutrition interventions offer a particularly promising approach [53]. This type of combined intervention has been researched in community-dwelling older adults to improve muscle strength, muscle mass, and physical performance [58, 67-69].

Hospitalized older adults

Hospitalization of older adults can lead to hospital-associated sarcopenia, driven by inactivity, malnutrition, and illness, and is commonly seen in both acute and long-term care settings [70]. When execution is possible, the vicious cycle of hospitalization, loss of muscle strength and mass, subsequent falls, and rehospitalization may be broken by integrating personalized nutrition and exercise strategies during and after hospital stays. Accordingly, this thesis investigated the feasibility of such combined interventions for hospitalized patients at risk for sarcopenia (**Chapter 5**).

A preventative approach aims to maintain or improve physical performance before sarcopenia develops. This proactive strategy, informed by the lessons learned from the feasibility study, is applied to the protocol of a follow-up randomized controlled trial entitled FITFOOD. In this study, a combined exercise and nutrition intervention is provided to a population of older hospitalized patients who are not specifically at risk for sarcopenia, and its effects are compared to usual care (**Chapter 6**).

Interprofessional collaboration

The effective prevention and management of sarcopenia and malnutrition require interventions that often span multiple modalities and therefore multiple healthcare professionals [58, 69, 71]. Many older adults already receive care from multiple healthcare providers for various comorbidities. Professionals from diverse disciplines must work together to implement this combined strategy, each contributing their unique specialties and expertise in a process of interprofessional collaboration. This collaboration may be more challenging for older adults living in

the community than in hospital settings, where teams of healthcare professionals routinely work in close coordination.

In interprofessional collaboration, health or social care professionals share accountability and goals to provide services to patients or clients [72, 73]. Interprofessional collaboration between professionals may be the best way to achieve optimal care outcomes [74]. Despite supporting evidence, the current implementation of interprofessional collaboration remains limited [75]. The perspectives of professionals and older adults at risk for sarcopenia and malnutrition on interprofessional collaboration have been evaluated and integrated into conceptual modal in this thesis (**Chapter 7 & Chapter 8**).

Aims

The population of older adults at risk for sarcopenia and malnutrition is growing. There is a need for more research on the measurement tools and interventions required to assess and address these conditions effectively. While interprofessional collaboration has shown promise in delivering high-quality care, there is limited understanding of how healthcare professionals and older adults envision such collaborative treatment.

This thesis aims to improve the care of older adults, particularly those at risk for sarcopenia and malnutrition, by evaluating the psychometric properties of tests and tools, examining the feasibility, effectiveness, and optimization of combined exercise and nutrition interventions, and exploring the perspectives of healthcare professionals and older adults on interprofessional collaboration in treatment.

The specific objectives of this thesis are:

- To assess and evaluate the psychometric properties of tests and tools used for people with sarcopenia. [Diagnosis, assessment, and evaluation]
- To evaluate the feasibility, effectiveness, and (re)design of a research protocol of exercise and nutrition interventions. [Interventions]
- To explore the perspectives of healthcare professionals and older adults at risk for sarcopenia and malnutrition on interprofessional collaboration. [Interprofessional collaboration]

Outline

In accordance with the aims of this thesis, it has been divided into three parts.

Part I: Diagnosis, assessment, and evaluation

In **Chapter 2**, we systematically review the literature on the psychometric properties of physical performance tests for sarcopenia severity in community-dwelling older adults. We provide an overview of the reliability, validity, and responsiveness of these tests. **Chapter 3** presents the results of a cross-sectional study amongst hospitalized adults investigating the diagnostic accuracy of SARC-F to screen for sarcopenia in this population. Together, these studies will enhance our knowledge of the tests that are recommended to use in populations possibly at risk for sarcopenia in two different settings.

Part II: Interventions

Chapter 4 analyzes the nutritional part of a multimodal prehabilitation intervention trial in colorectal and esophageal cancer patients. This study examines adherence to the high protein diet and the effectiveness of protein supplementation on protein intake. **Chapter 5** outlines the lessons learned in a feasibility trial for hospitalized patients at risk for sarcopenia. The trial randomizes patients into a combined exercise and nutrition intervention or usual care for 12 weeks. **Chapter 6** shows the adaptations that are made for the still ongoing FITFOOD trial through a protocol for a combined personalized exercise and nutritional intervention in hospitalized older patients from the hospital to home setting.

Part III: Interprofessional collaboration

Chapter 7 presents the results of a qualitative study where focus groups are held to gain the perspective of primary and social care professionals on the interprofessional management of (risk of) malnutrition and sarcopenia. Since older adults with (risk of) malnutrition and sarcopenia should be at the center of care, **Chapter 8** shows the qualitative research done through interviews and focus groups with older adults with (risk of) malnutrition and/or sarcopenia. This study identifies their wishes and needs they have for interprofessional treatment for these conditions. Both chapters in this part include conceptual models that provide an overview of the findings and illustrate their interconnectedness within these qualitative studies.

Table 1 Titles and methodology of studies addressed in this thesis.

Chapter	Title	Study design
2	A systematic review of the psychometric properties of physical performance tests for sarcopenia in community-dwelling older adults	Systematic review
3	The accuracy of screening for sarcopenia in the clinical setting	Cross-sectional study
4	Adherence to and Efficacy of the Nutritional Intervention in Multimodal Prehabilitation in Colorectal and Esophageal Cancer Patients	Secondary data analysis of an intervention trial
5	Lessons learned from a combined, personalized lifestyle intervention in hospitalized patients at risk for sarcopenia: a feasibility study	Feasibility study
6	Combined exercise program and high-protein nutritional intervention for hospitalized older patients: a protocol for a randomized controlled trial	Protocol of a randomized controlled trial
7	Interprofessional management of (risk of) malnutrition and sarcopenia: a grounded theory study from the perspective of professionals	Qualitative study using focus groups
8	Understanding the needs and wishes of older adults in interprofessional treatment for malnutrition and sarcopenia: a grounded theory study	Qualitative study using interviews and focus groups

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Part I

Diagnosis, assessment, and evaluation

Chapter 2

A systematic review of the psychometric properties of physical performance tests for sarcopenia in community-dwelling older adults

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Abstract

Background

This review provides an overview of the psychometric properties of the short physical performance battery (SPPB), timed up and go test (TUG), 4m gait speed test (4m GST), and the 400m walk test (400m WT) in community-dwelling older adults.

Methods

A systematic search was conducted in MEDLINE, CINAHL, and EMBASE, resulting in the inclusion of fifty studies with data from in total 19,266 participants (mean age 63.2 - 84.3). Data were extracted and properties were given a sufficient or insufficient overall rating following the COSMIN guideline for systematic reviews of patient-reported outcome measures. Quality of evidence (QoE) was rated using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach.

Results

The SPPB was evaluated in 12 studies, TUG in 30, 4m GST in 12, and 400m WT in 2. Reliability of the SPPB, TUG, and 4m GST was rated sufficient (moderate to good QoE). Measurement error of the SPPB was rated insufficient (low QoE). Criterion validity for the SPPB was insufficient in indicating sarcopenia (moderate QoE), while the TUG was sufficient and insufficient for determining mobility limitations (low QoE) and activities of daily living disability (low QoE), respectively. Construct validity of the SPPB, TUG, 4m GST and 400m WT was rated insufficient in many constructs (moderate to high QoE). Responsiveness was rated as insufficient for SPPB (high QoE) and TUG (very low QoE), while 4m GST was rated as sufficient (high QoE).

Conclusion

Overall, the psychometric quality of commonly used physical performance tests in community-dwelling older adults was generally rated insufficient, except for reliability. These tests are widely used in daily practice and recommended in guidelines; however, users should be cautious when drawing conclusions such as sarcopenia severity and change in physical performance due to limited psychometric quality of the recommended measurement instruments. There is a need for a disease-specific physical performance test for people with sarcopenia.

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This research received no specific grant from any funding agency and was registered a priori using the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42022359725).

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Introduction

Aging is an inevitable process that affects every human being and is associated with a decline in physical performance. Physical performance encompasses whole-body functioning related to muscle strength, balance, flexibility, endurance, and mobility [1]. Poor physical performance in older people results in the loss of cognitive function, increased fall risk, decreased quality of life, worse clinical outcomes, and a loss of independence in older people's ability to perform activities of daily living (ADL) [2-4]. Additionally, reduced physical performance indicates the progression and severity of sarcopenia, an age-related skeletal muscle disorder involving the accelerated loss of muscle mass and function [5]. Sarcopenia is related to frailty especially in terms of low grip strength and low physical performance [6].

As the number of older adults increases and healthcare resources become stretched, it is more crucial than ever for older adults to maintain their independence and promote living at home. This is essential not just for the adults themselves but for society as a whole since the larger group of community-dwelling older people with limited physical abilities often require a significant amount of care to live at home or may need admission to care facilities, leading to increased pressure on care and care costs [7]. Physical performance monitoring seems important to identify adults at risk and evaluate outcomes of treatment, making it vital to have reliable, valid, and responsive methods for assessing physical performance [1].

Healthcare professionals and researchers should select physical performance measurement outcomes based on their psychometric properties, which include reliability, validity, and responsiveness [8]. Moreover, a healthcare professional may determine physical performance to identify adults at risk that could benefit from interventions to improve their physical performance and overall quality of life. Therefore, a reliable and valid performance test is needed to do this correctly. Researchers may use physical performance outcomes as a part of a clinical trial aimed at improving physical performance and should therefore use a test with high responsiveness to capture change. Additionally, capturing change may also be the goal of healthcare providers to evaluate treatment outcomes by monitoring physical performance. This monitoring of community-dwelling older people several times over extended periods allows healthcare professionals to identify the need for intervention or assess the effects of an intervention over time. More assessment and, thus, earlier intervention could prevent further decline in physical performance and associated adverse health effects [4].

For individuals with sarcopenia, the assessment of physical performance is crucial. It serves as a key parameter indicating the severity of sarcopenia and can be used to initiate and evaluate interventions. There is an abundance of performance tests available to measure physical performance; however, there is no overview of their psychometric qualities. This systematic review provides this overview and focuses on physical performance measurement outcomes as outlined in the European guideline for sarcopenia definition and diagnosis (EWGSOP2) [1, 9]. The physical performance tests reviewed within this paper are the short physical performance battery (SPPB), timed up and go test (TUG), and two types of walking tests: the 4m gait speed test (4m GST) and the 400m walk test (400m WT) [9].

Given the growing number of community-dwelling older people who aim to live at home for as long as possible, it is crucial to evaluate the psychometric properties of physical performance tests. This review provides an in-depth overview of the psychometric properties of tests used to assess physical performance in the community-dwelling older population.

Methods

Protocol and registration

This review was conducted and reported following an adaptation of the COnsensus-based Standards for the selection of health Measurement Instruments (COSMIN) guideline for systematic reviews of patient-reported outcome measures [10]. Adaptations to the original COSMIN guideline have been made for the analysis of performance-based outcome measurement instruments instead of PROMs [11]. This protocol has been registered a priori with PROSPERO (CRD42022359725) and was reported according to an in-development reporting guideline for systematic reviews of outcome measurement instruments by Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and COSMIN [12].

Search strategy

The search strategy has been developed in collaboration with an experienced librarian. Search terms included categories for older people, sarcopenia, community-dwelling, short physical performance battery, timed up and go, gait speed test, walking test and psychometric properties. Search terms used were equal across databases (MEDLINE, CINAHL and EMBASE) although translated into the specific database vocabulary. The full search strategy can be seen in the Supporting

information. Searches were performed from database inception until 20 September 2022. Results were exported to EndNote for duplicate removal.

Screening

Deduplicated results were transferred to the systematic review manager Rayyan for the first screening based on title and abstract. A second screening was performed based on full text. Two reviewers independently carried out both the first and second screenings, and any disagreements were discussed and resolved after both rounds of screening.

Eligibility criteria

Studies reporting on individuals 60 years of age or older who live in the community (not hospitalized or institutionalized) were eligible for inclusion. The selected physical performance tests for this review are commonly used by physical therapists and have previously been selected by EWGSOP2 to determine sarcopenia severity. The EWGSOP2 working group selected these tests based on the feasibility for healthcare providers to use in daily practice and can be performed within many settings as they require no to a very minimal amount of equipment [13]. Therefore included studies were observational studies and report on the psychometric properties (reliability, validity or responsiveness) of the TUG [14, 15], SPPB [16, 17], 4m GST or 400m WT. A description of these tests can be found in the Supporting information. Excluded from this review were studies focusing on specific patient groups other than sarcopenia, such as patients with dementia or hip-fracture. Additionally, papers reporting on reviews or intervention studies, and those written in a language other than English or Dutch were excluded.

Methodological Quality

The COSMIN Risk of Bias tool [18] was used to critically appraise studies reporting on reliability and measurement error. The COSMIN Risk of Bias checklist [19] was used to critically appraise studies reporting on validity and responsiveness. This appraisal was completed by two independent reviewers, a consensus meeting was held to resolve conflicts.

Data extraction

Data extraction was carried out systematically by two independent reviewers. Both reviewers extracted data from all included papers using a data extraction form. The individually extracted data was checked during a consensus meeting. The following data was collected from all included articles: study reference, participant characteristics, outcome measures studied, and type of psychometric properties tested.

Participant characteristics including sex, age and BMI were recorded. Additional to physical performance data, data on co-morbidities was recorded when available. Finally, data on all psychometric properties measured for a physical performance test were recorded for analysis.

Evaluation of psychometric evidence

The psychometric properties evaluated were reliability, validity, and responsiveness. Reliability refers to the degree to which a measurement is free from measurement error. This review contains inter-rater, intra-rater, and test-retest reliability measures. Additionally, data on measurement errors are recorded. Validity is the degree to which an outcome measure measures the construct it purports to measure. Validity measures within this review contain construct validity and criterion validity. Responsiveness is the ability of an outcome measure to detect change over time in the construct to be measured [20].

An overall rating was given to the physical performance measure based on the criteria for good measurement properties [21]. The overall rating was scored sufficient (+) when the criteria were met, insufficient (-) when they were not met, or indeterminate (?) when not enough data were available. Further information on the rating system can be found in the Supporting information.

Possible heterogeneity among study results was explored using subgroup analysis. A modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used to evaluate the quality of evidence available for each outcome measure (high, moderate, low, very low evidence) [10]. Two independent reviewers performed this; a consensus meeting was held to resolve conflicts.

A summary of findings table was prepared to tabulate the results of each psychometric property by measurement outcome and, if relevant, grouped construct.

Results

A total of 5,323 records were retrieved from three databases: CINAHL (1,583), EMBASE (1,880) and MEDLINE (1,860). Following title and abstract screening, 98 full-text studies were retrieved and screened against the eligibility criteria. Next, 48 articles were excluded for reasons as mentioned in Figure 1.

Study characteristics

The 50 included studies were performed in 19 countries (Table 1). All studies were observational. Sample size ranged from 10 to 7,104 participants and a total of 19,266 participants are presented in this review.

The SPPB was researched in 12 studies [22-35], TUG in 30 studies [22, 23, 30, 36-65], 4m GST in 12 studies [24, 25, 32, 34, 37, 44, 53, 66-70], and the 400m WT in 2 studies [70, 71]. Inter-rater reliability was analyzed in 4 studies [39, 50, 55, 62], intra-rater reliability in 2 studies [39, 62], and test-retest reliability in 9 studies [26, 30, 37, 45, 61, 63, 66, 67, 70]. Measurement error was researched in 6 studies [30, 37, 45, 50, 63, 67], criterion validity in 3 studies [28, 49, 52] and construct validity in 38 studies [22-25, 27, 29-31, 33-36, 38-48, 51-54, 56-60, 65-71]. Lastly, responsiveness was measured in 2 studies [32, 52].

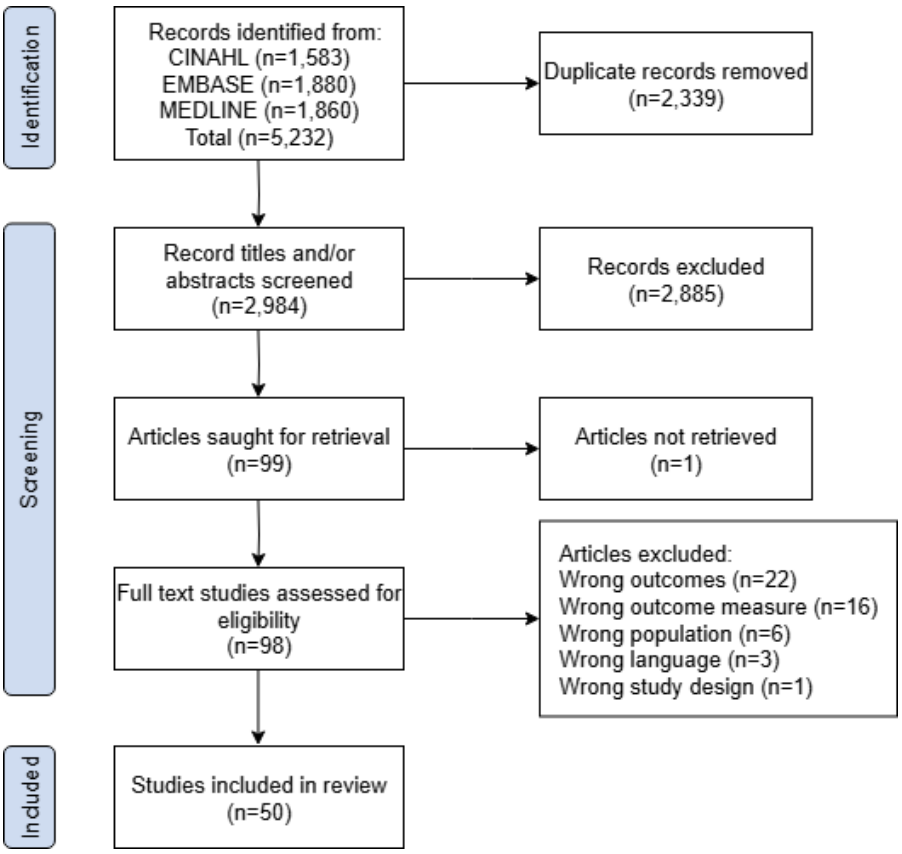

Figure 1 Flow chart of study selection and inclusion

Participant characteristics

The mean age of participants ranged from 63.2 to 84.3. Mean BMI was reported in 17 studies and ranged 22.1-29.6. Most studies were performed in both sexes, with two studies reporting only female participants [36, 40]. Co-morbidities were reported in various studies and include diabetes [22, 37, 64], gastrointestinal disease [50], heart conditions [22, 64], hypertension [22, 37], mental illness [37], musculoskeletal disease [24, 37], neurologic conditions [37, 41], orthopedic conditions [41], pulmonary disease [50], respiratory disease [37], vision disease [37, 64].

Only 2 out of 50 included studies described sarcopenia incidence in their population. Lee et al. included between 66 (21.8%) and 71 (23.4%) patients with sarcopenia in a total of 303 participants, depending on the definition used [28]. Out of a total of 140 participants, Looijaard et al. described between 5 (3.6%) and 33 (23.6%) to be sarcopenic [53].

Summary of findings

Physical performance average test scores

Mean SPPB score was reported in 16 studies and ranged from 7.88; 11.49. Mean TUG time was reported in 34 studies and ranged from 5.80; 24.10 seconds. Mean 4m GST was reported in 10 studies and ranged from 0.72; 1.57 m/s. Median time to complete the 400m WT was reported in one study and ranged from 5.09; 5.36 minutes. Full results of the physical performance test scores can be found in the Supporting information.

Reliability

Inter, intra and test-retest reliability was measured using ICC. Inter-rater reliability of the TUG ranged from 0.81; 0.98, intra-rater reliability of the TUG ranged from 0.96; 0.99 and test-retest reliability of the SPPB, TUG and 4m GST ranged from 0.64; 0.97. The quality of evidence was deemed to be between moderate and high (Table 2).

Measurement error was estimated in the SPPB, TUG and 4m GST using SEM and ranged from 0.05; 0.97 (Table 2). Quality of evidence for these analyses was between very low and high. The very low quality of evidence was due to serious risk of bias and very serious imprecision in SPPB studies.

Validity

Criterion validity was reported for the SPPB, and TUG using area AUC and ranged from 0.54; 0.80 (Table 2). The quality of evidence was low to moderate, studies researching TUG showed very serious risk of bias.

Construct validity was reported in the SPPB, TUG, 4m GST and 400m WT using several methods including SRCC, RCC, ICC, linear regression, odds ratio (OR), mean difference and limits of agreement (LoA). Comparator instruments used to assess construct validity were grouped with similar instruments to make the synthesis of results possible and explore possible heterogeneous results. For example, a group of short walking tests contains, amongst others, 3, 4, and 6m walking tests. All groups, as well as the ungrouped results, can be found in the Supporting information. Correlation coefficient results ranged from -0.910; 0.93 (Table 3). The quality of evidence ranged between moderate and high.

Responsiveness

Responsiveness was reported in the SPPB, TUG and 4m GST by AUC or SEM, small meaningful change and substantial meaningful change. The outcomes ranged from 0.05; 1.42 (Table 4). The quality of evidence for these findings was between very low and high with serious indirectness, and extremely serious risk of bias in the assessment of the TUG.

The risk of bias assessment and full GRADE scorings can be found in the Supporting information.

Discussion

This systematic review provides an overview of the psychometric properties of the SPPB, TUG, 4m GST and 400m WT in community-dwelling older adults. Reliability of the SPPB, TUG, and 4m GST was rated sufficient (moderate to good quality of evidence). The measurement error of the SPPB was rated insufficient (low quality of evidence) and indeterminate of the TUG and 4m GST (respectively high and moderate quality of evidence). Criterion validity of the SPBB was rated insufficient for diagnosing sarcopenia (moderate quality of evidence). The psychometric quality of the TUG was rated sufficient for determining mobility limitations (low quality of evidence), though insufficient for ADL disability (low quality of evidence). The construct validity of the SPPB, TUG, 4m GST and 400m WT was rated mainly insufficient (moderate to high quality of evidence). Responsiveness of the SPPB and TUG was rated insufficient (respectively high quality and very low quality of evidence, and 4m GST sufficient (high quality of evidence).

A previous review showed good to excellent test-retest reliability of the SPPB (0.82-0.92) in older adults in multiple settings [72]. Yet another review showed

excellent test-retest (0.96-0.97), inter-rater (0.99), and intra-rater (0.94-0.99) reliability of the TUG in typical adults [73]. Our current review also rated sufficient reliability for these psychometric properties, although we focused on community-dwelling older adults. The review of Freiburger et al. [74] also examined validity and responsiveness of the SPPB in community dwelling older adults and rated the psychometric quality as "very good" and "good". However, the authors used different quality criteria for overall rating of the psychometric quality. A different review assessing the validity and reliability of performance tests used in community-dwelling older people examined physical performance tests and other measures used in sarcopenia screening [75]. In the current review, the evidence of SPPB on construct validity with related comparators was mainly rated insufficient as the hypotheses were not confirmed. These outcomes conflict with the findings of a previous systematic review that showed sufficient construct validity of the SPPB based on PCC results for 400m WT and mobility disability [75]. No additional measurement for mobility disability was performed in the study referenced; however, 400m WT results were interpreted as mobility indicator [76]. The discrepancy in the overall sufficiency rating can be explained by a difference in hypotheses used to test construct validity. In the current study, the construct validity of the SPPB compared to short walking tests, like the 400m WT, using PCC is tested on the hypothesis of $0.4 \leq PCC \leq 0.7$ for related constructs. The result in this review shows PCC=0.776 and does not align with the hypothesis. This result, however, does align with the hypothesis in the previous review of $PCC \geq 0.50$ [75].

It should be acknowledged that the SPPB contains a short walking test, which influences the construct validity when using short walking tests as a comparator. The lack of a gold standard to measure physical performance makes it hard to test criterion validity, as this is part of the definition of criterion validity [20]. However, the TUG seems valid to determine mobility limitations with a low quality of evidence. Other reviews do not report on the criterion validity of physical performance outcome measures. To be able to indicate sarcopenia severity, a test needs sufficient criterion validity or construct validity. The validity varies by the definition of sarcopenia used. For the validity of the SPPB, the study by Lee et al. used the Asian Working Group for Sarcopenia 2019 definition [28]. Looijaard et al. split their results for the validity of the TUG according to five different definitions of sarcopenia according to Baumgartner, EWGSOP, Foundation for the National Institutes of Health, International Working Group on Sarcopenia, and Janssen [53]. Responsiveness was rated insufficient in the SPPB (high quality of evidence). This conclusion is in line with a previous review [72].

This systematic review has several strengths. The systematic search strategy was developed with information specialists, ensuring a thorough search of the available literature. The search resulted in the inclusion of fifty studies that offer a comprehensive and broad overview of the psychometric properties that have been examined. Additionally, this systematic review was established using a state-of-the-art methodology, which allows for an unbiased overall rating and grading of evidence [10]. The thorough methodological approach ensures the objective evaluation of psychometric properties with minimized bias. The grading of evidence using the GRADE approach provides a structured and transparent overview of the quality of evidence. Lastly, a significant strength lies in the alignment of the scope of this review with existing guidelines [13]. By critically examining and appraising the outcome measures recommended in the current guidelines, this review can offer insights for later revisions. One important insight is that the physical performance measures recommended have yet to be exhaustively approved on reliability, validity, and responsiveness. Therefore, caution must be taken with the interpretation of test results. There are also some limitations to this systematic review. There is a large difference in the quantity of available evidence about psychometric properties of different performance tests. This overview shows no measurement error of the TUG and 4m GST due to missing data on their M(C)IC. No criterion validity could be reported for the 4m GST. No reliability, measurement error, criterion validity, or responsiveness of 400m WT has been reported in community-dwelling older adults. Furthermore, due to the considerable heterogeneity between studies in design, data analysis, and reporting, it was not possible to perform a meta-analysis, and results had to be narratively summarized. [13]

Although the measurement outcomes discussed are suggested to assess sarcopenia severity as stated by EWGSOP2 [13], this systematic review could only include two studies that showed data on patients diagnosed with sarcopenia [28, 53]. A maximum of 22.8% [28] and 23.6% [53] of participants had sarcopenia, according to different sarcopenia definitions which influences prevalence, highlighting the paucity of research on the psychometric properties of physical performance tests in this population. This review, therefore, indicates the need for more studies reporting on the psychometric properties of physical performance outcome measures in the sarcopenic population because it is unclear whether results on community-dwelling older adults can be generalized to the sarcopenic population. Such studies are necessary to verify the tests' reliability, validity, and responsiveness in patients with sarcopenia.

Reliable and valid measurement performance tests are required to indicate patients (at risk) for limited physical performance or for evaluating interventions. This

review shows the SPPB, TUG, and 4m GST are reliable instruments. The SPPB has insufficient reliability according to measurement error and has insufficient criterion validity to indicate sarcopenia. The criterion validity of TUG was sufficient and insufficient in determining mobility limitations and ADL disability, respectively. Construct validity was often rated insufficient for every measurement outcome. The 4m GST has sufficient responsiveness to analyze changes in physical performance in community-dwelling older adults. The quality of evidence varied from very low to high and was mostly moderate. The psychometric quality of commonly used physical performance tests in community-dwelling older adults seems generally insufficient, except for reliability. The SPPB, TUG, 4m GST, and 400m WT are widely used in daily practice and recommended in clinical guidelines; however, users should be cautious when drawing conclusions such as sarcopenia severity and change in physical performance due to limited psychometric quality of the recommended measurement instruments. There is a need for a disease-specific physical performance test for people with sarcopenia.

Table 1 Study characteristics and demographics. NR: Not reported, SD: Standard deviation, USA: United States of America.

Reference	Participants	Age: mean (SD)	BMI: mean (SD)	Outcome measures	Psychometric properties tested	Country
Alcock [1]	n=39, sex 39f, 0m	71.5 (7.3)	NR	TUG	Construct validity	United Kingdom
Balachandran [2]	validity n=51, sex 32f, 19m reliability n=36, sex 19f, 17m	Validity: 71.3 (5.7) Reliability: 70.4 (5.4)	Validity: 26.6 (5.4) Reliability: 27.4 (5.4)	SPPB TUG	Construct validity	USA
Balasubramanian [3]	n=40, sex 26f, 14m	73.3 (6.9)	NR	SPPB TUG	Construct validity	USA
Bean [4]	n=138, sex 95f, 43m	75.4 (6.9)	27.5 (NR)	SPPB 4m GST	Construct validity	USA
Beauchamp [5]	n=147, sex 71f, 76m	69 (10)	28.6 (5.3)	TUG 4m GST	Test-retest reliability Measurement error	Canada
Cho [6]	n=167, sex NR	78 (7)	NR	TUG	Construct validity	USA
Creel [7]	n=30, sex 17f, 13m	77.5 (7)	NR	TUG	Construct validity Inter-rater reliability Intra-rater reliability	USA
de Vreede [8]	Validation n=24, sex 24f, 0m	Validation 74.6 (4.8)	NR	TUG	Construct validity	Netherlands
Di Fabio [9]	n=35, sex 31f, 4m	79.9 (8.5)	NR	TUG	Construct validity	USA
Fernández-Huerta [10]	n=136, sex 103f, 33m	72.8 (5.9)	NR	4m GST	Construct validity Test-retest reliability	Chile
Fusco [11]	n=73, sex 38f, 35m	77.6 (8.3)	NR	SPPB 4m GST	Construct validity	Italy
Gamerman [12]	n=78, sex 65f, 13m	76.6 (6.5)	NR	TUG	Construct validity	Israel
Goldberg [13]	intermediate gait n=15, sex 11f, 4m fast gait n=15, sex 13f, 2m	Intermediate: 74.2 (6.1) Fast: 72.1 (6)	Intermediate: 29.6 (8.6) Fast: 26.2 (4.6)	4m GST	Test-retest reliability Measurement error Construct validity	USA
Goldberg [14]	n=35, sex 28f, 7m	72.8 (1)	28.8 (1.1)	TUG	Construct validity	USA

Table 1 Continued

Reference	Participants	Age: mean (SD)	BMI: mean (SD)	Outcome measures	Psychometric properties tested	Country
Gómez [15]	n=150, sex 77f, 73m	69.5 (3.1)	NR	SPPB	Test-retest reliability	Colombia
Gordt [16]	n=51, sex 39f, 12m	69.9 (7.1)	NR	TUG 4m GST	Construct validity	Germany
Gray [17]	n=57, sex 41f, 16m	f 78.2 (6.4) m 78.2 (7.3)	NR	SPPB	Construct validity	USA
Griswold [18]	n=40, fender 22f, 18m	68.7 (8.6)	NR	TUG	Test-retest reliability Measurement error Construct validity	USA
Hachiya [19]	n=31, sex 19f, 12m	75.7 (6)	NR	TUG	Construct validity	Japan
Härdi [20]	n=109, sex 91f, 18m	74.1 (6.4)	26.3 (4.7)	TUG	Construct validity	Switzerland
Hashidate [21]	n=20, sex 12f, 8m	76.6 (5.1)	22.1 (3.2)	TUG	Construct validity	Japan
Kim [22]	n=433, sex NR	73.2 (5.7)	NR	TUG	Criterion validity Construct validity	South Korea
Kristensen [23]	outpatient n=11, sex 7f, 4m	Outpatient: 79.2 (6.8)	NR	TUG	Inter-rater reliability Measurement error	Denmark
Kwan [24]	n=280, sex 120f, 160m	74.9 (6.4)	NR	TUG	Construct validity	Taiwan
Lee [25]	total n=538, sex 311f, 227m 60+ n=299, sex 168f, 131m	Total: 59 (19) 61-65: 63 (1); 66-70: 68 (1); 71-75: 73 (2); 76-80: 78 (1); 80+: 84 (2)	Total: 25.2 (4.9) 61-65: 24.0 (2.9); 66-70: 24.0 (3.4); 71-75: 24.2 (3.2); 76-80: 23.7 (3.0); 80+: 23.5 (4.1)	SPPB	Criterion validity	Singapore
Lin [26]	n=1200, sex 491f, 709m	73.4 (NR)	NR	TUG	Criterion validity Construct validity Responsiveness	Taiwan

Table 1 Continued

Reference	Participants	Age: mean (SD)	BMI: mean (SD)	Outcome measures	Psychometric properties tested	Country
Looijaard [27]	n=140, sex 81f, 59m	80.9 (7.1)	NR	TUG 4m GST	Construct validity	Netherlands
Löppönen [28]	n=479, sex 287f, 192m	NR: 75-85	NR	SPPB	Construct validity	Finland
Maggio [29]	n=172, sex 103f, 69m	f 78.2 (5.6) m 79.0 (4.9)	f 26.6 (3.2) m 26.2 (3.8)	4m GST	Construct validity	Italy
Mathis [30]	n=31, sex 20f, 11m	81.1 (8.3)	NR	SPPB TUG	Construct validity Test-retest reliability Measurement error	USA
Minematsu [31]	n=599, sex 340f, 249m	f 73.0 (5.2) m 73.7 (5.3)	NR	TUG	Construct validity	Japan
Nepal [32]	n=100, sex 54f, 46m	69.1 (8.0)	NR	TUG	Inter-rater reliability	Nepal
Ni [33]	n=50, sex 26f, 24m	77.2 (6.1)	NR	SPPB	Construct validity	United Kingdom
O'Hoski [34]	n=79, sex NR	68.7 (10.6)	25.5 (4)	TUG	Construct validity	Canada
Olivares [35]	n=7,104, sex 6243f, 861m	NR: 50+	NR	TUG	Construct validity	Turkey
Özden [36]	n=65, sex 34f, 21m	68.9 (3.7)	28.1 (4.2)	TUG	Construct validity	Turkey
Pasma [37]	n=288, sex 187f, 101m	82.2 (7.1)	25.9 (4.5)	4m GST	Construct validity	Netherlands
Perera [38]	PEP study n=492, sex 213f, 279m	PEP: 74.1 (5.7)	NR	SPPB 4m GST	Responsiveness	USA
Portegijs [28, 39]	total n=848, sex 526f, 322m light PA n=306, sex 218f, 88m moderate PA n=253, sex 156f, 107m regular PA n=289, sex 152f, 137m	total: NR light: 82.5 (7.2) moderate: 80.0 (7.7) regular: 78.7 (5.9)	NR	SPPB	Construct validity	Finland
Riwniak [40]	n=89, sex 57f, 32m	74.9 (6.7)	27.4 (5)	SPPB 4m GST	Construct validity	USA

Table 1 Continued

Reference	Participants	Age: mean (SD)	BMI: mean (SD)	Outcome measures	Psychometric properties tested	Country
Rolland [41]	total n=60, sex 53f, 7m able to perform both 400m n=41, sex 36f, 5m	total: 84.3 (6.3) able to perform both 400m: 63.2 (6.4)	NR	4m GST 400m WT	Construct validity Test-retest reliability	USA
Schaubert [42]	n=10, sex 2f, 8m	74.5 (5.8)	NR	TUG	Construct validity	USA
Schepens [43]	n=35, sex 28f, 7m	72.9 (1.1)	28.8 (1.1)	TUG	Construct validity	USA
Simonsick [44]	n=3,075, sex NR	NR	NR	400m WT	Construct validity	USA
Stanziano [45]	n=145, sex 72f, 70m	79.6 (7.2)	NR	SPPB	Construct validity	USA
Steffen [46]	n=96, sex 59f, 37m	f: 73 (8) m: 73 (8)	f: 29 (6) m: 28 (5)	TUG	Test-retest reliability	USA
Suwannarat [47]	n=309, sex 193f, 116m	Walking device users: 76.6 (5.7) Non-device users: 73 (5.4)	Walking device users: 23.3 (4.1) Non-device users: 22.8 (3.7)	TUG	Inter-rater reliability Intra-rater reliability	Thailand
Suzuki [48]	n=718, sex 521f, 197m	f: 71.2 (4.5) m: 73.4 (5.3)	f: 22.1 (3.1) m: 22.8 (2.5)	TUG	Test-retest reliability Measurement error	Japan
Wang [49]	n=268, sex 119f, 149m	73.8 (5.2)	NR	TUG	Construct validity	Taiwan
Wrisley [50]	n=35, sex 18f, 17m	72.9 (7.8)	NR	TUG	Construct validity	USA

Table 2 Summary of findings: Reliability, Measurement error, and Criterion validity. The overall rating is scored sufficient (+), insufficient (-) or indeterminate (?) when not enough data is available, according to the criteria for good measurement properties [51]. A modified Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach was used to evaluate the quality of evidence [52]. AUC: Area under the curve, ICC: Intra-class correlation coefficient, SEM: Standard error of the mean, MDC: Minimal detectable change, N/A: Not applicable. [1]Compared to 10m walking test. [2]Compared to 7min walking test.

	Summarized result: range	Number of participants (number of studies)	Overall rating	Quality of evidence
Reliability				
SPPB	Test-retest reliability (ICC): 0.87;0.93 [15, 30]	181 (2)	+	⊕⊕⊕○ Moderate
TUG	Inter-rater reliability (ICC): 0.81;0.98 [7, 23, 32, 47]	450 (4)	+	⊕⊕⊕⊕ High
	Intra-rater reliability (ICC): 0.96;0.99 [7, 47]	339 (2)	+	
	Test-retest reliability (ICC): 0.80;0.97 [5, 18, 30, 46, 48]	1032 (5)	+	
4m GST	Test-retest reliability (ICC): 0.64;0.97 [5, 10, 13, 41]	373 (4)	+	⊕⊕⊕○ Moderate
400m WT	N/A	N/A	N/A	N/A
Measurement error				
SPPB	SEM: 0.60 [30] MDC_{95}: 1.9 [30]	31 (1) 31 (1)	-	⊕○○○ Very low
TUG	SEM: 0.32;0.97 [5, 18, 23, 30, 48] MDC_{90}: 2.26 [5] MDC_{95}: 1.6;1.8 [23, 30]	947 (5) 31 (1) 42 (2)	?	⊕⊕⊕⊕ High
4m GST	SEM: 0.05;0.10 [5, 13] MDC_{90}: 0.23 [5] MDC_{95}: 0.108;0.144 [13]	177 (2) 31 (1) 30 (1)	?	⊕⊕⊕○ Moderate
400m WT	N/A	N/A	N/A	N/A
Criterion validity				
SPPB	Sarcopenia diagnosis (AUC): 0.54;0.65 [25]	538 (1)	-	⊕⊕⊕○ Moderate
TUG	Mobility limitations (AUC): 0.72;0.80 [22] ADL disability (AUC): 0.648 [26]	433 (1) 1200 (1)	+ -	⊕⊕○○ Low
4m GST	N/A	N/A	N/A	N/A
400m WT	N/A	N/A	N/A	N/A

Table 3 Summary of findings: Construct validity. The overall rating is scored sufficient (+), insufficient (-) or indeterminate (?) when not enough data is available, according to the criteria for good measurement properties [51]. Hypotheses used for rating the correlation coefficient: same construct (>0.7), related construct (0.4-0.7), unrelated construct (<0.4). A modified GRADE approach was used to evaluate the quality of evidence [52]. ICC: Intra-class correlation coefficient, PCC: Pearson correlation coefficient, SRCC: Spearman's rank correlation coefficient.

	Summarized result per comparator group: range	Number of participants (number of studies)	Hypothesis used	Overall rating	Quality of evidence
Construct validity					
SPPB	Balance (PCC): -0.700;0.307 [17, 45]	202 (2)	Related construct	-	⊕⊕⊕○ Moderate
	Chair stand tests (PCC): 0.410;0.690 [2, 17]	108 (2)	Related construct	+	
	Rest: Free living sit to stand (SRCC): 0.170 [28]	479 (1)	Unrelated construct	+	
	Muscle strength (PCC): 0.190;0.290 [2, 33]	101 (2)	Unrelated construct	+	
	Muscle strength (SRCC): 0.420;0.510 [4]	138 (1)		-	
	Physical functioning questionnaires (PCC): 0.290;0.370 [30, 40]	120 (2)	Related construct	-	
	Physical functioning questionnaires (SRCC): 0.290;0.750 [3, 11, 39]	961 (3)		-	
	Short walking test (PCC): 0.190;0.350 [17]	57 (1)	Related construct	-	
	Short walking test (SRCC): 0.776 [11]	73 (1)		-	
	Long walking test (PCC): 0.630 [17]	57 (1)		+	

Table 3 Continued

	Summarized result per comparator group: range	Number of participants (number of studies)	Hypothesis used	Overall rating	Quality of evidence
TUG	Balance (PCC): -0.690;0.680 [14, 18, 34, 43] Balance (SRCC): -0.679;0.881 [6, 12, 36] Balance (NR): -0.550 [26]	199 (4) 310 (3) 1200 (1)	Related construct	- + ?	⊕⊕⊕⊕ High
	Chair stand tests (PCC): 0.370;0.918 [1, 2, 42]	100 (3)	Related construct	-	
	Mobility (PCC): 0.790;0.89 [7] Mobility (SRCC): -0.651 [6]	30 (1) 167 (1)	Related construct	- +	
	Muscle strength (PCC): -0.290;-0.228 [2, 35] Muscle strength (partial regression coefficient): -0.671;-0.079 [31]	7155 (2) 299 (1)	Unrelated construct	+ -	
	Physical functioning questionnaires (PCC): -0.910;0.210 [1, 8, 20, 24, 30] Physical functioning questionnaires (SRCC): -0.740;0.495 [2, 6, 9, 16, 21] Physical functioning questionnaires (NR): -0.450 [26]	472 (5) 313 (5) 1200 (1)	Related construct	- - ?	
	Sarcopenia (OR): 1.00;1.01 [27]	140 (1)	Unrelated construct	?	
	Short walking test (PCC): -0.830;0.960 [1, 19] Short walking test (SRCC) -0.840;0.596 [36, 50] Short walking test (NR): -0.530 [26] Long walking test (PCC): -0.573 [35] Long walking test (SRCC): -0.752 [6]	70 (2) 100 (2) 1200 (1) 7104 (1) 164 (1)	Related construct	- - ? + -	
	Rest (PCC): -0.300;0.317 [24, 35] Rest (SRCC): -0.020;0.370 [9]	7284 (2) 35 (1)	Unrelated construct	+ +	

Table 3 Continued

	Summarized result per comparator group: range	Number of participants (number of studies)	Hypothesis used	Overall rating	Quality of evidence
4m GST	Balance (PCC): 0.650 [13, 16]	30 (1)	Unrelated construct	-	⊕⊕⊕○ Moderate
	Muscle strength (PCC): 0.380;0.510 [29]	172 (1)	Unrelated construct	-	
	Muscle strength (SRCC): 0.290;0.560 [4]	138 (1)		-	
	Physical functioning questionnaires (PCC): 0.570 [40]	89 (1)	Unrelated construct	-	
	Physical functioning questionnaires (SRCC): -0.580;0.617 [11, 16]	124 (2)		-	
	Sarcopenia (OR): 0.410;1.540 [27]	140 (1)	Unrelated construct	?	
	Short walking test (PCC): 0.824 [41]	60 (1)	Related construct	-	
			Related construct	-	
	Short walking test (SRCC): 0.930 [41]	60 (1)		-	
				?	
	Short walking test (ICC): 0.867 [10]	136 (1)		?	
	Short walking test (mean difference1): -0.110 [37]	288 (1)		+	
	Short walking test (LoA1): -0.13;0.10 [37]	288 (1)		?	
	Long walking test (PCC): 0.490;0.590 [29]	172 (1)		?	
	Long walking test (mean difference2): -0.030 [37]	288 (1)			
	Long walking test (LoA2): -0.08; 0.03 [37]	288 (1)			
400m WT	Balance (PCC): -0.531; -0.307 [44]	3075 (1)	Unrelated construct	-	⊕⊕⊕○ Moderate
	Chair stand (PCC): -0.416; -0.376 [44]	3075 (1)	Unrelated construct	-	
	Physical functioning questionnaires (PCC): -0.614; -0.238 [44]	3075 (1)	Unrelated construct	-	
	Short walking test (PCC): -0.838; -0.589 [44]	3075 (1)	Related construct	-	
	Short walking test (SRCC): 0.930 [41]	60 (1)		-	

Table 4 Summary of findings: Responsiveness. The overall rating is scored sufficient (+), insufficient (-) or indeterminate (?) when not enough data is available, according to the criteria for good measurement properties [51]. A modified GRADE approach was used to evaluate the quality of evidence [52]. AUC: Area under the curve, N/A: Not applicable, SEM: Standard error of the mean.

	Summarized result	Number of participants (number of studies)	Overall rating	Quality of evidence
Responsiveness				
SPPB	Small meaningful change: 0.54 [38] Substantial meaningful change: 1.34 [38] SEM meaningful change: 1.42 [38]	429 (1)	-	⊕⊕⊕⊕ High
TUG	AUC: 0.592 [26]	1200 (1)	-	⊕○○○ Very low
4m GST	Small meaningful change: 0.05 [38] Substantial meaningful change: 0.12 [38] SEM meaningful change: 0.06 [38]	429 (1)	+	⊕⊕⊕⊕ High
400m WT	N/A	N/A	N/A	N/A

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Supporting information

Search strategy

PubMed

Older people

"aged"[MeSH Terms] OR
"aging"[MeSH Terms] OR
"geriatrics"[MeSH Terms] OR
"Frail Elderly"[Mesh] OR
"Sarcopenia"[MeSH Terms] OR
"aged"[Title/Abstract] OR
"geriatric*"[Title/Abstract] OR
"elder*"[Title/Abstract] OR
"ageing"[Title/Abstract] OR
"aging"[Title/Abstract] OR
"older people"[Title/Abstract] OR
"older adult*"[Title/Abstract] OR
"older patient*"[Title/Abstract] OR
"old people"[Title/Abstract] OR
"old adult*"[Title/Abstract] OR
"old patient*"[Title/Abstract] OR
"old population"[Title/Abstract] OR
"old women"[Title/Abstract] OR
"old men"[Title/Abstract] OR
"older women"[Title/Abstract] OR
"older men"[Title/Abstract] OR
"older population"[Title/Abstract] OR
"old person*"[Title/Abstract] OR
"older person*"[Title/Abstract] OR
senior*[Title/Abstract] OR
"sarcopeni*"[Title/Abstract] OR
"Frail*"[Title/Abstract]

Community-dwelling

"Independent Living"[Mesh] OR
"Community health services"[Mesh] OR
"Primary health care"[Mesh] OR
aging in place[Title/Abstract] OR
Community-based[Title/Abstract] OR
Communitybased[Title/Abstract] OR
Community center*[Title/Abstract] OR
Community health services[Title/Abstract] OR
Community living[Title/Abstract] OR
Community population[Title/Abstract] OR
Community setting*[Title/Abstract] OR
community-dwell*[Title/Abstract] OR
community dwell*[Title/Abstract] OR
community-living*[Title/Abstract] OR
day center*[Title/Abstract] OR
home-based*[Title/Abstract] OR
home-dwell*[Title/Abstract] OR
home vist*[Title/Abstract] OR
Independent*[Title/Abstract] OR
Living in the community[Title/Abstract] OR
Outpatient*[Title/Abstract] OR
Participant home*[Title/Abstract] OR
Patient home*[Title/Abstract] OR
Primary health care[Title/Abstract]

Physical performance outcome measures according to EWGSOP2

"walking speed"[MeSH Terms] OR
"walking speed*"[Title/Abstract] OR
"walking pace*"[Title/Abstract] OR
((walk*[Title/Abstract] OR gait[Title/Abstract])
AND (test[Title/Abstract] OR speed[Title/
Abstract] OR timed[Title/Abstract])) OR
"gait speed*"[Title/Abstract] OR
"gait analysis"[Title/Abstract] OR
"walk test"[Title/Abstract] OR
"walking test"[Title/Abstract] OR
"Timed up and go"[Title/Abstract] OR
"TUG"[Title/Abstract] OR
"SPPB"[Title/Abstract] OR
"short physical performance battery"[Title/
Abstract] OR
"National Institute on Aging Battery"[Title/
Abstract] OR
"NIA Battery"[Title/Abstract] OR
"Quartile Summary Physical
Performance Score"[Title/Abstract]

Psychometric properties (updated and adapted filter [1])

"Validation Study"[Publication Type]
OR "reproducibility of results"[MeSH Terms]
OR "reproducib*"[Title/Abstract]
OR "psychometrics"[MeSH Terms]
OR "psychometr*"[Title/Abstract]
OR "clinimetr*"[Title/Abstract]
OR "clinometr*"[Title/Abstract]
OR "observer variation"[MeSH Terms]
OR "observer variation"[Title/Abstract]
OR "discriminant analysis"[MeSH Terms]
OR "reliab*"[Title/Abstract]
OR "valid*"[Title/Abstract]
OR "coefficient"[Title/Abstract]
OR "internal consistency"[Title/Abstract]
OR ("cronbach*"[Title/Abstract]
AND ("alpha"[Title/Abstract]
OR "alphas"[Title/Abstract]))
OR "item correlation"[Title/Abstract]
OR "item correlations"[Title/Abstract]
OR "item selection"[Title/Abstract]
OR "item selections"[Title/Abstract]
OR "item reduction"[Title/Abstract]
OR "item reductions"[Title/Abstract]
OR "agreement"[Text Word]
OR "precision"[Text Word]
OR "imprecision"[Text Word]
OR "precise values"[Text Word]
OR "test-retest"[Title/Abstract]
OR ("test"[Title/Abstract]
AND "retest"[Title/Abstract])
OR ("reliab*"[Title/Abstract] AND ("test"[Title/
Abstract] OR "retest"[Title/Abstract]))
OR "stability"[Title/Abstract]
OR "interrater"[Title/Abstract]
OR "inter-rater"[Title/Abstract]
OR "intrarater"[Title/Abstract]
OR "intra-rater"[Title/Abstract]
OR "intertester"[Title/Abstract]
OR "inter-tester"[Title/Abstract]
OR "intratester"[Title/Abstract]
OR "intra-tester"[Title/Abstract]
OR "interobserver"[Title/Abstract]
OR "inter-observer"[Title/Abstract]
OR "intraobserver"[Title/Abstract]

OR "intra-observer"[Title/Abstract]
OR "intertechnician"[Title/Abstract]
OR "inter-technician"[Title/Abstract]
OR "intratechnician"[Title/Abstract]
OR "intra-technician"[Title/Abstract]
OR "interexaminer"[Title/Abstract]
OR "inter-examiner"[Title/Abstract]
OR "intraexaminer"[Title/Abstract]
OR "intra-examiner"[Title/Abstract]
OR "interassay"[Title/Abstract]
OR "inter-assay"[Title/Abstract]
OR "intraassay"[Title/Abstract]
OR "intra-assay"[Title/Abstract]
OR "interindividual"[Title/Abstract]
OR "inter-individual"[Title/Abstract]
OR "intraindividual"[Title/Abstract]
OR "intra-individual"[Title/Abstract]
OR "interparticipant"[Title/Abstract]
OR "inter-participant"[Title/Abstract]
OR "intraparticipant"[Title/Abstract]
OR "intra-participant"[Title/Abstract]
OR "kappa"[Title/Abstract]
OR "kappa's"[Title/Abstract]
OR "kappas"[Title/Abstract]
OR "coefficient of variation"[Title/Abstract]
OR "repeatab*"[Text Word]
OR (("replicab*"[Text Word] OR "repeated"[Text Word]) AND ("measure"[Text Word] OR "measures"[Text Word] OR "findings"[Text Word] OR "result"[Text Word] OR "results"[Text Word] OR "test"[Text Word] OR "tests"[Text Word]))
OR "generaliza*"[Title/Abstract]
OR "generalisa*"[Title/Abstract]
OR "concordance"[Title/Abstract]
OR ("intraclass"[Title/Abstract] AND "correlation*"[Title/Abstract])
OR "discriminative"[Title/Abstract]
OR "known group"[Title/Abstract]
OR "factor analysis"[Title/Abstract]
OR "factor analyses"[Title/Abstract]
OR "factor structure"[Title/Abstract]
OR "factor structures"[Title/Abstract]
OR "dimensionality"[Title/Abstract]
OR "subscale*"[Title/Abstract]
OR "multitrait scaling analysis"[Title/Abstract]
OR "multitrait scaling analyses"[Title/Abstract]
OR "item discriminant"[Title/Abstract]
OR "interscale correlation"[Title/Abstract]
OR "interscale correlations"[Title/Abstract]
OR (("error"[Title/Abstract] OR "errors"[Title/Abstract]) AND ("measure*"[Title/Abstract] OR "correlat*"[Title/Abstract] OR "evaluat*"[Title/Abstract] OR "accuracy"[Title/Abstract] OR "accurate"[Title/Abstract] OR "precision"[Title/Abstract] OR "mean"[Title/Abstract]))
OR "accuracy"[Title/Abstract]
OR "accurate"[Title/Abstract]
OR "individual variability"[Title/Abstract]
OR "interval variability"[Title/Abstract]
OR "rate variability"[Title/Abstract]
OR "variability analysis"[Title/Abstract]
OR ("uncertainty"[Title/Abstract] AND ("measurement"[Title/Abstract] OR "measuring"[Title/Abstract]))
OR "standard error of measurement"[Title/Abstract]
OR "sensitiv*"[Title/Abstract]
OR "responsive*"[Title/Abstract]

OR ("limit"[Title/Abstract]
AND "detection"[Title/Abstract])
OR "minimal
detectable concentration"[Title/Abstract]
OR "interpretab*"[Title/Abstract]
OR ("small*"[Title/Abstract] AND
("real"[Title/Abstract] OR "detectable"[Title/
Abstract]) AND ("change"[Title/Abstract]
OR "difference"[Title/Abstract]))
OR "meaningful change"[Title/Abstract]
OR "minimal important change"[Title/Abstract]
OR "minimal
important difference"[Title/Abstract]
OR "minimally
important change"[Title/Abstract]
OR "minimally
important difference"[Title/Abstract]
OR "minimal detectable change"[Title/Abstract]
OR "minimal
detectable difference"[Title/Abstract]
OR "minimally
detectable change"[Title/Abstract]
OR "minimally
detectable difference"[Title/Abstract]
OR "minimal real difference"[Title/Abstract]
OR "ceiling effect"[Title/Abstract]
OR "floor effect"[Title/Abstract]
OR "Item response model"[Title/Abstract]
OR "IRT"[Title/Abstract]
OR "Rasch"[Title/Abstract]
OR "Differential
item functioning"[Title/Abstract]
OR "DIF"[Title/Abstract]
OR "cross-cultural equivalence"[Title/Abstract]

Exclusion filter [1]

("address"[Publication Type]
OR "biography"[Publication Type]
OR "case reports"[Publication Type]
OR "comment"[Publication Type]
OR "directory"[Publication Type]
OR "editorial"[Publication Type]
OR "festschrift"[Publication Type]
OR "interview"[Publication Type]
OR "lecture"[Publication Type]
OR "legal case"[Publication Type]
OR "legislation"[Publication Type]
OR "letter"[Publication Type]
OR "news"[Publication Type]
OR "newspaper article"[Publication Type]
OR "patient education
handout"[Publication Type]
OR "popular work"[Publication Type]
OR "congress" [Publication Type]
OR "consensus development
conference"[Publication Type]
OR "consensus development conference,
nih"[Publication Type]
OR "practice guideline"[Publication
Type]) NOT ("animals"[MeSH Terms] NOT
"humans"[MeSH Terms])

EMBASE

Elderly

Exp aged/ OR
exp aging/ OR
exp geriatrics/ OR
frail elderly/ OR
sarcopenia/ OR
"aged".ti,ab,kf OR

"ageing".ti,ab,kf OR
"aging".ti,ab,kf OR
"elder*".ti,ab,kf OR
"frail*".ti,ab,kf OR
"geriatric*".ti,ab,kf OR
"old adult*".ti,ab,kf OR
"old patient*".ti,ab,kf OR
"old people".ti,ab,kf OR
"old person*".ti,ab,kf OR
"old population".ti,ab,kf OR
"older adult*".ti,ab,kf OR
"older patient*".ti,ab,kf OR
"older people".ti,ab,kf OR
"older person*".ti,ab,kf OR
"older population".ti,ab,kf OR
"sarcopeni*".ti,ab,kf OR
"senior*".ti,ab,kf OR
"old men".ti,ab,kf OR
"old women".ti,ab,kf OR
"older men".ti,ab,kf OR
"older women".ti,ab,kf

Community-dwelling

community living/ OR
exp community care/ OR
exp community dwelling person/ OR
exp independent living/ OR
exp primary health care/ OR
"Community center*".ti,ab,kf OR
"Community health services".ti,ab,kf OR
"Community living".ti,ab,kf OR
"Community population".ti,ab,kf OR
"Community setting*".ti,ab,kf OR
"Communitybased".ti,ab,kf OR
"Community-based".ti,ab,kf OR
"community-dwell*".ti,ab,kf OR
"community-living*".ti,ab,kf OR "aging in place".
ti,ab,kf OR
"day center*".ti,ab,kf OR
"home vist*".ti,ab,kf OR
"home-based*".ti,ab,kf OR
"home-dwell*".ti,ab,kf OR "Independent*".
ti,ab,kf OR
"Living in the community".ti,ab,kf OR
"Outpatient*".ti,ab,kf OR
"Participant home*".ti,ab,kf OR
"Patient home*".ti,ab,kf OR
"Primary health care".ti,ab,kf

Physical performance outcome measures according to EWGSOP2

exp walking speed/ OR
"gait analysis".ti,ab,kf OR
"gait speed*".ti,ab,kf OR
"National Institute on Aging Battery".ti,ab,kf OR
"NIA Battery".ti,ab,kf OR
"Quartile Summary Physical Performance Score".
ti,ab,kf OR
"short physical performance battery".ti,ab,kf OR
"SPPB".ti,ab,kf OR
"Timed up and go".ti,ab,kf OR
"TUG".ti,ab,kf OR
"walk test".ti,ab,kf OR
"walking pace*".ti,ab,kf OR
"walking speed*".ti,ab,kf OR
"walking test".ti,ab,kf OR
((walk*.ti,ab,kf OR gait.ti,ab,kf) AND (test.ti,ab,kf
OR speed.ti,ab,kf OR timed.ti,ab,kf))

Psychometric properties (updated, adapted and translated filter [1])

exp intermethod comparison/
OR exp validation study/
OR exp psychometry/
OR exp reproducibility/
OR reproducib*.ti,ab,kf.
OR psychometr*.ti,ab,kf.
OR clinimetr*.ti,ab,kf.
OR clinometr*.ti,ab,kf.
OR exp observer variation/
OR observer variation.ti,ab,kf.
OR exp discriminant analysis/
OR exp validity/
OR reliab*.ti,ab,kf.
OR valid*.ti,ab,kf.
OR coefficient.ti,ab,kf.
OR internal consistency.ti,ab,kf.
OR (cronbach*.ti,ab,kf. AND (alpha.ti,ab,kf.
OR alphas.ti,ab,kf.))
OR item correlation.ti,ab,kf.
OR item correlations.ti,ab,kf.
OR item selection.ti,ab,kf.
OR item selections.ti,ab,kf.
OR item reduction.ti,ab,kf.
OR item reductions.ti,ab,kf.
OR agreement.ti,ab,kf.
OR precision.ti,ab,kf.
OR imprecision.ti,ab,kf.
OR precise values.ti,ab,kf.
OR test-retest.ti,ab,kf.
OR (test.ti,ab,kf. AND retest.ti,ab,kf.)
OR (reliab*.ti,ab,kf. AND (test.ti,ab,kf.
OR retest.ti,ab,kf.))
OR stability.ti,ab,kf.
OR interrater.ti,ab,kf.
OR inter-rater.ti,ab,kf.
OR intrarater.ti,ab,kf.
OR intra-rater.ti,ab,kf.
OR intertester.ti,ab,kf.
OR inter-tester.ti,ab,kf.
OR intratester.ti,ab,kf.
OR interobserver.ti,ab,kf.
OR inter-observer.ti,ab,kf.
OR intraobserver.ti,ab,kf.
OR intra-observer.ti,ab,kf.
OR intertechnician.ti,ab,kf.
OR inter-technician.ti,ab,kf.
OR intratechnician.ti,ab,kf.
OR intra-technician.ti,ab,kf.
OR interexaminer.ti,ab,kf.
OR inter-examiner.ti,ab,kf.
OR intraexaminer.ti,ab,kf.
OR intra-examiner.ti,ab,kf.
OR interassay.ti,ab,kf.
OR inter-assay.ti,ab,kf.
OR intraassay.ti,ab,kf.
OR intra-assay.ti,ab,kf.
OR interindividual.ti,ab,kf.
OR inter-individual.ti,ab,kf.
OR intraindividual.ti,ab,kf.
OR intra-individual.ti,ab,kf.
OR interparticipant.ti,ab,kf.
OR inter-participant.ti,ab,kf.
OR intraparticipant.ti,ab,kf.
OR intra-participant.ti,ab,kf.
OR kappa.ti,ab,kf.
OR kappas.ti,ab,kf.
OR coefficient of variation.ti,ab,kf.
OR repeatab*.ti,ab,kf.

OR (replicab*.ti,ab,kf. OR repeated.ti,ab,kf.
AND (measure.ti,ab,kf. OR measures.ti,ab,kf. OR
findings.ti,ab,kf. OR result.ti,ab,kf. OR results.
ti,ab,kf. OR test.ti,ab,kf. OR tests.ti,ab,kf.))
OR generaliza*.ti,ab,kf.
OR generalisa*.ti,ab,kf.
OR concordance.ti,ab,kf.
OR (intraclass.ti,ab,kf. AND correlation*.ti,ab,kf.)
OR discriminative.ti,ab,kf.
OR known group.ti,ab,kf.
OR factor analysis.ti,ab,kf.
OR factor analyses.ti,ab,kf.
OR factor structure.ti,ab,kf.
OR factor structures.ti,ab,kf.
OR dimensionality.ti,ab,kf.
OR subscale*.ti,ab,kf.
OR multitrait scaling analysis.ti,ab,kf.
OR multitrait scaling analyses.ti,ab,kf.
OR item discriminant.ti,ab,kf.
OR interscale correlation.ti,ab,kf.
OR interscale correlations.ti,ab,kf.
OR (error.ti,ab,kf. OR errors.ti,ab,kf. AND
(measure*.ti,ab,kf. OR correlat*.ti,ab,kf.
OR evaluat*.ti,ab,kf. OR accuracy.ti,ab,kf.
OR accurate.ti,ab,kf. OR precision.ti,ab,kf.
OR mean.ti,ab,kf.))
OR accuracy.ti,ab,kf.
OR accurate.ti,ab,kf.
OR individual variability.ti,ab,kf.
OR interval variability.ti,ab,kf.
OR rate variability.ti,ab,kf.
OR variability analysis.ti,ab,kf.
OR (uncertainty.ti,ab,kf. AND (measurement.
ti,ab,kf. OR measuring.ti,ab,kf.))
OR standard error of measurement.ti,ab,kf.
OR sensitiv*.ti,ab,kf.
OR responsive*.ti,ab,kf.
OR (limit.ti,ab,kf. AND detection.ti,ab,kf.)
OR minimal detectable concentration.ti,ab,kf.
OR interpretab*.ti,ab,kf.
OR (small*.ti,ab,kf. AND (real.ti,ab,kf. OR
detectable.ti,ab,kf.) AND (change.ti,ab,kf.
OR difference.ti,ab,kf.))
OR meaningful change.ti,ab,kf.
OR minimal important change.ti,ab,kf.
OR minimal important difference.ti,ab,kf.
OR minimally important change.ti,ab,kf.
OR minimally important difference.ti,ab,kf.
OR minimal detectable change.ti,ab,kf.
OR minimal detectable difference.ti,ab,kf.
OR minimally detectable change.ti,ab,kf.
OR minimally detectable difference.ti,ab,kf.
OR minimal real change.ti,ab,kf.
OR minimal real difference.ti,ab,kf.
OR minimally real change.ti,ab,kf.
OR minimally real difference.ti,ab,kf.
OR ceiling effect.ti,ab,kf.
OR floor effect.ti,ab,kf.
OR item response model.ti,ab,kf.
OR irt.ti,ab,kf.
OR rasch.ti,ab,kf.
OR differential item functioning.ti,ab,kf.
OR dif.ti,ab,kf.
OR computer adaptive testing.ti,ab,kf.
OR cross-cultural equivalence.ti,ab,kf.

CINAHL

Elderly

MH "Aged+" OR

MH "Aging+" OR

MH "Frail Elderly" OR

MH "Geriatric Functional Assessment" OR

MH "Geriatrics+" OR

MH "Sarcopenia" OR

AB "aged" OR

AB "ageing" OR

AB "aging" OR

AB "elder*" OR

AB "frail*" OR

AB "geriatric*" OR

AB "old adult*" OR

AB "old patient*" OR

AB "old people" OR

AB "old person*" OR

AB "old population" OR

AB "older adult*" OR

AB "older patient*" OR

AB "older people" OR

AB "older person*" OR

AB "older population" OR

AB "sarcopeni*" OR

AB "senior*" OR

AB "old men" OR

AB "old women" OR

AB "older men" OR

AB "older women" OR

TI "aged" OR

TI "ageing" OR

TI "aging" OR

TI "elder*" OR

TI "frail*" OR

TI "geriatric*" OR

TI "old adult*" OR

TI "old patient*" OR

TI "old people" OR

TI "old person*" OR

TI "old population" OR

TI "older adult*" OR

TI "older patient*" OR

TI "older people" OR

TI "older person*" OR

TI "older population" OR

TI "sarcopeni*" OR

TI "senior*" OR

TI "old men" OR

TI "old women" OR

TI "older men" OR

TI "older women"

Community-dwelling

MH "Community Health Services" OR

MH "Community Living+" OR

MH "Primary Health Care" OR

AB aging in place OR

AB Community center* OR

AB Community health services OR

AB Community living OR

AB Community setting* OR

AB Communitybased OR

AB Community-based OR

AB community-dwell* OR

AB community-living* OR

AB day center* OR

AB home vist* OR

AB home-based* OR

AB home-dwell* OR
AB Independent* OR
AB Living in the community OR
AB Outpatient* OR
AB Participant home* OR
AB Patient home* OR
AB Primary health care OR
TI aging in place OR
TI Community center* OR
TI Community health services OR
TI Community living OR
TI community living OR
AB community living
TI Community setting* OR
TI Communitybased OR
TI Community-based OR
TI community-dwell* OR
TI community-living*
TI day center* OR
TI home vist* OR
TI home-based* OR
TI home-dwell* OR
TI Independent* OR
TI Living in the community OR
TI Outpatient* OR
TI Participant home* OR
TI Patient home* OR
TI Primary health care

Physical performance outcome measures according to EWGSOP2

MH "Walking Speed" OR
((AB walk* OR AB gait OR TI walk* OR TI gait)
AND (AB test OR AB speed OR AB timed OR TI
test OR TI speed OR TI timed)) OR
AB "gait analysis" OR
AB "gait speed*" OR
AB "National Institute on Aging Battery"[Title/
Abstract] OR
AB "NIA Battery" OR
AB "Quartile Summary Physical Performance
Score" OR
AB "short physical performance battery" OR
AB "SPPB" OR
AB "timed up and go" OR
AB "TUG" OR
AB "walk test" OR
AB "walking pace*" OR
AB "walking speed*" OR
AB "walking test" OR
TI "gait analysis" OR
TI "gait speed*" OR
TI "National Institute on Aging Battery"[Title/
Abstract] OR
TI "NIA Battery" OR
TI "Quartile Summary Physical Performance
Score" OR
TI "short physical performance battery" OR
TI "SPPB" OR
TI "Timed up and go" OR
TI "TUG" OR
TI "walk test" OR
TI "walking pace*" OR
TI "walking speed*" OR
TI "walking test"

Psychometric properties (updated, adapted and translated filter [1])

(MH "Validation Studies")
OR (MH "Psychometrics")

OR (MH "Reproducibility of Results")
OR (MH "Discriminant Analysis")
OR (MH "Internal Consistency+")
OR (MH "Reliability+")
OR (MH "Measurement Error+")
OR (MH "Reliability and Validity+")
OR (MH "Observer Bias+")
OR TI psychometr*
OR TI observer variation
OR TI Clinimetr*
OR TI Clinometr*
OR TI reproducib*
OR TI reliab*
OR TI unreliab*
OR TI valid*
OR TI coefficient
OR TI "internal consistency"
OR AB psychometr*
OR AB Clinimetr*
OR AB Clinometr*
OR AB observer variation
OR AB reproducib*
OR AB reliab*
OR AB unreliab*
OR AB valid*
OR AB coefficient
OR AB "internal consistency"
OR (TI cronbach* OR AB cronbach* AND (TI alpha OR AB alpha OR TI alphas OR AB alphas))
OR (TI item OR AB item AND (TI correlation* OR AB correlation* OR TI selection* OR AB selection* OR TI reduction* OR AB reduction*))
OR TI agreement
OR TI precision
OR TI imprecision
OR TI "precise values"
OR TI test-retest
OR AB agreement
OR AB precision
OR AB imprecision
OR AB "precise values"
OR AB test-retest
OR (TI test OR AB test AND (TI retest OR AB retest))
OR (TI reliab* OR AB reliab* AND (TI test OR AB test OR TI retest or AB retest))
OR TI stability
OR TI interrater
OR TI inter-rater
OR TI intrarater
OR TI intra-rater
OR TI intertester
OR TI inter-tester
OR TI intratester
OR TI intra-tester
OR TI interobserver
OR TI inter-observer
OR TI intraobserver
OR TI intra-observer
OR TI intertechnician
OR TI inter-technician
OR TI intratechnician
OR TI intra-technician
OR TI interexaminer
OR TI inter-examiner
OR TI intraexaminer
OR TI intra-examiner
OR TI interassay
OR TI inter-assay
OR TI intraassay

OR TI intra-assay
OR TI interindividual
OR TI inter-individual
OR TI intraindividual
OR TI intra-individual
OR TI interparticipant
OR TI inter-participant
OR TI intraparticipant
OR TI intra-participant
OR TI kappa
OR TI kappa's
OR TI kappas
OR TI repeatab*
OR AB stability
OR AB interrater
OR AB inter-rater
OR AB intrarater
OR AB intra-rater
OR AB intertester
OR AB inter-tester
OR AB intratester
OR AB intra-tester
OR AB interobserver
OR AB inter-observer
OR AB intraobserver
OR AB intra-observer
OR AB intertechnician
OR AB inter-technician
OR AB intratechnician
OR AB intra-technician
OR AB interexaminer
OR AB inter-examiner
OR AB intraexaminer
OR AB intra-examiner
OR AB interassay
OR AB inter-assay
OR AB intraassay
OR AB intra-assay
OR AB interindividual
OR AB inter-individual
OR AB intraindividual
OR AB intra-individual
OR AB interparticipant
OR AB inter-participant
OR AB intraparticipant
OR AB intra-participant
OR AB kappa
OR AB kappa's
OR AB kappas
OR AB repeatab*
OR ((TI replicab* OR AB replicab* OR TI repeated OR AB repeated) AND (TI measure OR AB measure OR TI measures OR AB measures OR TI findings OR AB findings OR TI result OR AB result OR TI results OR AB results OR TI test OR AB test OR TI tests OR AB tests))
OR TI generaliza*
OR TI generalisa*
OR TI concordance
OR AB generaliza*
OR AB generalisa*
OR AB concordance
OR (TI intraclass OR AB intraclass) AND (TI correlation* or AB correlation*))
OR TI discriminative
OR TI "known group"
OR TI factor analysis
OR TI factor analyses
OR TI dimensionality
OR TI subscale*

OR AB discriminative
OR AB "known group"
OR AB factor analysis
OR AB factor analyses
OR AB dimensionality
OR AB subscale*
OR ((TI multitrait OR AB multitrait) AND (TI scaling OR AB scaling) AND (TI analysis OR AB analysis OR TI analyses OR AB analyses))
OR TI item discriminant
OR TI interscale correlation*
OR TI "individual variability"
OR AB item discriminant
OR AB interscale correlation*
OR AB "individual variability"
OR (TI variability OR AB variability AND) (TI analysis OR AB analysis OR TI values OR AB values OR TI interval OR AB interval OR TI rate OR AB rate))
OR (TI uncertainty OR AB uncertainty) AND (TI measurement OR AB measurement OR TI measuring OR AB measuring))
OR TI "standard error of measurement"
OR TI sensitiv*
OR TI responsive*
OR AB "standard error of measurement"
OR AB sensitiv*
OR AB responsive*
OR (AB error OR AB errors AND (AB measure* OR AB correlat* OR AB evaluat* OR AB accuracy OR AB accurate OR AB precision OR AB mean.))
OR (TI error OR TI errors AND (TI measure* OR TI correlat* OR TI evaluat* OR TI accuracy OR TI accurate OR TI precision OR TI mean.))
OR AB accuracy
OR AB accurate
OR TI accuracy
OR TI accurate
OR ((TI minimal OR TI minimally OR TI clinical OR TI clinically OR AB minimal OR AB minimally OR AB clinical OR AB clinically) AND (TI important OR TI significant OR TI detectable OR AB important OR AB significant OR AB detectable) AND (TI change OR AB change OR TI difference OR AB difference OR TI concentration OR AB concentration))
OR (TI small* OR AB small* AND (TI real OR AB real OR TI detectable OR AB detectable) AND (TI change OR AB change OR TI difference OR AB difference))
OR TI meaningful change
OR TI "ceiling effect"
OR TI "floor effect"
OR TI "Item response model"
OR TI IRT
OR TI Rasch
OR TI "Differential item functioning"
OR TI DIF
OR TI "computer adaptive testing"
OR TI "cross-cultural equivalence"
OR AB meaningful change
OR AB "ceiling effect"
OR AB "floor effect"
OR AB "Item response model"
OR AB IRT
OR AB Rasch
OR AB "Differential item functioning"
OR AB DIF
OR AB "computer adaptive testing"
OR AB "cross-cultural equivalence"

OR TI "factor structure"

OR TI "factor structures"

OR AB "factor structure"

OR AB "factor structures"

OR ((TI limit OR AB limit) AND (TI detection OR

AB detection))

OR TI interpretab*

OR AB interpretab*

Description of tests

Short physical performance battery

The SPPB is a compound test aimed to measure physical performance. It comprises of a balance test, a walk test and 5-times chair rise test [2]. In the original SPPB designed in 1994 participants walk 8 feet. However, the test has since been adapted and can also be performed using a 3- and 4-meter walk test [3]. The minimum SPPB score indicating mobility disability is 0, the maximum score indicating no disability is 12.

Timed up and go test

During the TUG a participant begins seated, and is timed to stand up, walk 3 meters, turn around, walk back and sit back down [4, 5]. While standing up, participants should refrain from using their arms. Therefore, this test mostly relies on the lower limbs. The less time a person takes to complete the TUG, the better their physical performance.

4m gait speed test

The 4m GST is used to evaluate lower extremity functioning. The participant is timed completing a 4-meter walk at their usual pace. The less time a person needs to walk the 4m GST, the better their physical performance.

400m walk test

The 400m WT assesses a participant's walking ability and endurance. The participant is asked to complete 20 laps of 20m each, as fast as possible. They are allowed up to two rest stops during this test. The less time a person needs to perform the 400m WT, the better their physical performance.

Overall rating methodology

Test-retest, inter, or intra-reliability was deemed sufficient if the intra-class correlation coefficient (ICC) ≥ 0.70 [6]. Measurement error was rated sufficient when the minimal detectable change (MDC) < minimally (clinical) important difference (M(C)IC) [6]. Criterion validity was deemed sufficient when the area under the curve (AUC) ≥ 0.70 [7]. Construct validity analysis was performed for each measurement instrument. When multiple constructs were evaluated, groups were made of similar constructs and methods used for synthesis. Construct validity measured by ICC, Spearman's rank correlation coefficient (SRCC), Pearson correlation coefficient (PCC) was rated on sufficiency using hypothesis testing. Hypotheses were formed for comparators in the following categories: measuring the same construct (correlation coefficient >0.7), measuring a related construct (correlation coefficient 0.4-0.7), or

measuring a different construct (correlation coefficient <0.4). The construct validity of an instrument was rated as sufficient when 75% of the hypotheses were accurate for a physical performance measure and comparators [7]. Lastly, responsiveness was deemed sufficient when at least 75% of studies showed a standard error of measurement (SEM)<meaningful change or AUC ≥ 0.70 [7].

Mean values of physical performance tests

Table I SPPB mean values and standard deviations

First author	Subgroup	Mean score	SD
Balachandran [8]	Total	10.60	2.10
Balasubramanian [9]	Total	10.50	1.60
Bean [10]	Total	8.67	1.50
Fusco [11]	Total	8.06	2.84
Gómez [12]	Total	9.70	2.00
Gray [13]	High functioning	11.49	0.71
	Low functioning	7.88	1.09
	Men	11.37	0.96
	Women	10.12	1.98
Lee [14]	Sarcopenia AWGS19 GS	11.40	1.50
	Sarcopenia AWGS19 SPPB	11.10	1.50
	Sarcopenia AWGS19 STS	11.00	1.60
	Severe sarcopenia AWGS19 GS	10.30	1.90
	Severe sarcopenia AWGS19 SPPB	8.00	1.70
	Severe sarcopenia AWGS19 STS	9.00	2.00
Löppönen [15]	Men 75-80 y/o	10.80	1.60
	Men 80-85 y/o	10.50	2.00
	Men 85+ y/o	9.70	1.90
	Women 75-80 y/o	10.50	1.60
	Women 80-85 y/o	10.40	1.80
	Women 85+ y/o	9.20	2.20
Mathis [16]	Test 1	8.10	2.70
	Test 2	8.50	2.60
Ni [17]	Total	8.60	1.80
Perera [18]	Total	9.30	2.70
Portegijs [19]	Light self-reported physical activity	9.00	5.00
	Moderate self-reported physical activity	11.00	2.00
	Regular self-reported physical activity	11.00	2.00
Riwniak [20]	Total	10.70	2.10
Stanziano [21]	Total	n.r.	n.r.

Table II TUG mean values and standard deviations

First author	Subgroup	Mean time (s)	SD
Alcock [22]	Total	7.85	2.90
Balachandran [8]	Fast	6.60	2.50
	Normal	8.50	2.30
Balasubramanian [9]	Total	10.50	2.20
Beauchamp [23]	Test 1	10.47	2.17
	Test 2	10.07	2.20
Cho [24]	Total	15.00	8.00
Creel [25]	Total	n.r.	n.r.
de Vreede [26]	Total	6.00	1.90
Di Fabio [27]	Total	n.r.	n.r.
Gamerman [28]	Total	n.r.	n.r.
Goldberg [29]	Total	12.30	0.50
Gordt [30]	Total	11.50	5.10
Griswold [31]	Total	n.r.	n.r.
Hachiya [32]	Total	6.70	1.40
Härdi [33]	Total	10.90	2.50
Hashidate [34]	Total	24.10	13.10
Kim [35]	No mobility limitations	6.21	1.10
	Moderate mobility limitations	8.35	2.60
	Severe mobility limitations	10.50	4.60
Kristensen [36]	Rater 1	10.80	4.80
	Rater 2	11.00	4.70
Kwan [37]	Total	10.90	3.68
Lin [38]	Total	13.30	n.r.
Looijaard [39]	No mobility limitations	6.21	1.10
	Moderate mobility limitations	8.35	2.60
	Severe mobility limitations	10.50	4.60
Mathis [16]	Test 1	11.40	4.70
	Test 2	10.90	4.60
Minematsu [40]	Men	6.65	1.22
	Women	6.96	1.38
Nepal [41]	Total	14.80	6.00
O'Hoski [42]	Total	8.70	1.90

Table II Continued

First author	Subgroup	Mean time (s)	SD
Olivares [43]	Total	n.r.	n.r.
Özden [44]	Total	7.94	2.27
Schaubert [45]	Total	n.r.	n.r.
Schepens [46]	Total	12.35	0.49
Steffen [47]	Men 60-69 y/o	8.00	2.00
	Men 70-79 y/o	9.00	3.00
	Men 80-89 y/o	10.00	1.00
	Women 60-69 y/o	8.00	2.00
	Women 70-79 y/o	9.00	2.00
	Women 80-89 y/o	11.00	3.00
Suwannarat [48]	Caregivers	12.01	2.98
	Health volunteers	13.06	3.48
	Physical therapists	12.32	3.39
Suzuki [49]	Test 1	6.00	1.00
	Test 2	5.80	0.90
Wang [50]	Total	8.60	1.80
Wrisley [51]	Total	10.90	4.10

Table III 4m GST mean values and standard deviations

First author	Subgroup	Mean speed (m/s)	SD
Bean [10]	Total	0.93	0.23
Beauchamp [23]	Test 1	0.90	0.16
	Test 2	0.91	0.15
Fernández-Huerta [52]	Test 1	1.57	0.33
	Test 2	1.57	0.35
Fusco [11]	Total	0.85	0.30
Goldberg [53]	Total	1.08	0.27
	Intermediate gait speed	0.85	0.10
	Fast gait speed	1.30	0.19
Maggio [54]	Total	n.r.	n.r.
Pasma [55]	Total	0.72	0.27
Perera [18]	Total	0.88	0.24
Riwniak [20]	Total	1.00	0.20
Rolland [56]	Total	0.77	0.24
van Ancum [57]	Total	1.43	0.21

Table IV Median (IQR) values 400m WT

First author	Subgroup	Median	IQR
Rolland [56]	Total	n.r.	n.r.
Simonsick [58]	Men (speed: m/s)	1.30	1.15-1.43
	Women (speed: m/s)	1.19	1.06-1.31
	Men (time: min)	5.09	4.39-5.48
	Women (time: min)	5.36	5.06-6.16

Risk of bias assessment

Table V Risk of Bias Assessment of each study. COSMIN Risk of Bias tool [59] used for reliability and measurement error. COSMIN Risk of Bias checklist [60] used for validity and responsiveness.

Reference	Reliability	Measurement error	Criterion validity	Hypothesis testing for construct validity	Responsiveness
Alcock [22]	N/A	N/A	N/A	Adequate	N/A
Balachandran [8]	N/A	N/A	N/A	Inadequate	N/A
Balasubramanian [9]	N/A	N/A	N/A	Very good	N/A
Bean [10]	N/A	N/A	N/A	Very good	N/A
Beauchamp [23]	Adequate	Adequate	N/A	N/A	N/A
Cho [24]	N/A	N/A	N/A	Inadequate	N/A
Creel [25]	Doubtful	N/A	N/A	Very good	N/A
de Vreede [26]	N/A	N/A	N/A	Very good	N/A
Di Fabio [27]	N/A	N/A	N/A	Very good	N/A
Fernández-Huerta [52]	Inadequate	N/A	N/A	Inadequate	N/A
Fusco [11]	N/A	N/A	N/A	Inadequate	N/A
Gamerman [28]	N/A	N/A	N/A	Inadequate	N/A
Goldberg [53]	Doubtful	Doubtful	N/A	N/A	N/A
Goldberg [29]	N/A	N/A	N/A	Very good	N/A
Gómez [12]	Inadequate	N/A	N/A	N/A	N/A
Gordt [30]	N/A	N/A	N/A	Very good	N/A
Gray [13]	N/A	N/A	N/A	Doubtful	N/A
Griswold [31]	Doubtful	Doubtful	N/A	Doubtful	N/A
Hachiya [32]	N/A	N/A	N/A	Very good	N/A
Härdi [33]	N/A	N/A	N/A	Doubtful	N/A
Hashidate [34]	N/A	N/A	N/A	Doubtful	N/A
Kim [35]	N/A	N/A	Inadequate	N/A	N/A
Kristensen [36]	Very good	Very good	N/A	N/A	N/A
Kwan [37]	N/A	N/A	N/A	Doubtful	N/A
Lee [14]	N/A	N/A	Very good	N/A	N/A
Lin [38]	N/A	N/A	Inadequate	Inadequate	Inadequate
Looijaard [39]	N/A	N/A	N/A	Very good	N/A
Löppönen [15]	N/A	N/A	N/A	Doubtful	N/A
Maggio [54]	N/A	N/A	N/A	Doubtful	N/A
Mathis [16]	Adequate	Adequate	N/A	Adequate	N/A
Minematsu [40]	N/A	N/A	N/A	Inadequate	N/A

Table V Continued

Reference	Reliability	Measurement error	Criterion validity	Hypothesis testing for construct validity	Responsiveness
Nepal [41]	Very good	N/A	N/A	N/A	N/A
Ni [17]	N/A	N/A	N/A	Very good	N/A
O'Hoski [42]	N/A	N/A	N/A	Very good	N/A
Olivares [43]	N/A	N/A	N/A	Very good	N/A
Özden [44]	N/A	N/A	N/A	Very good	N/A
Pasma [55]	N/A	N/A	N/A	Inadequate	N/A
Perera [18]	N/A	N/A	N/A	N/A	Very good
Portegijs [15, 19]	N/A	N/A	N/A	Adequate	N/A
Riwniak [20]	N/A	N/A	N/A	Doubtful	N/A
Rolland [56]	Doubtful	N/A	N/A	Very good	N/A
Schaubert [45]	N/A	N/A	N/A	Very good	N/A
Schepens [46]	N/A	N/A	N/A	Very good	N/A
Simonsick [58]	N/A	N/A	N/A	Inadequate	N/A
Stanziano [21]	N/A	N/A	N/A	Inadequate	N/A
Steffen [47]	Doubtful	N/A	N/A	N/A	N/A
Suwannarat [48]	Doubtful	N/A	N/A	N/A	N/A
Suzuki [49]	Doubtful	Doubtful	N/A	N/A	N/A
Wang [50]	N/A	N/A	N/A	Very good	N/A
Wrisley [51]	N/A	N/A	N/A	Very good	N/A

GRADE Evaluation

Table VI GRADE evaluation: Reliability

	Risk of Bias	Inconsistency	Imprecision	Indirectness
SPPB	Serious (-1)	No	No	No
TUG	No	No	No	No
4M GST	Serious (-1)	No	No	No
400M WT	N/A	N/A	N/A	N/A

Table VII GRADE evaluation: Measurement error

	Risk of Bias	Inconsistency	Imprecision	Indirectness
SPPB	Serious (-1)	No	Very serious (-2)	No
TUG	No	No	No	No
4M GST	Serious (-1)	No	No	No
400M WT	N/A	N/A	N/A	N/A

Table VIII GRADE evaluation: Criterion validity

	Risk of Bias	Inconsistency	Imprecision	Indirectness
SPPB	No	No	No	Serious (-1)
TUG	Very serious (-2)	No	No	No
4M GST	N/A	N/A	N/A	N/A
400M WT	N/A	N/A	N/A	N/A

Table IX GRADE evaluation: Construct validity

	Risk of Bias	Inconsistency	Imprecision	Indirectness
SPPB	No	Serious (-1)	No	No
TUG	No	No	No	No
4M GST	No	Serious (-1)	No	No
400M WT	No	Serious (-1)	No	No

Table X GRADE evaluation: Responsiveness

Responsiveness	Risk of Bias	Inconsistency	Imprecision	Indirectness
SPPB	No	No	No	No
TUG	Very serious (-2)	No	No	Serious (-1)
4M GST	No	No	No	No
400M WT	N/A	N/A	N/A	N/A

Construct validity comparator groups

Balance: 3m backward walk, activities-specific balance confidence, activity-specific balance confidence skill, Berg balance scale, BESTest (including briefBESTest and mini-BESTest), functional reach, maximal step length, maximal step length, modified total body rotation test, narrow walk score, rapid step test, standing balance score, tandem stance time, Tinetti balance, TUG (and 3f up-and-go), TURN180 and unipedal stance time.

Chair stand tests: chair stand test, sit to stand test.

Mobility: performance-oriented mobility assessment and timed movement battery.

Muscle strength: double leg press power, handgrip strength, knee extension strength, knee flexion strength, leg press power and stair climb power.

Physical functioning questionnaires: activities of daily living, assessment of daily activity performance, community balance and mobility scale (English and German), elderly physical function scale, fast evaluation of mobility, balance and fear, life-space assessment, life-space mobility at home, patient-specific functional scale, self-reported health, self-reported vitality and SF-36 physical component.

Sarcopenia: diagnostic validity sarcopenia (Baumgarter, EWGSOP, FNIH, IWGS, Janssen).

Short walking test: 3m, 3f, 4m, 6m, 10m, 20m, 50m, 50ft, 400m and 2 minute walking tests, functional gait assessment and Tinetti gait assessment.

Long walking test: 6 minute walking test.

Rest: Back Scratch, Bodily Pain, Fast Evaluation of Mobility, Balance, and Fear (fear complaints), Fast Evaluation of Mobility, Balance, and Fear (risk factors), Fear of Falling, Gariatric Depression Scale Score, MMSE, Number of Free Living Sit to Stand and Sit and Reach.

Construct validity results

Table XI Construct validity of SPPB.

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Gray [1]	Balance	8f Up and Go	PCC	-0.700	<0.05	n.r.	n.r.	n.r.
Stanziano [2]	Balance	Modified Total Body Rotation Test	PCC	0.307	0.002	n.r.	n.r.	n.r.
Balachandran [3]	Chair stand tests	Sit to Stand	PCC	0.410	n.r.	0.17	0.59	n.r.
Gray [1]	Chair stand tests	Chair Stand Test	PCC	0.690	<0.05	n.r.	n.r.	n.r.
Bean [4]	Muscle strength	Stair Climb Power	SRCC	0.510	<0.001	n.r.	n.r.	n.r.
Ni [5]	Muscle strength	Stair Climb Power (10 Steps)	PCC	0.220	0.039	n.r.	n.r.	n.r.
Ni [5]	Muscle strength	Stair Climb Power (4 Steps)	PCC	0.190	0.041	n.r.	n.r.	n.r.
Balachandran [3]	Muscle strength	Leg Press Power	PCC	0.290	n.r.	0.07	0.51	n.r.
Bean [4]	Muscle strength	Double Leg Press Power (40% one rep maximum)	SRCC	0.420	<0.001	n.r.	n.r.	n.r.
Bean [4]	Muscle strength	Double Leg Press Power (70% one rep maximum)	SRCC	0.440	<0.001	n.r.	n.r.	n.r.
Balasubramanian [6]	Questionnaire	Community Balance and Mobility Scale	SRCC	0.750	<0.001	n.r.	n.r.	n.r.
Fusco [7]	Questionnaire	Activities of Daily Living	SRCC	0.478	<0.001	n.r.	n.r.	n.r.
Fusco [7]	Questionnaire	Instrumental Activities of Daily Living	SRCC	0.626	<0.001	n.r.	n.r.	n.r.
Mathis [8]	Questionnaire	Patient Specific Functional Scale	PCC	0.370	0.030	n.r.	n.r.	n.r.
Portegijs [9]	Questionnaire	Self-Reported Scale Assessing Habitual Physical Activity	SRCC	0.400	<0.001	n.r.	n.r.	n.r.
Riwniak [10]	Questionnaire	Neuro-QOL Lower Extremity-Mobility Function	PCC	0.290	<0.05	n.r.	n.r.	n.r.
Fusco [7]	Short walking test	4m Gait Speed	SRCC	0.776	<0.001	n.r.	n.r.	n.r.
Gray [1]	Short walking test	3f Walking Velocity (Maximal Speed)	PCC	0.350	<0.05	n.r.	n.r.	n.r.
Gray [1]	Short walking test	3f Walking Velocity (Usual Speed)	PCC	0.190	n.r.	n.r.	n.r.	n.r.
Gray [1]	Long walking test	6 Minute Walk	PCC	0.630	<0.05	n.r.	n.r.	n.r.
Löppönen [11]	Rest	Number of Free Living Sit to Stand	SRCC	0.170	<0.001	n.r.	n.r.	n.r.

Table XII Construct validity of TUG.

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Gamerman [12]	Balance	TURN180 (Total)	SRCC	0.881	<0.001	n.r.	n.r.	n.r.
Griswold [13]	Balance	TUG VR	PCC	0.878	<0.01	n.r.	n.r.	n.r.
O'Hoski [14]	Balance	BESTest	PCC	0.680	<0.001	n.r.	n.r.	n.r.
O'Hoski [14]	Balance	briefBESTest	PCC	-0.600	<0.001	n.r.	n.r.	n.r.
O'Hoski [14]	Balance	mini-BESTest	PCC	-0.066	<0.001	n.r.	n.r.	n.r.
Olivares [15]	Balance	Functional Reach	PCC	-0.386	<0.001	n.r.	n.r.	n.r.
Cho [16]	Balance	Activity-Specific Balance Confidence Skill	SRCC	-0.606	<0.001	n.r.	n.r.	n.r.
Cho [16]	Balance	Tandem Stance Time	SRCC	-0.485	<0.001	n.r.	n.r.	n.r.
Cho [16]	Balance	Tandem Stance Time	SRCC	0.564	<0.001	n.r.	n.r.	n.r.
Cho [16]	Balance	Unipedal Stance Time	SRCC	-0.558	<0.001	n.r.	n.r.	n.r.
Lin [17]	Balance	Tinetti Balance	n.r. Convergent	-0.550	n.r.	n.r.	n.r.	n.r.
Schepens [18]	Balance	Activities-Specific Balance Confidence (16)	PCC	-0.650	<0.001	n.r.	n.r.	n.r.
Schepens [18]	Balance	Activities-Specific Balance Confidence (6)	PCC	-0.690	<0.001	n.r.	n.r.	n.r.
Wang [19]	Balance	Berg Balance Scale	SRCC	-0.530	<0.01	n.r.	n.r.	n.r.
Goldberg [20]	Balance	Maximal Step Length	PCC	-0.650	<0.01	n.r.	n.r.	n.r.
Cho [16]	Balance	Maximal Step Length	SRCC	-0.679	<0.001	n.r.	n.r.	n.r.
Cho [16]	Balance	Rapid Step Test	SRCC	0.346	<0.001	n.r.	n.r.	n.r.
Özden [21]	Balance	3m Backward Walk (Test 1)	SRCC	0.649	<0.01	n.r.	n.r.	n.r.
Özden [21]	Balance	3m Backward Walk (Test 2)	SRCC	0.645	<0.01	n.r.	n.r.	n.r.
Alcock [22]	Chair stand tests	Sit to Stand	PCC	0.380	<0.05	n.r.	n.r.	n.r.
Balachandran [3]	Chair stand tests	Sit to Stand	PCC	0.370	n.r.	-0.57	-0.05	n.r.

Table XII Continued

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Schaubert [23]	Chair stand tests	Sit to Stand (Baseline)	PCC	0.734	<0.05	n.r.	n.r.	n.r.
Schaubert [23]	Chair stand tests	Sit to Stand (Week 12)	PCC	0.918	<0.01	n.r.	n.r.	n.r.
Schaubert	Chair stand tests	Sit to Stand (Week 6)	PCC	0.882	<0.01	n.r.	n.r.	n.r.
Cho [16]	Mobility	Performance-Oriented Mobility Assessment	SRCC	-0.651	<0.001	n.r.	n.r.	n.r.
Creel [24]	Mobility	Timed Movement Battery (Max-Movement Speed)	PCC	0.790	<0.001	n.r.	n.r.	n.r.
Creel [24]	Mobility	Timed Movement Battery (Self-Selected Speed)	PCC	0.890	<0.001	n.r.	n.r.	n.r.
Balachandran [3]	Muscle strength	Leg Press Power	PCC	-0.290	n.r.	-0.53	-0.07	n.r.
Minematsu [25]	Muscle strength	Handgrip Strength (Female)	Partial regression coefficient	-0.114	n.r.	-0.148	-0.080	n.r.
Minematsu [25]	Muscle strength	Handgrip Strength (Male)	Partial regression coefficient	-0.079	n.r.	-0.104	-0.053	n.r.
Minematsu [25]	Muscle strength	Knee Extension Strength (Female)	Partial regression coefficient	-0.367	n.r.	-0.463	-0.272	n.r.
Minematsu [25]	Muscle strength	Knee Extension Strength (Male)	Partial regression coefficient	-0.167	n.r.	-0.247	-0.860	n.r.
Minematsu [25]	Muscle strength	Knee Flexion Strength (Female)	Partial regression coefficient	-0.671	n.r.	-0.854	-0.489	n.r.

Table XII Continued

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Minematsu [25]	Muscle strength	Knee Flexion Strength (Male)	Partial regression coefficient	-0.444	n.r.	-0.581	-0.306	n.r..
Olivares [15]	Muscle strength	Handgrip Strength	PCC	-0.228	<0.001	n.r.	n.r.	n.r.
Alcock [22]	Questionnaire	SF-36 Physical Component	PCC	-0.470	<0.05	n.r.	n.r.	n.r.
Balasubramanian [6]	Questionnaire	Community Balance and Mobility Scale	SRCC	-0.690	<0.001	n.r.	n.r.	n.r.
Cho [16]	Questionnaire	Elderly Physical Function Scale	SRCC	0.495	<0.001	n.r.	n.r.	n.r.
de Vreede	Questionnaire	Assessment of Daily Activity Performance	PCC	-0.910	<0.01	n.r.	n.r.	n.r.
di Fabio [26]	Questionnaire	Fast Evaluation of Mobility, Balance, and Fear (mobility complaints)	SRCC	0.600	<0.05	n.r.	n.r.	n.r.
di Fabio [26]	Questionnaire	Fast Evaluation of Mobility, Balance, and Fear (pain complaints)	SRCC	0.010	n.r.	n.r.	n.r.	n.r.
di Fabio [26]	Questionnaire	Fast Evaluation of Mobility, Balance, and Fear (strength complaints)	SRCC	0.420	<0.05	n.r.	n.r.	n.r.
di Fabio [26]	Questionnaire	Fast Evaluation of Mobility, Balance, and Fear (task completion)	SRCC	-0.380	<0.05	n.r.	n.r.	n.r.
Gordt [27]	Questionnaire	Community Balance and Mobility Scale (German)	SRCC	-0.580	n.r.	-0.74	-0.36	n.r.
Härdi [28]	Questionnaire	Continuous-Scale Physical Functional Performance Test (German)	PCC	-0.710	<0.01	n.r.	n.r.	n.r.
Hashidate [29]	Questionnaire	Life-Space Assessment	SRCC	0.060	0.840	n.r.	n.r.	n.r.
Hashidate [29]	Questionnaire	Life-Space Mobility at Home	SRCC	-0.740	0.010	n.r.	n.r.	n.r.
Kwan [30]	Questionnaire	Self-Reported Health	PCC	0.230	<0.01	n.r.	n.r.	n.r.
Kwan [30]	Questionnaire	Vitality	PCC	0.210	<0.001	n.r.	n.r.	n.r.

Table XII Continued

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Lin [17]	Questionnaire	Activities of Daily Living	n.r. Convergent	-0.450	n.r.	n.r.	n.r.	n.r.
Lin [17]	Questionnaire	Activities of Daily Living (Disability)	OR	16.500	n.r.	n.r.	n.r.	12
Lin [17]	Questionnaire	Activities of Daily Living (No Disability)	OR	11.200	n.r.	n.r.	n.r.	5
Mathis [8]	Questionnaire	Patient Specific Functional Scale	PCC	-0.016	0.140	n.r.	n.r.	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (Baumgarter)	OR	1.010	n.r.	1.00	1.02	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (EWGSOP)	OR	1.000	n.r.	0.99	1.02	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (FNIH)	OR	1.010	n.r.	0.99	1.01	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (IWGS)	OR	1.010	n.r.	1.00	1.02	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (Janssen)	OR	1.000	n.r.	0.99	1.01	n.r.
Alcock [22]	Short walking test	10m Gait Speed	PCC	-0.830	<0.05	n.r.	n.r.	n.r.
Hachiya [32]	Short walking test	10m Walk Test (Female)	PCC	0.810	<0.01	n.r.	n.r.	n.r.
Hachiya [32]	Short walking test	10m Walk Test (Male)	PCC	0.870	<0.01	n.r.	n.r.	n.r.
Hachiya [32]	Short walking test	50m Walk Test (Female)	PCC	0.960	<0.01	n.r.	n.r.	n.r.
Hachiya [32]	Short walking test	50m Walk Test (Male)	PCC	0.810	<0.01	n.r.	n.r.	n.r.
Lin [17]	Short walking test	3m Walking Speed	n.r. Convergent	-0.530	n.r.	n.r.	n.r.	n.r.
Lin [17]	Short walking test	Tinetti Gait	n.r. Convergent	-0.530	n.r.	n.r.	n.r.	n.r.
Özden [21]	Short walking test	50f Forward Walk (Test 1)	SRCC	0.550	<0.01	n.r.	n.r.	n.r.
Özden [21]	Short walking test	50f Forward Walk (Test 2)	SRCC	0.596	<0.01	n.r.	n.r.	n.r.
Wrisley [33]	Short walking test	Functional Gait Assessment	SRCC	-0.840	<0.001	n.r.	n.r.	n.r.
Cho [16]	Long walking test	6 Minute Walk	SRCC	-0.752	<0.001	n.r.	n.r.	n.r.
Olivares [15]	Long walking test	6 Minute Walk	PCC	-0.573	<0.001	n.r.	n.r.	n.r.

Table XII Continued

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
di Fabio [26]	Rest	Fast Evaluation of Mobility, Balance, and Fear (fear complaints)	SRCC	-0.020	n.r.	n.r.	n.r.	n.r.
di Fabio [26]	Rest	Fast Evaluation of Mobility, Balance, and Fear (risk factors)	SRCC	0.370	<0.05	n.r.	n.r.	n.r.
Kwan [30]	Rest	Bodily Pain	PCC	0.290	<0.001	n.r.	n.r.	n.r.
Kwan [30]	Rest	Fear of Falling	PCC	0.200	<0.01	n.r.	n.r.	n.r.
Kwan [30]	Rest	Gariatric Depression Scale Score	PCC	0.170	<0.01	n.r.	n.r.	n.r.
Kwan [30]	Rest	MMSE	PCC	-0.300	<0.001	n.r.	n.r.	n.r.
Olivares [15]	Rest	Back Scratch	PCC	0.317	<0.001	n.r.	n.r.	n.r.
Olivares [15]	Rest	Sit and Reach	PCC	-0.292	<0.001	n.r.	n.r.	n.r.

Table XIII Construct validity of 4m gait speed test.

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Goldberg [34]	Balance	Maximal Step Length	PCC	0.650	<0.01	n.r.	n.r.	n.r.
Bean [4]	Muscle strength	Stair Climb Power	SRCC	0.290	<0.001	n.r.	n.r.	n.r.
Bean [4]	Muscle strength	Double Leg Press Power (40% one rep maximum)	SRCC	0.540	<0.001	n.r.	n.r.	n.r.
Bean [4]	Muscle strength	Double Leg Press Power (70% one rep maximum)	SRCC	0.560	<0.001	n.r.	n.r.	n.r.
Maggio [35]	Muscle strength	Handgrip Strength (Female)	PCC	0.380	<0.0001	n.r.	n.r.	n.r.
Maggio [35]	Muscle strength	Handgrip Strength (Male)	PCC	0.510	<0.0001	n.r.	n.r.	n.r.
Fusco [7]	Questionnaire	Activities of Daily Living	SRCC	0.514	<0.001	n.r.	n.r.	n.r.
Fusco [7]	Questionnaire	Instrumental Activities of Daily Living	SRCC	0.617	<0.001	n.r.	n.r.	n.r.
Gordt [27]	Questionnaire	Community Balance and Mobility Scale (German)	SRCC	-0.580	<0.001	-0.74	-0.36	n.r.
Riwniak [10]	Questionnaire	Neuro-QOL Lower Extremity-Mobility Function	PCC	0.570	<0.05	n.r.	n.r.	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (Baumgarter)	n.r.	0.410	n.r.	0.08	2.07	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (FNIH)	OR	0.720	n.r.	0.02	21.40	n.r.
Looijaard [31]	Sarcopenia	Diagnostic Validity Sarcopenia (Janssen)	OR	1.540	n.r.	0.30	7.83	n.r.
Fernández-Huerta [36]	Short walking test	10m Gait Speed	ICC	0.867	n.r.	0.813	0.905	n.r.
Pasma [37]	Short walking test	10m Gait Speed	Mean Difference	-0.110	<0.001	n.r.	n.r.	n.r.
Pasma [37]	Short walking test	10m Gait Speed	LoA	-0.13;0.10	n.r.	n.r.	n.r.	n.r.
Rolland [38]	Short walking test	400m Walk (Baseline)	SRCC	0.930	n.r.	n.r.	n.r.	n.r.
Rolland [38]	Short walking test	4m Gait Speed (Test 2)	PCC	0.824	<0.001	n.r.	n.r.	n.r.
Maggio [35]	Long walking test	6 Minute Walk (Female)	PCC	0.490	<0.0001	n.r.	n.r.	n.r.
Maggio [35]	Long walking test	6 Minute Walk (Male)	PCC	0.590	<0.0001	n.r.	n.r.	n.r.
Pasma [37]	Long walking test	6 Minute Walk	Mean Difference	-0.030	0.340	n.r.	n.r.	n.r.
Pasma [37]	Long walking test	6 Minute Walk	LoA	-0.08;0.03	n.r.	n.r.	n.r.	n.r.

Table XIV Construct validity of 400m walk test.

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Simonsick [39]	Balance	Standing Balance Score (Female)	PCC	-0.307	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Balance	Standing Balance Score (Male)	PCC	-0.329	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Balance	Walk Score (Narrow) (Female)	PCC	-0.531	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Balance	Walk Score (Narrow) (Male)	PCC	-0.476	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Chair stand tests	Chair Stand Test (Female)	PCC	-0.376	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Chair stand tests	Chair Stand Test (Male)	PCC	-0.416	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Reported Ease of Walking 1 mile (Female)	PCC	-0.377	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Reported Ease of Walking 1 mile (Male)	PCC	-0.316	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Reported ease lifting 20lbs (Female)	PCC	-0.265	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Reported ease lifting 20lbs (Male)	PCC	-0.238	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Established Populations for the Epidemiologic Studies of the Elderly Scale (Female)	PCC	-0.461	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Established Populations for the Epidemiologic Studies of the Elderly Scale (Male)	PCC	-0.450	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Health ABC Performance Score (Female)	PCC	-0.614	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Health ABC Performance Score (Male)	PCC	-0.603	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Reported Ease of Walking 20 steps (Female)	PCC	-0.332	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Questionnaire	Reported Ease of Walking 20 steps (Male)	PCC	-0.320	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Short walking test	Walk Score 6m walk (Usual) (Female)	PCC	-0.650	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Short walking test	Walk Score 6m walk (Usual) (Male)	PCC	-0.589	<0.0001	n.r.	n.r.	n.r.
Rolland [38]	Short walking test	4m Gait Speed	SRCC	0.930	n.r.	n.r.	n.r.	n.r.

Table XIV Continued

First author	Comparator group	Comparator	Method	Value	P value	95%CI lower	95%CI upper	SD
Simonsick [39]	Short walking test	20m Walk Speed (Female)	PCC	-0.770	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Short walking test	20m Walk Speed (Male)	PCC	-0.764	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Short walking test	2min Walk Distance (Female)	PCC	-0.838	<0.0001	n.r.	n.r.	n.r.
Simonsick [39]	Short walking test	2min Walk Distance (Male)	PCC	-0.828	<0.0001	n.r.	n.r.	n.r.

PRISMA checklist

From: Page et al. (2021) [40]

Additional items added (PC 1-7) according to Elsman et al. (2022) [41]

Section and Topic	Item #	Checklist item	Location
TITLE			
Title	1	Identify the report as a systematic review.	Title
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Introduction
METHODS			
Followed guidelines	PC2	Specify, with citations, the methodology and/or guidelines used to conduct the systematic review.	Protocol and registration
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Eligibility criteria
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Search strategy
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supporting information
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Search strategy
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Data extraction

PRISMA checklist Continued

Section and Topic	Item #	Checklist item	Location
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Data extraction
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Data extraction
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Methodological Quality
Measurement properties	PC3	Specify the methods used to rate the results of a measurement property for each individual study and for the summarized or pooled results. Specify how many reviewers rated each study and whether they worked independently.	Evaluation of psychometric evidence
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Evaluation of psychometric evidence
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Evaluation of psychometric evidence
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Evaluation of psychometric evidence
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Evaluation of psychometric evidence
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Evaluation of psychometric evidence
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Evaluation of psychometric evidence
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Evaluation of psychometric evidenc

PRISMA checklist Continued

Section and Topic	Item #	Checklist item	Location
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Methodological Quality
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Evaluation of psychometric evidence
Formulating recommendations	PC4	If appropriate, describe any methods used to formulate recommendations regarding the suitability of an OMI for a particular use.	Evaluation of psychometric evidence
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results, Figure 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Not applicable
OMI characteristics	PC5	Present characteristics of each included OMI, with appropriate citations.	Description of instruments & Summary of findings
Study characteristics	17	Cite each included study and present its characteristics.	Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Supporting information
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Tables 2-6 Supporting information
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Summary of findings
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Tables 2-6
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Validity
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Result synthesis only possible with summarizing, no meta-analysis.

PRISMA checklist Continued

Section and Topic	Item #	Checklist item	Location
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Tables 2-6
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Tables 2-6
Interpretability and feasibility	PC6	Describe interpretability and feasibility aspects for each OMI.	Description of instruments
Recommendations	PC7	If appropriate, make recommendations for suitable OMIs for a particular use.	Discussion
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion
	23b	Discuss any limitations of the evidence included in the review.	Discussion
	23c	Discuss any limitations of the review processes used.	Discussion
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Protocol and registration
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Protocol and registration
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Not applicable
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Other information
Competing interests	26	Declare any competing interests of review authors.	Other information
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Not applicable

Supporting information references

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Chapter 3

The accuracy of screening for sarcopenia in the clinical setting

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Submitted

Abstract

Objectives

Sarcopenia is common among hospitalized patients, yet the diagnostic accuracy of screening tools in this setting is uncertain. To evaluate the diagnostic performance of the Strength, Assistance in walking, Rise from a chair, Climb stairs, Falls history (SARC-F) questionnaire for identifying sarcopenia in hospitalized patients. Secondary objectives were to assess the diagnostic accuracy of handgrip strength (HGS) and to determine the ability of SARC-F to predict probable sarcopenia.

Design and setting

Cross-sectional study in Canisius Wilhelmina Hospital (Nijmegen).

Participants

255 patients aged ≥50 years admitted to the wards of Cardiology, Internal Medicine, Pulmonology, Gastroenterology, Psychiatry, Urology, Orthopedics, Surgery, and Neurology.

Measurements

SARC-F, HGS, and bioelectrical impedance analysis were performed. Sarcopenia was defined according to the revised European Working Group on Sarcopenia in Older People (EWGSOP2) criteria, which distinguish probable sarcopenia (low muscle strength) from confirmed sarcopenia (low muscle strength and low muscle mass). Diagnostic performance was assessed using sensitivity, specificity, and the area under the receiver operating characteristic curve (AUC).

Results

Among participants, 28% were at risk of sarcopenia, 20% had probable sarcopenia, and 9% met criteria for confirmed sarcopenia. For diagnosing sarcopenia, SARC-F (cut-off ≥4) showed moderate sensitivity (59%), specificity (75%), and AUC (0.67). HGS, as part of the diagnostic criteria, showed 100% sensitivity and high specificity (88%), with excellent accuracy (AUC 0.94) for diagnosing sarcopenia. For probable sarcopenia, SARC-F demonstrated lower sensitivity (48%), moderate specificity (77%), and AUC (0.62).

Conclusion

SARC-F showed limited diagnostic accuracy and is not suitable as a standalone screening tool for sarcopenia in hospitalized older adults. In contrast, handgrip strength provides a reliable and objective first-line measure. Incorporating direct

strength assessments may enable earlier detection and more targeted care for patients at risk, with SARC-F serving as a complementary screening tool.

Trial registration and ethics

This trial was not subject to the Dutch Medical Research Involving Human Subjects Act (WMO), as determined by recognized Medical Ethics Review Committee 'METC Oost-Nederland' (2024-17001).

Introduction

Sarcopenia is the term used for age-related progressive and generalized skeletal muscle disorder associated with an increased risk of impaired physical performance with adverse outcomes, including falls, fractures, physical disability, and death [1, 2]. It has a major impact on general daily life activities and independence and lowers quality of life [3]. The main risk factors for developing sarcopenia include aging, low physical activity, poor nutrition, obesity, chronic diseases, hormonal and neurological changes, and medication [4, 5]. Age-related muscular atrophy is noticeable from the age of 50 onwards and accelerates as age increases [2, 4, 6-8].

Sarcopenia is formally recognized as a muscle disease with an ICD-10-MC diagnosis code [9]. The overall estimated prevalence of sarcopenia varies between 9%-51% and a prevalence of 23-37% in hospital patients from 50 years of age, depending on the population and the diagnostic criteria used [2, 10-14]. Sarcopenia is associated with increased healthcare costs due to longer recovery times, more long-term care, and a higher prevalence of comorbidities [15, 16]. Nutritional assessment is needed to diagnose sarcopenia; however, it is not yet routinely used for screening, diagnosis, and treatment in clinical care [7, 17, 18]. A misdiagnosis or failure to diagnose sarcopenia can have a significant impact on the health and well-being of affected individuals, on the ability to perform daily activities to live independently and can increase the risk of hospital (re)admission. Therefore, the correct diagnosis of sarcopenia is relevant to both clinic and society [5, 19].

To diagnose and determine the severity of sarcopenia in practice, a decision tree was developed by the European Working Group on Sarcopenia in Older People (EWGSOP2) [1, 20]. The steps of the decision tree are represented as Find-Assess-Confirm-Severity or F-A-C-S. The first step of the decision tree (F) is identifying the risk of sarcopenia by using the simple Strength, Assistance in walking, Rise from a chair, Climb chairs and Falls questionnaire (SARC-F) administered by the healthcare professional. SARC-F is recommended by several key expert groups as a screening tool for sarcopenia [1, 21, 22]. However, literature suggests that SARC-F is less suited for use in hospital settings due to its limited overall accuracy in identifying sarcopenia and its subjective nature due to bias in self-reporting [23-25].

The next step in the decision tree (A) to assess probable sarcopenia by testing muscle strength using the handgrip strength (HGS) or the chair stand test [20]. In the hospital setting, HGS is preferred because the chair stand test is not always possible. HGS is a simple, objective, inexpensive, and easily administered method

that requires minimal equipment and can also be used in cognitively impairment older adults [26]. HGS has a moderate to high sensitivity (62-100%) and low to moderate specificity (37.5% -76%) to detect sarcopenia [23, 27, 28].

The third step of the decision tree (C) is to confirm the diagnosis of sarcopenia by the addition of muscle mass using Bioelectrical Impedance Analysis (BIA), dual-energy X-ray absorptiometry (DEXA), Magnetic Resonance Imaging (MRI), or Computed Tomography (CT)[1]. BIA is most applicable for clinical practice and, therefore, used as the reference standard for sarcopenia [29, 30].

Despite guidelines recommending SARC-F as a screening tool for sarcopenia, concerns remain about its reliability, particularly in hospitalized populations. Given the importance of early detection and timely intervention, this study primarily aims to evaluate the accuracy of SARC-F in predicting sarcopenia diagnosis in a hospital setting. Additionally, it will assess the diagnostic accuracy of HGS for sarcopenia and examine how well SARC-F predicts probable sarcopenia or low handgrip strength. These findings will help identify the most effective method for assessing sarcopenia in clinical practice.

Methods

Study design and setting

This monocenter cross-sectional study was conducted at Canisius Wilhelmina Hospital (CWZ) in Nijmegen, the Netherlands, between February and April 2024. The study was not subject to the Medical Research Involving Human Subjects Act (WMO) (2024-17001), as all assessments were part of routine nutritional evaluations.

Data collection was performed by trained and qualified dietitians and research nurses from CWZ, who were authorized to administer the SARC-F questionnaire, measure handgrip strength (HGS), and conduct bioelectrical impedance analysis (BIA).

A database was generated using the electronic patient record system (HIX), selecting patients based on age and admission to the clinical wards specified in the inclusion criteria. From this database, patient summary lists were extracted to facilitate recruitment. Eligible patients were informed about the study both orally and via a written patient information letter. Written informed consent was obtained before participation.

Participants

Participants were hospitalized adults aged 50 years or older who were fluent in Dutch. They were recruited from the following departments: Cardiology, Internal Medicine, Pulmonology, Gastroenterology, Psychiatry, Urology, Orthopedics, Surgery, and Neurology.

Exclusion criteria included cognitive impairment, limited comprehension, cerebral infarction, terminal illness, and the presence of a cardiac implantable electronic device (CIED). Patients unable to perform handgrip strength (HGS) measurements due to physical limitations—such as paralysis, amputation, rheumatoid arthritis, arm fractures, osteoarthritis in the hand, large abdominal wounds, or extensive chest wounds following coronary artery bypass grafting (CABG) or hemodialysis shunt placement—were also excluded.

Measurements

Anthropometric assessments, SARC-F screening, HGS measurement, and BIA analysis were conducted sequentially at a single time point, following standardized protocols outlined in the Standard Operating Procedure (SOP) of the Nutritional Assessment Platform [31]. Data was stored in Castor Electronic Data Capture (EDC) and was checked for missing data and errors.

All tests were non-invasive, posed no additional risks, and were performed within 48 hours of hospital admission. The total assessment time averaged approximately 15 minutes.

Sarcopenia risk, probable sarcopenia, and sarcopenia diagnosis were determined using the guideline by the European Working Group on Sarcopenia in Older People of 2019 (EWGSOP2) [1].

Anthropometry

Body weight (kg) and height (cm) were measured in light clothing, without shoes, to the nearest 0.1 kg and 0.1 cm using standardized equipment (SECA 704 column scale with integrated measuring rod) and SOP.

SARC-F

SARC-F is a brief questionnaire consisting of five items, with response options for each question as follows: 0 = none, 1 = some, and 2 = a lot or unable [19]. The total score can range from 0 to 10 points, with a cut-off score of ≥ 4 indicating a positive risk for sarcopenia according to EWGSOP2 [32]. However, previous studies suggest

that the optimal cut-off value may vary depending on the population. Therefore, alternative cut-off points of ≥2, ≥3, and ≥6 were also analyzed in this study [33-36]. The SARC-F questionnaire was administered by a dietician or research nurse through an interview focused on the patient's "usual" home situation, rather than their acute condition during hospitalization.

Handgrip strength

HGS was measured in kilograms using the Jamar hand dynamometer (Patterson Medical Manufacturer), which has a maximum strength of 90 kg [37]. The SOP involved the patient sitting, with the arm at a 90-degree angle, the wrist in a neutral position, and unsupported. Verbal encouragement was provided during the test. Both the dominant and non-dominant hands were measured three times, with 30-second intervals between measurements to prevent fatigue. The highest value from both hands was recorded as the HGS result [32, 38]. To assess probable sarcopenia, the study used the EWGSOP2-recommended cut-off points for handgrip strength: less than 27 kg for males and less than 16 kg for females [1, 39].

Bioelectrical Impedance Analysis procedure

Fat-free mass (FFM) was assessed using Bioelectrical Impedance Analysis (BIA) with the Bodystat 500 device (Bodystat, EuroMedix) according to the SOP [31, 40]. FFM primarily reflects muscle mass, which constitutes most of the body's intracellular water, but it also includes bone and organ tissue, excluding fat. Muscle mass refers to the collective muscle tissue in the body. The BIA device measures impedance (tissue resistance and reactance) when a low-voltage current of 50 kHz is passed through the body. FFM was then calculated using the Kyle formula, which incorporates resistance, height, weight, gender, and age [41-44].

The accuracy of BIA measurements is influenced by tissue hydration status [29]. To mitigate this, all BIA analyses were supplemented with bioelectrical impedance vector analysis (BIVA), which is independent of hydration status and served as a quality control measure for accurate interpretation of BIA results [40, 45, 46]. BIVA was performed using BodygramPlus software (version 1.2.1, Akern) to ensure the validity of the single-frequency BIA measurement. BIVA results are presented on a nomogram with tolerance ellipses corresponding to the 50th, 75th, and 95th percentiles of a healthy reference population. Values outside the 95th percentile are considered abnormal and may indicate fluid retention, leading to exclusion from data analysis (Figure 1).

Subsequently, appendicular skeletal muscle mass (ASSM) was calculated using BIA measurement, weight, and gender. The appendicular skeletal muscle mass index

(ASSMI) was derived by adjusting ASSM for body size using height squared (ASSM/height^2), providing a more reliable assessment of muscle mass, as it accounts for body size and height differences. This makes the ASSMI a more accurate indicator of sarcopenia [1, 23, 31, 47]. The ASSM formula of Kyle was applied to patients aged 50-60 years, while the Sergi formula was used for patients older than 60 years [48]. Sarcopenia was defined by a combination of low muscle strength and low muscle mass using the EWGSOP2-recommended cut-off points for ASSMI: < 7.0 kg/m^2 for men and < 5.5 kg/m^2 for women [1].

Statistical analyses

Normally distributed continuous data were presented as means with standard deviation (SD), while skewed continuous data were presented as medians with interquartile range (IQR). Categorical data were expressed as numbers and percentages.

The primary outcome, diagnostic accuracy of the SARC-F for predicting sarcopenia diagnosis, was assessed through sensitivity, specificity, and receiver operating characteristic (ROC) analysis, with the area under the curve (AUC) as the performance measure. In addition to the continuous SARC-F and standard cut-off of ≥4, cut-off points of 2, 3 and 6 were also analyzed [33-36].

The same approach was applied to the secondary outcomes: the diagnostic accuracy of handgrip strength (HGS) in predicting sarcopenia diagnosis, and the accuracy of the SARC-F in identifying probable sarcopenia.

A 2x2 contingency table was used to represent the incidence and overlap of sarcopenia risk, probable sarcopenia, sarcopenia diagnosis.

Sensitivity and specificity were categorized as poor (<50%), moderate (>50% and <80%), and good (≥80%). AUC values were classified as poor (<0.60), moderate (0.60–0.80), and good (>0.80). The SARC-F was considered valid when the diagnostic accuracy, defined by AUC, exceeded 0.80.

Results

A total of 266 inpatients admitted to Canisius Wilhelmina Hospital (CWZ) in Nijmegen between February and April 2024 were tested, with 11 patients excluded for various reasons (Figure 1). The characteristics of the remaining 255 participants (59% male, 41% female) are presented in Table 1. Of these, 72 (28%) were at risk for

sarcopenia, 50 (20%) had probable sarcopenia, and 22 (9%) were diagnosed with sarcopenia based on HGS and BIA. The incidence and overlap of these categories are provided in Table 2.

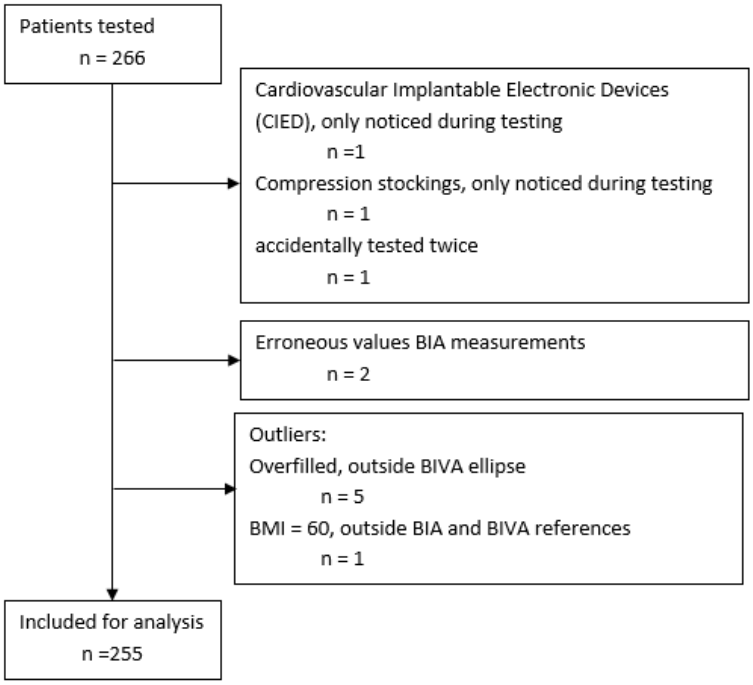

Figure 1 Flow chart of study participants.

Table 1 Characteristics of participants. Mean + SD, median [IQR], n (%)

	Total (n = 255)	**Male (n=151)**	**Female (n=104)**
Age (years)	71.0 ± 9.8	70.6 ± 8.9	70.9 ± 11.0
Length (cm)	173 ± 9.9	178 ± 7.4	165 ± 8.0
Weight (kg)	80.2 ± 17.3	85.2 ± 16.7	73.0 ± 11.0
BMI (kg/m^2)	26.9 ± 5.2	27.0 ± 5.0	26.9 ± 5.5
SARC-F score (points)	2 [3]	2.5 [3]	1 [3]
Handgrip strength (kg)	31.2 ± 13.1	37.8 ± 11.6	21.6 ± 8.3
Appendicular muscle mass index (kg/m^2)	6.8 ± 1.1	6.8 ± 1.0	6.2 ± 1.0
At risk for sarcopenia based on SARC-F	72 (28.2%)	37 (24.5%)	35 (33.7%)
Probable sarcopenia based on HGS	50 (19.6%)	25 (16.6%)	25 (24.0%)
Diagnosis sarcopenia based on HGS and BIA	22 (8.6 %)	14 (9.3 %)	8 (7.7%)

Table 2 Incidence of risk of sarcopenia, probable sarcopenia, and sarcopenia diagnosis

Table 2a Incidence of the risk for sarcopenia (SARC-F≥4) and sarcopenia diagnosis (low handgrip strength and low muscle mass)

	Sarcopenia diagnosis	No sarcopenia diagnosis	
At risk for sarcopenia	13	59	72
Not at risk for sarcopenia	9	174	183
	22	233	

Table 2b Incidence of the risk for sarcopenia (SARC-F≥4) and probable sarcopenia (low handgrip strength) (n values)

	Probable sarcopenia	No probable sarcopenia	
At risk for sarcopenia	24	48	72
Not at risk for sarcopenia	26	157	183
	50	205	

Table 2c Incidence of probable sarcopenia (low handgrip strength) and sarcopenia diagnosis (low handgrip strength and low muscle mass)

	Sarcopenia diagnosis	No sarcopenia diagnosis	
Probable sarcopenia	22	28	50
No probable sarcopenia	0	205	205
	22	233	

The primary analysis showed SARC-F demonstrated moderate sensitivity (59%) and specificity (75%) for diagnosing sarcopenia. The PPV was 18%, and the NPV was 95%. Lowering the SARC-F cut-off leads to increased sensitivity and decreased specificity. The highest sensitivity (91%) was seen when using a cut-off of ≥2, with moderate specificity (53%). AUC analysis revealed moderate accuracy for the continuous SARC-F variable in predicting sarcopenia diagnosis (0.74). SARC-F with a cut-off of ≥2 had the highest AUC of all cut-offs tested (0.66) (Table 3, Supporting information).

Table 3 Accuracy of SARC-F to predict sarcopenia diagnosis (EWGSOP2) in hospitalized patients. PPV, Positive Predictive Value; NPV, Negative Predictive Value; AUC, Area Under the Curve; CI, Confidence Interval.

	Sensitivity	Specificity	PPV	NPV	AUC (95% CI)
Continuous		n/a			0.74 (0.64-0.85)
Cut-off≥2	91%	53%	16%	98%	0.72 (0.65-0.79)
Cut-off≥3	68%	61%	14%	95%	0.65 (0.54-0.75)
Cut-off≥4	59%	75%	18%	95%	0.67 (0.56-0.78)
Cut-off≥6	32%	90%	23%	93%	0.61 (0.51-0.71)

Secondary analysis showed HGS exhibited high specificity (88%) for diagnosing sarcopenia, with 100% sensitivity. The PPV was 44%, and the NPV was 100%. HGS demonstrated good accuracy in diagnosing sarcopenia, with an AUC of 0.94 (95% CI 0.92–0.96) (Supporting information). SARC-F displayed poor sensitivity (48%) and moderate specificity (77%) for identifying probable sarcopenia. The positive predictive value (PPV) for probable sarcopenia was 33%, and the negative predictive value (NPV) was 86%. AUC analysis revealed moderate accuracy for the continuous SARC-F variable in predicting probable sarcopenia (0.69) (Supporting information).

Discussion

This study evaluated the diagnostic accuracy of the SARC-F questionnaire to predict sarcopenia diagnosis in hospitalized patients aged 50 years and older. Our findings reveal that the SARC-F exhibits poor sensitivity (59%), moderate specificity (75%), and an AUC of 0.74 for predicting sarcopenia diagnosis. While its specificity was acceptable, these results indicate that a considerable proportion of patients at risk for sarcopenia may go undetected when relying on SARC-F alone due to poor sensitivity. Secondly, HGS showed high specificity (88%) and an AUC of 0.94 to predict sarcopenia diagnosis. For identifying probable sarcopenia, SARC-F exhibits poor sensitivity (48%), moderate specificity (77%), and an AUC of 0.69.

In contrast to our findings, a recent meta-analysis using EWGSOP2 criteria across various populations reported higher sensitivity (77%) but lower specificity (63%) and a comparable AUC (0.75) [49]. We believe the age and context of the study population are highly determinant of the outcome of these tests and think one measurement outcome or cut-off may not be the best candidate for alle populations. Studies in a more similar context to our study also show higher sensitivity and lower specificity and AUC. In geriatric rehabilitation patients, SARC-F showed a sensitivity of 74–84%, but specificity was low (20–37%) with an AUC of 0.52–0.56 [50], while in hospitalized geriatric patients, sensitivity was 72%, specificity 41%, and AUC 0.63 [51]. However, these populations were significantly older than ours (mean ages of 84 and 79, respectively), with our populations mean age of 71. The higher sensitivity and lower specificity observed in older populations may be attributed to the increased prevalence of sarcopenia, as higher prevalence can influence diagnostic test characteristics by increasing sensitivity and decreasing specificity [52]. This underscores the limitation of relying on a single measurement or universal cut-off across diverse populations, and highlights that the performance of the SARC-F varies depending on age and clinical context.

The SARC-F is a self-report instrument and is susceptible to self-report bias—a discrepancy between reported and actual functional capacity [25, 53]. We observed that some patients struggled to interpret certain SARC-F questions. Patients encountered two main challenges when completing the SARC-F. First, the interpretation of certain questions was difficult. For example, many participants were unsure what a 5 kg (10-pound) object represents in daily life, making it hard to answer accurately. Second, the reference to the "usual home situation prior to hospitalization" was inconsistently interpreted. While some referred to the past week or month, others based their answers on their condition years ago. To reduce recall bias, we recommend anchoring responses to a specific time frame, such as "the past month.". Moreover, the current SARC-F mainly focuses on self-reported muscle strength and physical performance, while it neglects muscle mass—an essential component of sarcopenia as defined by the Global Leadership Initiative on Sarcopenia (GLIS) [54]. This limitation may lead to underdiagnosis in individuals with muscle wasting who have not yet developed significant functional impairments. To address this, the inclusion of a question regarding perceived muscle mass loss could enhance the questionnaire's sensitivity. Additionally, incorporating a simple, objective measurement of muscle mass such as calf circumference, as used in the SARC-Calf, has shown promise in increasing diagnostic accuracy, particularly in clinical populations [51]. These adjustments may offer a more comprehensive and practical approach to identifying patients at risk of sarcopenia in hospital settings.

Strengths and limitations

This study provides valuable insight into the hospitalized population aged over 50 years, a group at elevated risk for sarcopenia. It evaluates the diagnostic accuracy of SARC-F for sarcopenia diagnosis, as well as the performance of HGS and the ability of SARC-F to predict probable sarcopenia. The study was conducted using SOPs and involved well-trained dietitians and research nurses, ensuring consistent and reliable testing. Additionally, feedback from both healthcare professionals and patients on the screening tools contributed to practical recommendations for improving sarcopenia screening in clinical practice.

However, several limitations should be acknowledged. First, muscle mass was assessed using BIA, which is sensitive to hydration status and may result in over- or underestimation [50]. To mitigate this, bioelectrical impedance vector analysis (BIVA) was employed to exclude participants with abnormal hydration levels. Second, the number of confirmed sarcopenia cases was relatively low (n=22), reflecting a lower-than-expected prevalence of 8.6% compared to 23–37% in other hospital-based studies, depending on the population and diagnostic criteria

used [10-14]. This low prevalence may be attributed to the average age of our study participants, which is 71 years, lower than in most studies. Furthermore, planned admission patients were also included, who tend to be more physically fit than acutely admitted patients [55]. Lastly, the use of a convenience sample from a single center over a limited three-month period may have introduced selection bias, limiting the generalizability of the findings.

Clinical implications

Due to the low sensitivity of the SARC-F in hospitalized patients, handgrip strength (HGS) should be used as the initial step in sarcopenia assessment in this population. HGS demonstrated substantially higher sensitivity and is readily available in clinical settings, offering both objective results and valuable feedback for patients. If HGS is not available, lowering the SARC-F cut-off can improve sensitivity, although this comes at the cost of reduced specificity. Sensitivity may be further enhanced by refining SARC-F items or incorporating an additional question or simple measurement of muscle mass. Nevertheless, since a positive SARC-F screening would typically be followed by HGS, its added value as a first step is limited. These findings highlight the limitations of a fixed cut-off and support the use of HGS as a more practical and informative first-line assessment in this setting.

Conclusion

Given the poor diagnostic accuracy of SARC-F in hospitalized adults aged over 50, it is not an appropriate tool for sarcopenia screening in this setting. Instead, we recommend direct assessment of muscle strength using HGS as the first-line method for identifying sarcopenia. HGS offers a more reliable and objective measure of sarcopenia in this population. Adopting this approach may facilitate earlier detection and intervention, ultimately improving patient outcomes and enabling more targeted care for those at risk.

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Supporting information

Table I Accuracy of SARC-F to predict probable sarcopenia (EWGSOP2) in hospitalized patients. PPV, Positive Predictive Value; NPV, Negative Predictive Value; AUC, Area Under the Curve; CI, Confidence Interval.

	Sensitivity	Specificity	PPV	NPV	AUC (95% CI)
Continuous		n/a			0.69 (0.61-0.77)
Cut-off≥2	76%	56%	29%	90%	0.66 (0.59-0.73)
Cut-off≥3	58%	62%	27%	86%	0.60 (0.53-0.68)
Cut-off≥4	48%	77%	33%	86%	0.62 (0.55-0.70)
Cut-off≥6	26%	92%	43%	84%	0.59 (0.52-0.65)

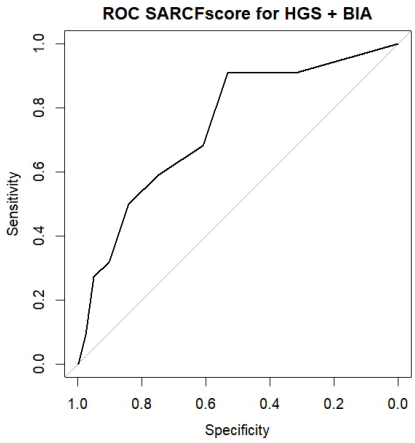

Figure I Comparative ROC of the sensitivity and specificity of the SARC-F to diagnose sarcopenia (HGS and BIA). AUC SARC-F to predict sarcopenia diagnosis: 0.74

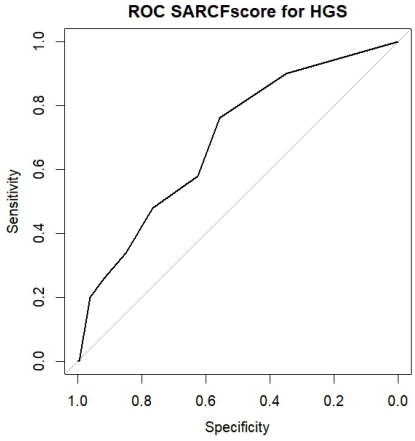

Figure II Comparative ROC of the sensitivity and specificity of the SARC-F to predict probable sarcopenia (HGS). AUC SARC-F to predict probable sarcopenia: 0.69

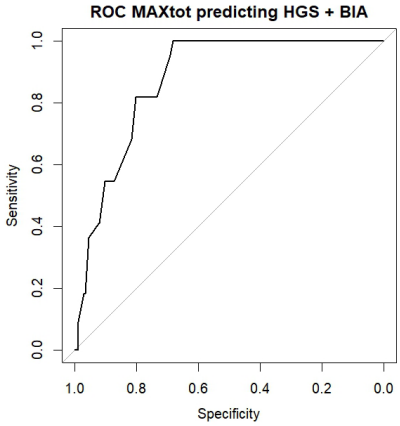

Figure III ROC of the sensitivity and specificity of handgrip strength to predict sarcopenia diagnosis (HGS and BIA). AUC HGS to predict sarcopenia diagnosis: 0.74

Part II

Interventions

Chapter 4

Adherence to and efficacy of the nutritional intervention in multimodal prehabilitation in colorectal and esophageal cancer patients

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Abstract

Background

Multimodal prehabilitation programs to improve physical fitness before surgery often include nutritional interventions. This study evaluates the efficacy of and adherence to a nutritional intervention among colorectal and esophageal cancer patients undergoing the multimodal Fit4Surgery prehabilitation program.

Methods

The intervention aims to achieve an intake of ≥1.5 g of protein/kg body weight (BW) per day through dietary advice and daily nutritional supplementation (30 g whey protein).

Results

This study shows 56.3% of patients met this goal after prehabilitation. Mean daily protein intake significantly increased from 1.20 ± 0.39 g/kg BW at baseline to 1.61 ± 0.41 g/kg BW after prehabilitation ($p < 0.001$), with the main increase during the evening snack. BW, BMI, 5-CST, and protein intake at baseline were associated with adherence to the nutritional intervention.

Conclusion

These outcomes suggest that dietary counseling and protein supplementation can significantly improve protein intake in different patient groups undergoing a multimodal prehabilitation program.

Trial registration and ethics

This research received no external funding. The authors declare no conflicts of interest. Ethical approval for this study was granted by the CMO Arnhem-Nijmegen (NL73777.091.20). Informed consent was obtained from all participants. Data supporting the findings of this study are available from the corresponding author upon reasonable request.

Introduction

The cornerstone of most oncological treatment regimens is surgery. In colorectal (CRC) and esophageal cancer (EsC) surgery, postoperative complications occur in approximately 33% and 40% of patients, respectively [1, 2]. These complications are associated with a prolonged hospital stay, increased mortality rate, hospital costs, and a lower reported quality of life [1-5]. Even in the absence of complications, both functional and physiological capacity are known to diminish in the postoperative period, as surgery represents a major stressor [6, 7].

Preoperative physical fitness has consistently been associated with postoperative outcomes after major elective surgery [8-11]. Therefore, the preoperative period is increasingly considered an opportunity to improve patients' preoperative physical status, a process termed prehabilitation. Modern prehabilitation programs encompass multiple modalities, including physical exercise, nutritional interventions, psychological support, and smoking cessation programs. Currently, multimodal prehabilitation has mainly been studied in CRC surgery, with patients showing increased preoperative physical fitness, reduced postoperative complications, and shortened length of stay [12-14].

Nutritional interventions within prehabilitation programs mainly focus on adequate protein, energy, and micronutrient intake. The average healthy person is estimated to require 0.83 g of protein/kg body weight (BW)/day, while protein requirements for presurgical cancer patients are at least 1.2–1.5 g/kg BW/day [15-17]. However, many cancer patients do not meet this minimum recommended intake [18]. Compared to CRC patients, EsC patients are more often nutritionally compromised, which is the result of physical complaints such as rapidly developing dysphagia [19, 20]. Since malnutrition has been associated with increased morbidity and mortality, early screening and optimization of the nutritional status in EsC patients awaiting surgery is common practice in the Netherlands. Dietary management in some EsC patients consists of enteral tube feeding or oral nutritional supplementation (ONS).

Patients participating in a prehabilitation program require a higher total intake of protein in order to stimulate exercise-induced muscle protein synthesis (MPS) [21]. Increased protein intake during prehabilitation programs is often achieved via providing patients with dietary advice and supplemental nutrients [22-24]. Protein intake is most effective for MPS when spread throughout the day, with multiple high-protein meals resulting in so-called protein peaks [25-27].

When striving for MPS, energy requirements should also be taken into account to maintain a stable or anabolic nutritional state [15]. Energy requirements can be calculated using the World Health Organization (WHO) formula, which includes a surcharge factor to account for physical activity or illness [28]. Complementary to this, micronutrients may be supplied to achieve the recommended daily intake, with a special focus on vitamin D, as this micronutrient plays an important role in maintaining muscle function and promotes protein synthesis [29, 30].

Measuring adherence to a nutritional intervention is vital to determine the intervention's efficacy and feasibility correctly. However, adherence to nutritional interventions in multimodal prehabilitation programs is often not reported or lacks a detailed description of nutritional intake [22, 24, 31, 32]. This study aims to evaluate adherence to a nutritional objective of reaching a total protein intake of 1.5 g of protein/kg BW/day in CRC and EsC patients undergoing the multimodal Fit4Surgery prehabilitation program. Daily protein intake and distribution throughout the day are determined at baseline and after prehabilitation. Furthermore, energy intake and the intake of protein supplements and multivitamins are recorded. Additionally, it is investigated whether certain patient characteristics at baseline may be associated with nutritional adherence in order to further optimize the prehabilitation program based on specific patient characteristics and needs.

Methods

Study design

In this exploratory prospective cohort study, data were derived from patients participating in the F4S PREHAB trial, performed in the Radboudumc (Nijmegen, The Netherlands). The trial received ethical approval from METC Oost-Nederland (NL73777.091.20). The trial has been registered in the International Clinical Trials Registry Platform (NL8699). The methods and outline of the study protocol can be found in the Supporting information.

Study Population

Patients aged sixteen years and older, undergoing a multimodal prehabilitation program prior to elective high-impact surgery for CRC or EsC, were included.

Exclusion criteria in the F4S PREHAB trial were premorbid conditions (i.e., respiratory or cardiac disease) or impaired mobility that hampered or contraindicated exercise, cognitive disabilities, inability to read and understand the Dutch language, an

American Society of Anesthesiologists (ASA) score ≥ 4 (a subjective assessment of a patient's overall health), and chronic kidney disease at a stage ≥ 3. An additional exclusion criterion in this study was missing data regarding nutritional intake at baseline or after prehabilitation.

Study Outline

In addition to standard preoperative care, patients underwent a personalized multimodal prehabilitation program. The length of the program depended on the available time between diagnosis and surgery. In the case of neoadjuvant chemoradiotherapy, the start of the intervention was postponed until the last treatment. This multimodal prehabilitation program contained four different modalities: a nutritional intervention, an exercise program, psychological support, and a smoking cessation program (Supporting information).

Nutritional assessment occurred at baseline and prior to surgery (after prehabilitation), collecting the following parameters: BW, height, hand grip strength, fat free mass measured through bioelectrical impedance analysis (BIA), and a three-day food diary. A general impression of a patient's nutritional status was obtained using the Patient-Generated Subjective Global Assessment Short Form (PG-SGA SF). Additionally, all patients were referred to a registered in-hospital dietician in order to provide personalized dietary advice aiming for optimal nutritional intake (protein, energy, and micronutrients) to support achieving an anabolic state and enhancing the effect of physical training on lean body mass increment.

A daily protein intake of at least 1.5 g/kg BW was aimed for since it is fundamental for muscle health [33, 34]. BW was corrected for patients with a body mass index (BMI) lower than 20 or higher than 30 to fit a BMI of 20 or 27.5, respectively [35, 36]. Nutritional advice was given to aim for at least two meals per day containing 25 g of protein or more. Patients received high-quality whey protein shakes (Nutri Whey™ Isolate, FrieslandCampina, Wageningen, the Netherlands) containing 30 g of whey protein and 20 µg vitamin D. Patients were instructed to consume the protein shakes before bedtime on a daily basis, and an additional shake within one hour following supervised exercise. Patients relying on tube feeding received one sachet of PROSource NoCarb (Generic Life quality enhancing Niche Products, GLNP, Naarden, the Netherlands) daily, containing 15 g of protein. Energy requirements were calculated using the WHO formula with a 30% addition to account for physical activity. Additionally, daily multivitamin supplementation (50% of the daily recommendation) was provided to all patients to target possible vitamin deficiencies.

The exercise program was preceded by an assessment and screening using the American College of Sports Medicine (ACSM) exercise preparticipation health screening questionnaire to identify possible individuals at risk of exercise-related adverse cardiovascular events. Exercise was supervised by a first-line physiotherapist and performed two to three times a week, focusing on both resistance and high-intensity endurance training. Patients were also advised to perform 60 min of low-intensity aerobic exercise on days without supervised training.

Patients at risk for anxiety and depression were identified using the Hospital Anxiety and Depression Scale (HADS) and referred to a trained psychologist to improve coping mechanisms regarding future surgery. Furthermore, all active smokers were offered a smoking cessation program, including counseling and nicotine replacement therapy.

Study outcomes

The primary aim of this study was to assess the adherence of patients to the nutritional intervention (daily protein intake ≥1.5 g/kg BW or ≥1.9 g/kg FFM [37]). The total protein intake was measured using three-day food records including two weekdays and one weekend day, at baseline and after prehabilitation, and expressed as g per day, g per kg BW per day, and g per kg fat-free mass (FFM) per day. Food records were structured according to meal moments. During dietary consultations at baseline and after prehabilitation, food records were reviewed by both patient and dietician to ensure an adequate description of dietary intake. A dietary history assessment was conducted in case of incomplete food records. Nutrient intake was calculated using Evry (version 2.7.4.2), a dietary calculation tool based on the Dutch Food Composition Table 7.0 (National Institute for Public Health and the Environment, Bilthoven, the Netherlands).

Secondary outcomes were protein distribution throughout the day (defined as the number of patients achieving ≥25 g in at least two meals per day), daily energy intake, and daily consumption of protein and multivitamin supplements. Furthermore, characteristics associated with adherence to the nutritional intervention were evaluated.

Statistical analyses

Baseline characteristics of the study population and data regarding protocol adherence and nutritional intake were described separately for CRC and EsC patients. To determine potential associations with adherence, baseline characteristics were also described separately for adherent and non-adherent patients. Continuous

data are presented as mean ± SD or median [inter-quartile range] in normally and non-normally distributed data, respectively, and compared using independent samples t-tests or Mann–Whitney U tests. Categorical data are described as total numbers (percentages) and compared using chi-square and Fisher's exact tests. The difference in protein goal achievement between baseline and after prehabilitation was compared using McNemar's test for related samples. Changes in protein intake per meal moment between baseline and after prehabilitation were compared using the Wilcoxon signed rank test.

Results

Baseline characteristics of the study population

Between March 2021 and September 2022, 139 CRC and EsC patients were included in the F4S PREHAB trial. After the exclusion of 75 patients due to incomplete or missing data on nutritional intake at baseline or after prehabilitation, 35 CRC and 29 EsC patients were eligible for analysis (Table 1). Patients had a median age of 66 years at the time of inclusion and were predominantly male (70.3%), without significant differences between CRC and EsC patients. The PG-SGA SF score was significantly higher in EsC patients compared to CRC patients (7 [8] vs. 2 [4], $p = 0.003$). Ten (15.6%) patients were at high risk for malnutrition based on the PG-SGA SF score. Among EsC patients, 20 (69.0%) received either tube feeding or ONS at baseline.

Daily protein intake at baseline and after prehabilitation

Daily protein intake relative to kg BW increased significantly from 1.20 ± 0.39 g/kg BW at baseline to 1.61 ± 0.41 g/kg BW after prehabilitation in the total study population ($p < 0.001$). Analysis in CRC and EsC patients showed a significant increase in relative daily protein intake after prehabilitation compared to baseline, from 1.09 ± 0.40 g/kg BW and 1.33 ± 0.34 g/kg BW to 1.61 ± 0.45 g/kg BW and 1.61 ± 0.39 g/kg BW, respectively, with a higher increment in protein intake per kg BW in CRC patients ($p = 0.006$) (Figure 1).

At baseline, the number of patients with a mean protein intake of ≥1.5 g/kg BW per day was 12 (18.8%), which increased to 36 (56.3%) following prehabilitation ($p < 0.001$) (Figure 2). Additional analyses comparing the number of patients achieving mean protein intakes of ≥1.2 and ≥0.83 g/kg BW at baseline and after prehabilitation showed increments of 30 (46.9%) to 54 (84.4%) patients and 52 (81.2%) to 63 (98.5%) patients, respectively, both statistically significant ($p < 0.001$).

Considering the protein intake per kg FFM, a total of 46 (75.4%) patients achieved a mean protein intake of 1.9 g/kg FFM after prehabilitation, compared to 19 (31.1%) at baseline. Protein intake relative to FFM also significantly increased from 1.70 ± 0.66 g/kg FFM to 2.27 ± 0.75 g/kg FFM for the total study population ($p < 0.001$) (Supporting information).

Table 1 Baseline characteristics of the study population.

Characteristic	All Patients (n = 64)	CRC (n = 35)	EsC (n = 29)	*p*-Value
Age in years, median [IQR]	66 [16]	65 [16]	66 [15]	0.746
Male sex (%)	45 (70.3%)	24 (68.6%)	21 (72.4%)	0.738
ASA score				
I	3 (4.7%)	3 (8.6%)	0 (0)	0.264
II	45 (70.3%)	24 (68.6%)	21 (72.4%)	
III	16 (25.0%)	8 (22.9%)	8 (27.6%)	
Weight in kg, median [IQR]	77 [19]	72 [26]	81 [12]	0.103
Fat free mass in kg, mean ± SD	54.5 ± 10.6	53.8 ± 11.3	55.4 ± 9.8	0.572
Fat-free mass index in kg/m^2, mean ± SD	18.1 ± 2.3	18.1 ± 2.5	18.1 ± 2.1	0.954
BMI in kg/m^2, median [IQR]	26 [4]	25 [8]	27 [2]	0.671
Smoking				0.357
No	19 (29.7%)	13 (37.1%)	6 (20.7%)	
Yes	8 (12.5%)	4 (11.4%)	4 (13.8%)	
Former smoker	37 (57.8%)	18 (51.4%)	19 (65.5%)	
Hand grip strength at baseline in kg, mean ± SD	38.0 ± 13.1	37.5 ± 14.4	38.6 ± 11.5	0.739
Male	43.5 ± 11.1	43.5 ± 13.0	43.6 ± 8.7	0.967
Female	25.1 ± 6.9	24.9 ± 7.6	25.4 ± 6.2	0.889
5-CST in seconds, median [IQR]	9 [4]	9 [4]	9 [5]	0.569
PG-SGA score, median [IQR]	3 [8]	2 [4]	7 [8]	0.003
PG-SGA categories (%)				<0.001
Low risk (≤3)	33 (51.6%)	25 (71.4%)	8 (27.6%)	
Moderate risk (4–8)	21 (32.8%)	8 (22.9%)	13 (44.8%)	
High risk (≥9)	10 (15.6%)	2 (5.7%)	8 (27.6%)	
Oral Nutritional Supplement (%)	10 (15.6%)	0 (0)	10 (34.5%)	<0.001
Tube feeding (%)	10 (15.6%)	0 (0)	10 (34.5%)	<0.001
Number of trainings, median [IQR]	9 [6]	10 [5]	8 [5]	0.267
Duration of prehabilitation in days [IQR]	34 [12]	33 [8]	35 [24]	0.204

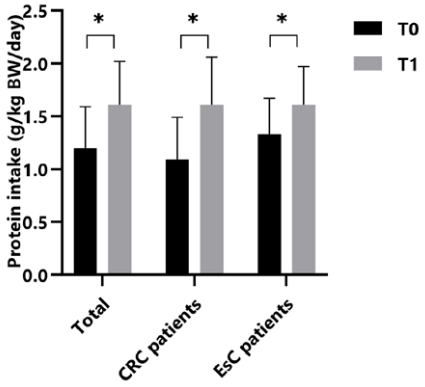

Figure 1 Daily protein intake corrected for body weight (BW) between baseline and after prehabilitation, presented for the total population (n = 64), colorectal cancer (CRC) patients (n = 35), and esophageal cancer (EsC) patients (n = 29). * $p < 0.05$.

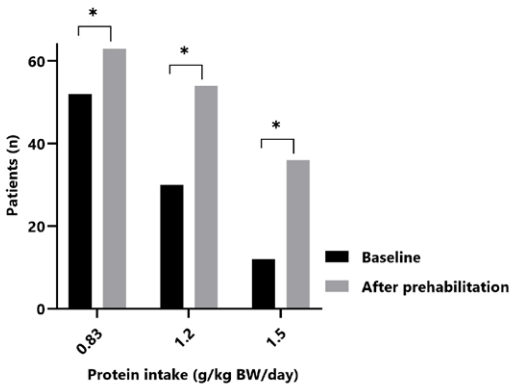

Figure 2 Number of patients achieving daily protein goals set to 0.83 g/kg bodyweight (BW), 1.2 g/kg BW, and 1.5 g/kg BW at baseline and after prehabilitation. * $p < 0.05$.

The crude daily protein intake increased significantly in this study population from 93 ± 31 g/day at baseline to 124 ± 28 g/day after prehabilitation ($p < 0.001$). EsC patients had a significantly higher protein intake compared to CRC patients at baseline (107 ± 30 g/day vs. 82 ± 27 g/day, $p < 0.001$). However, there was no significant difference between the groups after prehabilitation (129 ± 30 g/day vs. 121 ± 27 g/day, $p = 0.248$). The total increase in protein intake was lower in EsC patients compared to CRC patients (22 ± 27 g/day vs. 39 ± 23 g/day, $p = 0.009$).

Daily protein intake at baseline and after prehabilitation per meal moment

Daily protein intake per meal moment was analyzed for 54 patients, since 10 patients received continuous tube feeding. Median protein intake was highest at dinner, both at baseline and after prehabilitation (Figure 3). Protein intake increased significantly during breakfast as well as morning, afternoon, and evening snacks, while the changes were non-significant for lunch and dinner. The largest increase in protein intake was during the evening snack (4.1 [7.5] g vs. 34.8 [8.3] g, $p < 0.001$).

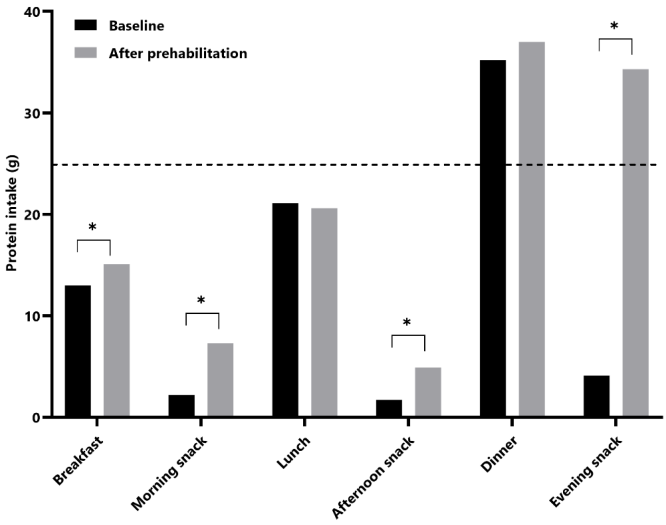

Figure 3 Median protein intake in grams (g) per meal for n = 54 patients at baseline and after prehabilitation. Threshold of 25 g protein visualized as dashed line. * $p < 0.05$.

A mean protein intake of ≥25 g in ≥2 meals per day was achieved by 43 (79.6%) patients, which was a significant increase when compared to 20 (37.0%) patients at baseline ($p < 0.001$). After prehabilitation, median protein intake was ≥25 g for dinner and the evening snack.

Energy and Supplement Intake

Mean (SD) energy intake at baseline was 2040 (570) kcal and significantly increased to 2287 (513) kcal after prehabilitation ($p < 0.001$). This meant that 29 (45.3%) patients achieved the energy requirement of WHO + 30% at baseline, and 46 (71.8%) achieved this after prehabilitation ($p < 0.001$).

Almost all patients (59 (92.2%)) reported daily consumption of protein shakes. Adherence to daily multivitamin supplementation was reported by 54 (84.4%) patients.

Characteristics Associated with Nutritional Adherence

There were no significant differences between adherence and non-adherence to the primary nutritional goal regarding age and sex. Patients who had a daily protein intake of ≥1.5 g/kg BW had a significantly lower BMI compared to patients who had not (25 [5] vs. 28 [4], $p < 0.001$). Patients who were adherent also had a faster 5-CST time in seconds (8 [3] vs. 9 [5], $p = 0.017$) and higher protein intake at baseline in g/kg BW/day (1.36 ± 0.39 vs. 0.99 ± 0.27, $p < 0.001$) compared to patients who were non-adherent (Supporting information).

Discussion

This study shows that 56% of patients with CRC and EsC met the primary criterion of ≥1.5 g protein/kg BW per day after prehabilitation. The total protein intake increased from 1.2 g/kg BW per day to more than 1.6 g/kg BW per day in this study population, without significant difference between CRC and EsC patients. Additionally, adherence to daily consumption of nutritional supplements was more than 90%. With a mean increment of 31 g of protein intake, supplementation seems essential in nutritional interventions as part of multimodal prehabilitation programs.

Protein intake per meal moment significantly increased during breakfast as well as morning, afternoon, and evening snacks. The distribution of protein intake across meal times was found to be skewed towards the end of the day. The largest increase in protein intake was observed during the evening snack, which corresponds to the protocol recommendation to consume daily protein shakes before bedtime. Consuming a high amount of protein during the evening can stimulate overnight muscle protein synthesis [38]. Although protein intake during breakfast increased significantly, it remained relatively low and could be improved through providing additional nutritional advice to achieve a high-protein breakfast. Protein supplementation at breakfast might be an effective way to increase protein intake during prehabilitation. Protein intake during lunch did not change significantly, but mean intake nearly reached the threshold of ≥25 g protein. Nutritional advice encouraging a small increase in protein during lunch could help reach the threshold of ≥25 g protein. Reaching a third or even fourth peak in protein intake would further stimulate MPS and remove the skewness of the protein intake distribution [39, 40]. Our study found that nearly 80% of patients reached ≥2 mean peaks of ≥25 g protein per day. A previous study in preoperative patients prescribed six protein-rich dishes per day and reported ≥2 peaks of ≥20 g protein per day in merely one-third of patients [41]. This finding further emphasizes that protein supplementation can be helpful in attaining a high-protein diet in addition to dietary changes alone.

This study found several baseline characteristics that were associated with a lowered adherence to the primary goal of this nutritional intervention. A higher median BW and median BMI were seen in patients that did not achieve the protein goal. As protein goals were not adjusted to actual body composition, they may be more difficult to attain when BW increases. A technique to eliminate heightened protein goals in patients with a high BW due to fat mass instead of lean body mass is through using FFM measurements. The protein goal based on FFM is ≥1.9 g/kg FFM

per day and is a more accurate way to determine protein requirements [42]. Results show 75% of patients achieved the protein goal based on FFM, which is higher than the 56% when protein requirements are based on BW. It is recommended that future trials use FFM to estimate protein requirements when measurements on FFM are available.

Patients that did not adhere to the daily protein goal showed a lower protein intake at baseline, both absolute and relative. This indicates that nutritional support may be even more important for patients with a lower protein intake at baseline. Intensive dietary counseling focusing on extra protein intake during breakfast and lunch may be helpful. Furthermore, patients with a reduced food intake may benefit from an additional serving of protein supplementation. Non-adherent patients also needed more time to complete the 5-CST at baseline. This suggests physical capacity at baseline may impact protocol adherence and possibly correlates with a prolonged protein deficit. Since protein intake is essential to retain and gain muscle strength, insufficient intake may lead to reduced muscle strength and physical performance [43].

To evaluate and compare nutritional adherence in patients with a compromised nutritional status, this study included both CRC and EsC patients undergoing elective surgery. EsC patients are often nutritionally compromised due to physical restrictions such as dysphagia and adverse effects caused by neoadjuvant treatment. However, these patients had higher protein intake at baseline. This could be the result of the majority of EsC patients (69%) receiving either tube feeding or ONS prior to prehabilitation. Furthermore, EsC patients already receive extensive dietary counseling before neoadjuvant treatment as part of standard preoperative care in the Netherlands. The higher protein intake at baseline in EsC patients supports the relevance of the early involvement of a registered dietician in the dietary management of those patients.

While some earlier prehabilitation studies did report adherence to the intake of nutritional supplementation, they did not address the total dietary intake before and after prehabilitation [44, 45]. This study is one of the first to describe the assessment of adherence to a nutritional intervention in detail using validated methods. Furthermore, the results of this study show that a nutritional intervention as part of multimodal prehabilitation is feasible in different groups of patients. However, this study has some limitations. Firstly, the sample size of this study is relatively small, which limited statistical options to identify predictors regarding adherence. Secondly, selection bias might have been introduced in this study via the exclusion

of patients based on missing data on food intake. It is plausible that patients who recorded their food intake at both timepoints also had higher overall motivation regarding the nutritional intervention as part of multimodal prehabilitation.

In conclusion, the nutritional intervention as part of multimodal prehabilitation increased protein intake significantly in both CRC and EsC patients during prehabilitation. This shows that dietary counseling and providing protein supplementation are effective methods to increase protein intake in cancer patients during prehabilitation. Further dietary counseling should be given to reach additional protein peaks during breakfast and lunch. Future research, preferably estimating protein requirements using FFM, should include larger study populations to identify predictors of protocol adherence more accurately. Qualitative research on the wishes and needs of patients regarding dietary advice and supplementation can help gain more understanding of how to optimize adherence to nutritional interventions.

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Supporting information

Study Protocol Methods and Outline

Methods

Study Design

The Fit4Surgery PREHAB trial is a monocenter randomized stepped-wedge cluster trial in the Radboudumc in Nijmegen, the Netherlands. According to a stepped-wedge approach, a multimodal prehabilitation program will be implemented as standard preoperative care in one cluster every month. Patient inclusion and prospective data collection started in March 2021 and is planned to run for a total of 30 months. Additional data, regarding patients who underwent elective high-impact surgery in the two-year period prior to the start of this trial, will be gathered retrospectively.

Study Population

All patients aged sixteen years and older, undergoing elective high-impact surgery, will be included. Based on different diagnoses, patients will be grouped into twenty clusters: colon cancer, rectal cancer, esophageal cancer, liver cancer or metastases (of colorectal origin), pancreaticobiliary cancer, (retro)peritoneal malignancies, abdominal aortic aneurysm (open and endovascular repair), renal cancer, bladder cancer, supratentorial meningioma, hip arthrosis, hip or knee arthroplasty failure, head and neck cancer, mouth cancer, autologous breast reconstruction, ovarian cancer, endometrial cancer, and vulvar cancer.

Exclusion criteria are premorbid conditions (i.e., cardiac or respiratory disease) or impaired mobility that contraindicates or hampers exercise; cognitive disabilities; illiteracy (inability to read and understand the Dutch language); chronic kidney disease at stage ≥ 4, which contraindicates protein supplementation; and patients with an ASA score ≥ 4.

Study Outline

Control and Intervention Group

Patients participating in the control group will undergo standard preoperative care according to Dutch guidelines. For study purposes and measurements, patients receive three additional appointments, combined with standard pre- and postoperative outpatient clinic visits. Data regarding physical fitness, nutritional status, mental health, and health behavior in the pre- and postoperative phase will be collected.

Patients participating in the intervention group will undergo a personalized multimodal prehabilitation program with a duration of three to four weeks, depending on the available time between diagnosis and surgery. The program contains four different elements: an exercise program, a nutritional intervention, psychological support, and smoking cessation. Outcomes regarding these elements will be gathered in advance of the prehabilitation program and shortly before surgery (after prehabilitation). Prior to the start of the program, hemoglobin and glucose levels will be determined and will be addressed and treated accordingly.

Exercise Program

The content of the exercise programs consists of:

Endurance training (HIIT):

- Interval training with a total duration of 28 min, consisting of a 2 min warm-up, followed by alternating intervals of high intensity (4 intervals of 4 min) and moderate intensity (4 intervals of 3 min).
- High-intensity workload is dosed at 90% of the peak wattage obtained via the steep ramp test (corresponding to an estimated 90% VO2 peak) and aims to reach Borg scores of 15–17 and ≥85% of the age-predicted maximal heart rate [46, 47].
- Moderate intensity workload is dosed at 30% of the peak wattage.
- Examples of aerobic exercise machines on which HIIT may be performed are: bicycle, rower, treadmill, and cross-trainer.
- Workload should be adjusted by 5–10% when patient is not able to complete the high intensity intervals.

Resistance training:

- Training targeting all major muscle groups composes six exercises (leg press, chest press, abdominal crunch, low row, lat pulldown, and step up) and consists of two series of 10 repetitions.
- The strength exercises are performed according to two seconds of concentric strength and 2 s of eccentric strength. The weight of the exercises will be adjusted to the muscle strength (indirect 1RM) measured at baseline using the Brzycki formula (1RM = weight/(1.0278–0.0278 ◦ number of repetitions)) [48]. Exercises start at 65% of the calculated 1RM with a weekly increase of 5%, resulting in 80% of baseline 1RM in the fourth exercise week.
- Weight should be adjusted by 5–10% according to a patients' ability to perform 10 repetitions in the second series.

Unsupervised training:

- Patients are instructed to perform at least 60 min of aerobic exercise on days without supervised training. This may be divided into 2–3 periods of 20–30 min in case of insufficient physical capacity. Examples of aerobic exercises are: walking, cycling, and swimming.
- All patients will be given advice regarding adequate rest and sleep.

Nutritional Intervention
The content of this modality is described in Section 2.3.

Psychological Support
Planned surgical treatment can be accompanied by anxiety and depression. These components could have a potential influence on motivation regarding prehabilitation and postoperative outcomes. Therefore, patients at risk will be identified using the Hospital Anxiety and Depression Scale (HADS).

Patients at risk will be referred to a trained psychologist to optimize psychological well-being and learn about coping mechanisms regarding the surgical treatment. Additional sessions will be planned in the preoperative period when necessary.

Smoking Cessation Program
All patients who are active smokers during the baseline assessment will be offered a smoking cessation program including counseling and nicotine replacement therapy prior to surgery. With a substantial number of patients being smokers at the time of (cancer) diagnosis, the goal is to achieve a smoking cessation rate of 80%.

Protein Intake per kg FFM

Table I Number of participants achieving a goal intake of 1.9 g of protein/kg FFM. Presented for the total population (n = 61), colorectal cancer (CRC) patients (n = 33), and esophageal cancer (EsC) patients (n = 28).

	Baseline	**After Prehabilitation**
Total (n = 61)	19 (31.1%)	46 (75.4%)
CRC (n = 33)	6 (18.1%)	23 (69.7%)
EsC (n = 28)	13 (46.4%)	23 (82.1%)

Table II Daily protein intake relative to FFM: median [IQR]. Presented for the total population (n = 61), colorectal cancer (CRC) patients (n = 33), and esophageal cancer (EsC) patients (n = 28).

	Baseline	**After Prehabilitation**	***p*-Value**
Total (n = 61)	1.70 [0.66]	2.27 [0.75]	<0.001
CRC (n = 33)	1.45 [0.68]	2.27 [0.85]	<0.001
EsC (n = 28)	1.80 [0.86]	2.27 [0.61]	0.001

Baseline Characteristics of Adherent and Non-Adherent Patients

Table III Characteristics based on adherence to protein intake of ≥1.5 g (g)/kg BW (body weight)/day.

Characteristic	All Patients (n = 64)	Adherent (n = 36)	Non-Adherent (n = 28)	*p*-Value
Age in years, median [IQR]	66 [16]	65 [16]	67 [14]	0.386
Male sex (%)	45 (70.3%)	28 (77.8%)	17 (60.7%)	0.173
ASA score				0.763
I	3 (4.7%)	2 (5.6%)	1 (3.6%)	
II	45 (70.3%)	24 (66.7%)	21 (75.0%)	
III	16 (25.0%)	10 (27.8%)	6 (21.4%)	
Weight in kg, median [IQR]	77 [19]	72 [20]	81 [23]	0.003
Fat free mass in kg, mean ± SD	54.5 ± 10.6	53.7 ± 9.3	55.6 ± 12.1	0.503
Fat-free mass index in kg/m^2, mean ± SD	18.1 ± 2.3	17.8 ± 2.0	18.6 ± 2.5	0.155
BMI in kg/m^2, median [IQR]	26 [4]	25 [5]	28 [4]	<0.001
Smoking				0.145
No	19 (29.7%)	9 (25.0%)	10 (35.7%)	
Yes	8 (12.5%)	7 (19.4%)	1 (3.6%)	
Former smoker	37 (57.8%)	20 (55.6%)	17 (60.7%)	
Hand grip strength at baseline in kg, mean ± SD	38.0 ± 13.1	38.1 ± 12.1	37.9 ± 14.5	0.961
5-CST in seconds, median [IQR]	9 [4]	8 [3]	9 [5]	0.017
PG-SGA score, median [IQR]	3 [8]	3 [8]	4 [8]	0.732
PG-SGA categories (%)				0.513
Low risk (≤3)	33 (51.6%)	20 (55.6%)	13 (46.4%)	
Moderate risk (4–8)	21 (32.8%)	12 (33.3%)	9 (32.1%)	
High risk (≥9)	10 (15.6%)	4 (11.1%)	6 (21.4%)	
Type of cancer				0.454
CRC	35 (54.7%)	18 (50.0%)	17 (60.7%)	
EsC	29 (45.3%)	18 (50.0%)	11 (39.3%)	
Protein intake at baseline				
g/day mean ± SD	93.1 ± 30.7	101.1 ± 34.1	82.8 ± 22.2	0.017
g/kg BW/day ± SD	1.20 ± 0.39	1.36 ± 0.39	0.99 ± 0.27	<0.001
Number of trainings, median [IQR]	9 [6]	8 [5]	9 [7]	0.523
Duration of prehabilitation in days [IQR]	34 [12]	35 [24]	34 [12]	0.473

Supporting information references

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Chapter 5

Lessons learned from a combined, personalized lifestyle intervention in hospitalized patients at risk for sarcopenia: a feasibility study

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Abstract

Background

To examine the feasibility of a combined, personalized exercise and nutrition intervention in hospitalized patients at risk of sarcopenia.

Methods

The study is part of the FITFOOD randomized controlled trial. Eligible patients were randomized into two groups: receiving a personalized nutrition and exercise intervention or receiving usual care. The intervention entailed a high-protein diet with daily protein supplementation combined with functional training with strength and aerobic exercises. Feasibility was assessed using quantitative data, such as recruitment rate, and qualitative data retrieved from focus group and individual semi-structured interviews.

Results

In total, 14 out of 115 eligible patients participated. The recruitment rate was 12%, and the dropout rate was 50% (7 out of 14 participants). Patients at risk for sarcopenia found it difficult to be involved in a lifestyle intervention, because they were often preoccupied with their recovery, had little interest in changing their diet or level of exercise, and were often unable to participate fully due to health issues and mobility difficulty.

Conclusion

The evaluated combined, personalized lifestyle intervention had limited feasibility in hospitalized patients at risk for sarcopenia, with low recruitment and high dropout rates. The current lifestyle intervention might be too challenging for this vulnerable population.

Trial registration and ethics

The trial associated with this feasibility study was pre-registered on ClinicalTrials.gov (NCT05413616) on June 7, 2022. The authors declare no conflicts of interest. All co-authors have reviewed and approved the manuscript, and no financial interests are disclosed. This research received no external funding.

Introduction

The increasing pressure on healthcare systems and rising healthcare expenditures, primarily driven by an aging population, necessitates a shift towards a preventive approach with a focus on lifestyle interventions [1]. A role for hospitals within this setting lies in health-related prevention aimed at mitigating the impact of ongoing illnesses. Hospital admission may be a wake-up call for patients to develop a healthier lifestyle. Interventions during and after hospitalization hold the potential to promote healthier lifestyles upon discharge, using admission as a teachable moment.

Aging can be accompanied by the loss of muscle strength and lead to sarcopenia [2, 3]. Sarcopenia is associated with many adverse clinical outcomes, including readmission, lower quality of life (QoL), lower (recovery of) activities of daily living (ADL), mortality, and complications [4-10]. There is evidence that combined exercise and nutrition intervention can mitigate muscle-strength loss [11, 12]. However, there is still a knowledge gap regarding the efficacy of these interventions in the population of hospitalized people at risk for sarcopenia. Before embarking on a large intervention trial, it is important to study the feasibility of such an intervention initiated during hospitalization and continued after discharge.

While studies in community-dwelling elderly have demonstrated the effectiveness of combined exercise and high-protein diet interventions [13], the key question is whether the more vulnerable, hospitalized population can successfully engage in a comparable intervention while dealing with the challenges associated with illness.

This article evaluates the feasibility of an intervention study (FITFOOD) in hospitalized patients at risk for sarcopenia. This allowed us to draw lessons learned while performing this study. We address the challenges encountered to provide insights that can guide and help prepare fellow researchers for potential obstacles inherent to conducting trials of a similar nature within this vulnerable group of patients.

Methods

Study design

Here we present a thorough analysis of the FITFOOD study and its procedures, according to the MRC framework for designing complex interventions [14]. The study was performed at the Radboudumc (RUMC) and Canisius Wilhelmina Ziekenhuis (CWZ) in Nijmegen, the Netherlands (ClinicalTrials.gov NCT05413616)

from July 2022 until July 2023. The study was approved by the Medical Ethics Committee (METC) of East Netherlands (2020-6664).

Participants were randomly assigned to either an intervention group, receiving the personalized FITFOOD intervention, or a control group, receiving usual care. The intervention is a combined personalized intervention with a physical activity program and nutritional intervention. Randomization was performed using the Castor electronic data capture platform [15] and a variable block randomization model of 2 or 4, stratified by study site and department at hospital admission. The nature of the intervention did not allow blinding of the study

Population

To be eligible to participate, patients had to be aged ≥50 years old, Dutch-speaking, mentally competent according to a treating healthcare professional, and living within 40km of Nijmegen. All participants had to be admitted to the hospital through the wards of Gastroenterology and Hepatology, Internal Medicine, and Pulmonology (RUMC or CWZ), or Cardiology (CWZ). Patients had to be at risk for sarcopenia, assessed with the Strength, Assistance with walking, Rise from a chair, Climb stairs and Falls (SARC-F) questionnaire (score ≥ 4) as recommended by the European Working Group on Sarcopenia in Older People [2]. Exclusion criteria were the use of complete tube feeding or parental nutrition and renal insufficiency (estimated Glomerular Filtration Rate (eGFR) <30ml/min).

Combined personalized intervention

Physical intervention

The physical activity program was personalized and focused on functional training (e.g., rising from a chair or walking) with additional strength exercises (e.g., leg press), aerobic exercises (e.g., cycling), and balance exercises (e.g., standing with closed eyes). The physical activity program consisted of two phases: during hospitalization and after hospital discharge.

During hospitalization (phase 1), daily physiotherapy sessions took place. At the start of the intervention and before each session, participants set personal goals based on their daily physical activity [16, 17]. These personal goals were based on one of the daily activities reported through patient-specific complaints as discussed between the patient and physiotherapist and aligned with the criteria that promote hospital discharge [18]. The training content depended on the participants' physical

capabilities, as judged by the physiotherapist. Physical exercise during and outside physiotherapy sessions was based on safe functional activities,

After hospital discharge (phase 2), the participants trained unsupervised at their homes. The hospital physiotherapist visited the patient before discharge to set goals and exercises for at-home training. These exercises were given to the patient using the Vivica application [19], which gives the participant a calendar with planned exercises and videos on how to perform them. Exercises could also be given on paper, depending on the preferences of the patient. At least one primary care physiotherapy session (4 weeks after baseline) was given to all intervention participants. During these sessions, a physiotherapist inspected the patient's progress and adjusted goals to increase the program load when possible.

Nutritional intervention

We designed a personalized nutritional intervention supported by a dietitian during time of hospital admission. The nutritional intervention aimed at reaching individual protein requirements using optimal amount, timing, and distribution of high-quality protein intake to stimulate muscle protein synthesis (MPS). The nutritional energy requirement was calculated according to the World Health Organization equation of 2001 [20]. Dietary requirements were defined as 1.9 g/kg fat-free mass (FFM), corresponding to 1.5 g/kg body weight [21], with an optimal high-quality protein distribution of at least two daily peaks [22-26]. Participants with lowered renal function (eGFR 30-60 ml/min) received a lower dose of 1.6g/kg FFM, equating to 1.3g/kg body mass. This ensured that the protein consumption remained safe for all participants and was aligned with the Dutch guideline on protein restriction in chronic kidney injury [27]. Intervention participants were given a post-workout drink containing 30g whey protein, 3.24g leucine, and 800IU vitamin D (FrieslandCampina U.A., Amersfoort). To use the effect of timing in this combined intervention, the drink was served within 60 minutes after the graded functional training program to improve MPS [23, 25]. To stimulate MPS during the night, participants received a portion of a 25g whey protein drink, including 2.4g leucine without any added vitamin D, 30 minutes before bedtime [28-30]. At least one primary care session with a dietitian (4 weeks after baseline) was provided for all intervention participants. The dietitian assessed the nutritional intake with the patient using a food diary to provide nutritional counseling to reach energy and protein requirements and stimulate or adjust the optimal amount and timing of supplementation if needed.

Control group

Participants assigned to the control group received usual care. This did include physiotherapy, when indicated, aimed at mobilization before discharge. Consultation with a dietitian was given to patients at risk for malnutrition (Malnutrition Universal Screening Tool (MUST) score ≥2). An energy and protein-enriched meal service within the hospital was served to all patients.

Study procedures

Patients were pre-screened by a researcher via their electronic health record (EHR) based on hospital specialization for admission, age, living area, mental competence, and renal functioning. Nurses reached out to patients who met the inclusion criteria when requested by researcher. After oral consent patients were screened for eligibility using the SARC-F questionnaire [31]. Patients with a SARC-F score ≥ 4 were eligible for inclusion and were randomized to the intervention or control group after signing for informed consent The intervention started at hospital admission and continued for 12 weeks regardless of the timing of hospital discharge. Study measurements were performed at four fixed time points during the study period in the hospital at (baseline T0) and in the hospital or home situation four weeks after baseline (T1), 12 weeks after baseline (T2), and 24 weeks after baseline (T3) (1). All measurements were performed by a member of the research team except for T1 measurements in the intervention group, which were performed by instructed primary care physiotherapists and dietitians.

Next to the aforementioned study procedures, a focus group and interviews were performed to gather information on feasibility according to study participants.

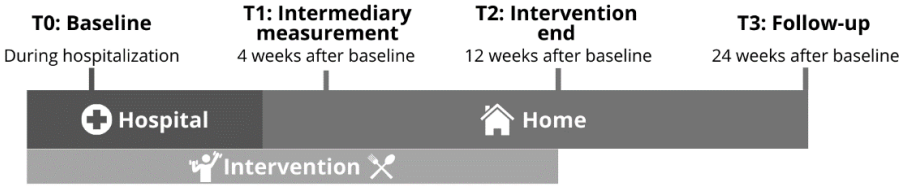

Figure 1 Timeline of intervention and study measurements.

Outcomes

Feasibility is described using quantitative and qualitative data.

Quantitative data

Quantitative data includes recruitment and dropout rates with respective reasons for not participating or dropping out. Recruitment rate and dropout rate were

calculated using the formulas below. Additionally, information about eligibility, and reasons for exclusion and dropout were documented. Additionally, the feasibility of the main study outcome of the FITFOOD intervention, physical performance using Timed Up and Go (TUG), is reported in the Supporting information.

$$recruitment\ rate = \frac{recruited\ participants}{eligible\ participants} \times 100$$

$$dropout\ rate = \frac{participant\ drop\ outs}{recruited\ participants} \times 100$$

Qualitative data

Qualitative data includes the perceived appropriateness of the intervention by participants as found in a focus group and through further interviews. All participants were asked to partake in the focus group. Three participants agreed to join the focus group session. One patient participated in the intervention group and two in the control group. During the focus group, a list of pre-defined topics was discussed. The topics were derived from experiences of the research team during study execution. The topics discussed in the focus group and further interviews were point of study start, communication with researchers, physical intervention, nutritional intervention, mobile application, study measurements, and lifestyle adaptations.

The focus group was audio-recorded, transcribed, and coded using ATLAS.ti (version 23). The results from the focus group were used to ask additional questions during interviews with participants not involved in the focus group to gain a broader view of the participants' views. Two additional participants from the intervention group were questioned on the topics after the focus group.

Data analysis

Descriptive statistics were used to analyze the recruitment rate, dropout rate, baseline characteristics and main outcome (IBM SPSS Statistics 29). The focus group transcript was analyzed using ATLAS.ti (version 23) by integrative thematic analysis. Open codes were made, which were then categorized in code groups to extract the information. No quantitative statistical analyses with the data of the secondary outcome measurements were performed because this study primarily focused on feasibility, and the number of participants was too low for statistical analysis.

Results

Protocol deviations

To bolster recruitment, we widened the inclusion criteria across four distinct stages. Figure 2 depicts the participant inclusions per stage during the lifetime of the study

During the initial stage (Version 1 (V1); July 2022 to mid-August 2022), most admitted patients were not eligible due to living area limitations based on postal codes within Nijmegen city. To address this, the capture region was expanded by adding additional postal codes that surround the city.

During the 2nd stage (V2; mid-August 2022 to September 2022), proteinuria and renal insufficiency, as initially defined by eGFR < 60, appeared to be an important reason for exclusion. After consultation with a nephrologist, proteinuria was removed as an exclusion criterion, and the inclusion criterion of renal function was expanded to eGFR < 30. The offered diet for patients with an eGFR of 30-60 contained lower protein content (1.6g/kg FFM protein as opposed to the standard 1.9g/kg FFM). Age inclusion criteria were also broadened to ≥ 50 years instead of ≥ 65 years because muscle strength decline can already be seen from 50 years of age, especially in people with underlying conditions [32].

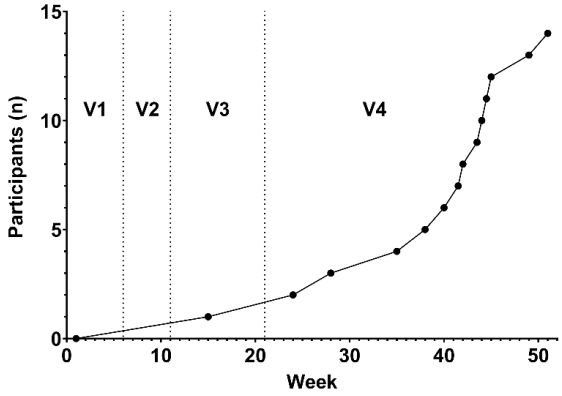

Figure 2 Participant inclusions over time and for each stage of the study (V1-V4).

During the 3rd stage (V3; October 2022 to mid-December 2022), it appeared that screening and taking baseline measurements within 48 hours of hospital admission in many patients was not feasible because of regular healthcare procedures. Therefore, this inclusion criterion was removed, and the baseline measurements were conducted

at any point during hospitalization. The living area criterion was further expanded from a small postal code region in and surrounding Nijmegen to a 40 km radius from RUMC.

With final 4th stage (V4; mid-December 2022 to June 2023) we saw that recruitment improved as a result of less strict inclusion and exclusion criteria. The addition of a second study site (CWZ) expanded the pool of eligible patients. The main factors that still hampered recruitment rate were twofold, living outside the catchment area and many eligible patients refused to join the study.

Quantitative data

Eligibility

In total, 2,183 patients were pre-screened for the study (Figure 3). Patients were pre-screened using their EHR and consultation with the patients' assigned nurse. Here, 1,773 patients proved ineligible to be approached for the full study screening based on SARC-F.

The reasons patients were ineligible for full screening were based on living area being too far from the RUMC (n=883), logistics (n=252), brief hospital admission (n=128), participating in another intervention study (n=93), transfer beyond the catchment area of the study (n=90), renal insufficiency (n=78), mentally incompetent (n=65), too ill to be approached (n=52), no consent to be approached (n=47), non-Dutch speaking (n=38), complete tube feeding or parental nutrition (n=27), admitted for too long (n=10), proteinuria (n=7), and miscellaneous (n=3).

In total, 410 patients were approached for full screening for eligibility (Figure 8). During full screening, 295 patients (72%) were excluded because they were not at risk for sarcopenia, and 115 patients were eligible for the study. Ultimately only 14 patients (at risk for sarcopenia) were recruited (12%). Some 101 patients were not included because of various reasons. A total of 59 patients were not willing to participate due to experiencing they were too busy recovering (n=26), not interested in study participation (n=20), not interested in adapting their diet (n=7), exercise (n=3), or general lifestyle (n=2), or financial reasons (n=1). A total of 18 already participated in another dietetic or physiotherapist program (n=10), rehabilitation program (n-7), and another intervention study (n=1). A total of 15 patients were not well enough to start an intervention physically (n=13) or mentally (n=2). Lastly, some patients could not join the study due to logistics (n=9). The 14 participants were randomized into the intervention group (n=9) and the control group (n=5). Baseline characteristics of the participants can be found in Table 1.

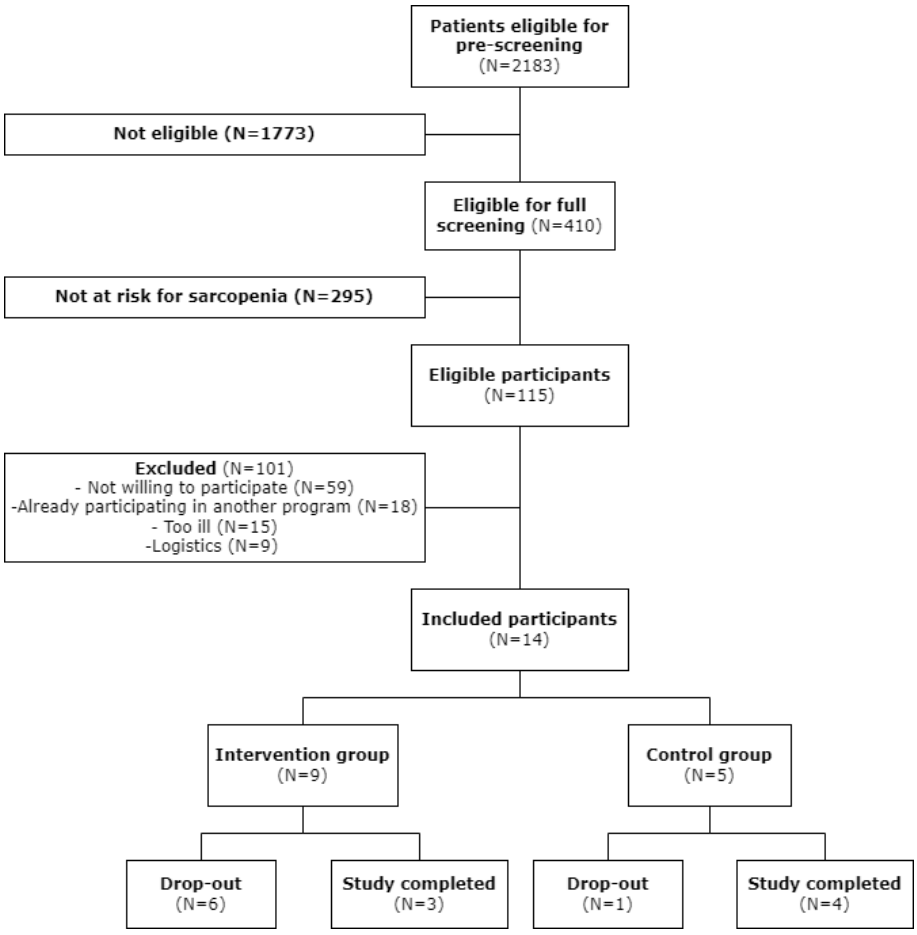

Figure 3 Flowchart of participant eligibility and inclusion.

Dropout

During the study, six participants from the intervention group and one from the control group withdrew from the study, resulting in a dropout rate of 50%. Reasons for dropout were being too ill and prioritizing focus on other healthcare procedures (n=4), unrelated death resulting from COVID-19 (n=1), diagnosis of contra-indicated muscle illness (n=1), and mental health reasons (n=1).

Timed Up and Go

TUG could not be performed in 5 out of 14 participants during hospital admission (T0). This was due to physical constraints where study participants were bedridden. Some participants dropped out before they could be mobilized,

and others could not be measured during the end of their hospitalization due to a shortage of personnel. The results for all TUG measurements can be found in the Supporting information.

Table 1 Baseline characteristics of study participants.

	Total population (n=14)	**Intervention group (n=9)**	**Control group (n=5)**
Age in years, median [min-max]	71.5 [54-89]	74 [54-89]	69 [57-77]
Male, n (%)	6 (42.9)	3 (33.3)	3 (60.0)
Admitted hospital ward, n (%) Cardiothoracic surgery Gastroenterology &Hepatology Internal Medicine Pulmonary Medicine	2 (14.3) 1 (7.1) 3 (21.4) 8 (57.1)	1 (11.1) 1 (11.1) 3 (33.3) 4 (44.4)	1 (20.0) 0 (0.0) 0 (0.0) 4 (80.0)
Duration of hospital stay, days	6 [2-11]	6 [2-9]	6 [2-11]
BMI, kg/m^2	28 [20-37]	24 [20-36]	31 [25-37]
eGFR, ml/min	81 [50-90]	86 [58-90]	78 [50-87]
SARC-F score	6.5 [4-10]	7 [4-10]	4 [4-8]

Qualitative outcomes

The qualitative assessment of the feasibility of this study, as experienced by the participants, was performed based on the seven pre-defined topics. From this qualitative assessment, four themes were derived based on the importance experienced by participants: study recruitment, physical intervention, mobile applications, and nutritional intervention.

Study recruitment

Participants were reluctant to respond to screening questions while hospitalized, expressing that the challenging hospitalization period left them occupied. Screening visits, spaced between physician and staff visits, were difficult to plan.

Lesson learned:

1. Patients are occupied during hospitalization, making it difficult to find the attention and time to discuss study participation during this period.

Patients opted out of the study due to a reluctance to change their lifestyle. Those who participated, motivated by medical background or intrinsic drive, aimed to

adopt healthy habits for post-hospital discharge or elective surgery preparation. Motivation waned post-surgery, and participants found it challenging to maintain nutrition advice and exercise.

Lesson learned:

2. Patients have to be motivated to enroll in a lifestyle intervention study. This motivation can come from information about the possible benefits of the lifestyle changes on their health and the prospect of an upcoming major surgery.

Physical intervention

Participant preferences for the physical intervention varied. Some favored a daily regimen of high-intensity gym training, while others leaned towards multiple low-intensity sessions conducted at home. External elements, such as weather conditions, played a role in shaping these preferences. In the Netherlands, physiotherapy is only reimbursed for people with specific health conditions or through additional insurance. This is different from the 3 hours of consultation with a dietitian that is reimbursed with basic health insurance. Participants agreed that the FITFOOD study should cover the financial aspect of all physiotherapist sessions. A participant in further interviews said she did not feel like she had enough time with a clinical physiotherapist and needed more guidance to be able to perform the exercises by herself properly once discharged.

Lessons learned:

3. A physical intervention should be tailored to patient preferences.
4. Participants should have enough time with a clinical or primary care physiotherapist to receive the proper guidance in performing the physical intervention.
5. Participants described that no financial burden should be placed on a participant for engaging in an intervention study.

Mobile applications

Focus group participants showed enthusiasm for using applications in making lifestyle changes. They expressed interest in health-related technology; some already used pedometers and other health apps, like the 'Eetmeter'. However, they preferred an application with minimal features to ensure usability. For instance, they were not interested in having an additional chat function with the research team or access to educational articles or videos. Instead, they highlighted the importance of having videos demonstrating how to perform the physical exercises as a valuable addition to an app. Further interviews with other participants showed the major differences between participants. Interviewed participants would not

be able to use such an application due to limited technological ability. They also explained that many older people may prefer paper versions of the exercise plans because they are less complicated.

Lesson learned:

6. Participants showed major differences in their capability to use mobile applications. Therefore, an intervention should provide an intervention option with and without the use of apps.

Nutritional intervention

Interviewed participants had previous experiences with nutritional supplements such as protein shakes. The shakes were a nice addition to a healthy diet and were not unpleasant to consume. An intervention participant showed appreciation for the protein shakes and said she would like to keep consuming them after the study to mitigate her low food intake due to a lack of hunger. The control group participants were enthusiastic about the potential health benefits of the shakes. Participants found the taste of the protein supplements to be relatively bland. However, they viewed this aspect positively and mentioned that they could enhance the flavor by using sugar-free syrup, which added versatility to the supplements.

Lessons learned:

7. Participants are positive about using neutral-tasting protein shakes to increase protein intake.

Discussion

This study assessed the feasibility of a combined personalized lifestyle intervention to improve physical performance among hospitalized patients at risk for sarcopenia. The recruitment rate was low as a result of multiple factors, including participants' unwillingness to participate, often linked to their physical or mental health. The dropout rate was high, with half of the patients discontinuing their study participation for reasons linked to the present illness, co-morbidities, and other healthcare procedures with a perceived higher priority. The feasibility of this combined exercise and nutrition intervention was considered insufficient.

We learned lessons related to the use of measurement outcomes in this population. The poor physical condition of patients impaired their ability to perform physical performance tests at baseline. This led to missing data. Participants in our study

were very vulnerable patients selected through the screening of the risk for sarcopenia using SARC-F. This questionnaire may also be too subjective by asking patients to rate their physical abilities, as scores sometimes had to be adjusted after a family member who was present corrected the patient in their answer. Participants should be appropriately guided by a physical therapist for the physical intervention. Transferring care to a primary care physiotherapist at an earlier stage could improve the participation and quality of home-based intervention, and the financial responsibility for this should not be on the participants.

A few feasibility studies on lifestyle interventions in (older) hospitalized patients have been published [33, 34]. One pilot study started their intervention in older patients at nutritional risk after hospital discharge. Their pilot showed that using technology during a nutritional intervention study is feasible in older patients with a risk of malnutrition. The nutritional intervention entailed 12 weeks of home-delivered, enriched meals after hospital discharge. A tablet with an application was used by participants to choose and order food, monitor their intake, and get feedback on their protein and energy balance. Limitations in the use of technology were mainly due to the immaturity of the app, and participants found the tablet and app easy to use. The study also revealed issues with recruitment because of exhaustion related to frailty and a high number of dropouts due to death [33]. Another study described the differences between participants and non-participants in a lifestyle intervention in outpatient care for patients with cardiovascular disease. The study participants were younger, single, had a higher level of education, and were employed. They specified that participants often consented because they were motivated to alter their lifestyle and, in turn, improve their health. These results show how important it is to motivate patients and provide them with insights into the positive effects of lifestyle changes. The authors concluded that study participation may improve by providing an easily accessible lifestyle intervention program not causing a financial burden [34].

Previous lifestyle interventions have demonstrated the effectiveness of nutrition and resistance exercise on physical performance in community-dwelling, healthy older adults [13, 35]. Our findings identified challenges in initiating a combined personalized lifestyle intervention within the hospital setting for patients at risk for sarcopenia due to them experiencing they were too busy recovering or unwilling to change their diet and exercise. Previous qualitative research used interviews to show that many older patients do not make lifestyle modifications after hospital admission, often due to functional limitations. [36]. These functional and mental limitations were also experienced by participants in our study and impacted

feasibility. However, personalized lifestyle interventions can reduce physical limitations, and discussing this may increase motivation for study participation.

The main strength of this study is the in-depth analysis of the feasibility of a combined personalized lifestyle intervention in a hospitalized population at risk for sarcopenia. Quantitative and qualitative data show the insufficient feasibility of the intervention in this unique patient population. Multiple adaptations to the study protocol show a transparent study development process and its impact on recruitment. Limitations of this study are the low number of participants compared to the number of eligible patients. Although involved healthcare professionals and researchers were queried to gather their opinions on the feasibility of this study, this was not done systematically. This feasibility study did not account for participants' intervention adherence and researchers' protocol adherence. A subsequent study could evaluate intervention adherence by comparing the physical activity and nutritional intake of intervention and control participants. Recording adherence to protocol guidelines during each study visit would be necessary to assess researchers' protocol adherence.

Implications

This study shows that patients at risk for sarcopenia find it difficult to start a lifestyle intervention aimed at changing their nutrition and exercise habits, especially during hospitalization as they are too busy recovering or are unwilling to change their diet and exercise. The possible value of lifestyle interventions is still unclear for patients and seen as optional and inferior to conventional medical interventions, negatively impacting motivation. Both nutritional and physical intervention should be personalized to account for individuals' burden of illness, preferences, and possibilities. It is important to find a balance to keep the intervention's burden manageable to keep the patient motivated but challenging enough to establish an effect. Assessment through physical performance tests was not possible in the most vulnerable participants.

Conclusions

In conclusion, the feasibility of the evaluated nutrition and physical exercise intervention in hospitalized adults at risk for sarcopenia is insufficient, reflected by a low recruitment and high drop-out rate. The current lifestyle intervention might be too complex for this vulnerable population at risk for sarcopenia. The nutrition

and exercise intervention should be offered to a less vulnerable patient population for a future randomized controlled trial to increase feasibility.

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Supporting information

Table I Measurement of study outcomes performed at different timepoints. T0: During hospitalization, T1: 4 weeks after T0, T2: 12 weeks after T0, T3: 24 weeks after T0.

Outcome measures	T0	T1	T2	T3
Physical performance using Timed Up and Go [1]	X	X	X	X
Physical performance using Short Physical Performance Battery [2]	X	X	X	X
Muscle strength using Handgrip strength [3]	X		X	X
Fat-free mass and appendicular skeletal muscle mass index (ASMI) using bioelectrical impedance analysis (BIA) [4]	X		X	X
Nutritional status using Patient-Generated Subjective Global Assessment (PG-SGA) [5, 6]	X	X	X	X
Nutritional intake using food diary [7]	X	X	X	X
Movement using Activ8 actometer [8]	X		X	X
ADL using Late-Life Function and Disability Instrument Computer Adaptive Test (LLFDI-CAT) [9]	X		X	X
QoL using EQ-5D-5L [10]	X		X	X
Clinical outcomes: length of stay, re-admission, complications, mortality				X

Table II Timed up and Go data in seconds (Control group & Intervention group). T0= baseline, T1=four weeks after baseline, T2= 12 weeks after baseline, T3= 24 weeks after baseline. NP=Not performed, DO=Dropout. Five T0 measurements could not be performed due to physical constraints. One T1 measurement was performed by a primary care physiotherapist and not properly reported to researchers.

	T0	T1	T2	T3
1	16.50	8.53	7.78	6.66
2	*NP*	*129.00*	*DO*	*DO*
3	*NP*	*DO*	*DO*	*DO*
4	*20.43*	*8.47*	*8.15*	*6.79*
5	14.05	14.63	14.19	13.88
6	*NP*	*DO*	*DO*	*DO*
7	*14.74*	*Not reported by physiotherapist*	*7.33*	*15.24*
8	*NP*	*DO*	*DO*	*DO*
9	10.70	7.79	8.69	8.95
10	*44.03*	*DO*	*DO*	*DO*
11	10.93	4.09	*DO*	*DO*
12	18.36	10.68	12.91	10.98
13	*NP*	*DO*	*DO*	*DO*
14	*15.21*	*10.41*	*8.36*	*9.79*

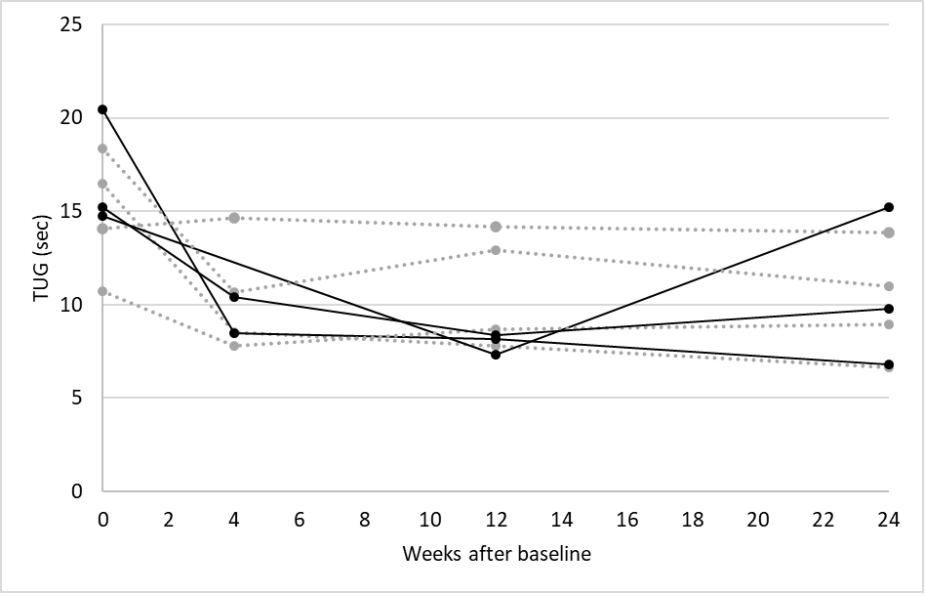

Figure I Results of Timed Up and Go in seconds of study participants that completed the full study. Results from intervention group participants in black and full line. Results from control group participants in grey and dotted line.

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Chapter 6

Combined exercise program and high-protein nutritional intervention for hospitalized older patients: a protocol for a randomized controlled trial

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Abstract

Background

The aging hospitalized population is at increased risk of sarcopenia, leading to reduced muscle strength, muscle mass, physical function, and independence, as well as higher readmissions and nursing home placement. Current knowledge shows that a combined exercise program and high-protein nutritional intervention can improve muscle mass and physical performance in healthy older adults. This effect remains understudied in hospitalized older adults. This study investigates the impact of a combined exercise program and nutritional intervention on physical performance in this vulnerable population.

Methods

This randomized controlled trial will include hospitalized adults aged ≥65 years, randomized to either a combined exercise program and high-protein nutritional intervention (intervention group) or usual care (control group). The nutritional intervention optimizes protein intake, quality, and timing, while the exercise program employs goal setting to maximize training effects. The intervention begins during hospitalization and continues post-discharge in the home care setting. The primary outcome is the difference in change in physical performance, measured by the Timed Up and Go (TUG) test, between baseline and 12 weeks post-intervention. TUG data will be analyzed using regression analysis of covariance. Secondary outcomes include the Short Physical Performance Battery (gait speed, chair stand, and balance test), muscle strength, fat-free mass, nutritional status, physical activity, independence, quality of life, clinical outcomes, and cost-effectiveness. This trial is currently ongoing in two hospitals, with the first participant inclusion on 04-04-2024.

Discussion

This study will provide valuable insights into the effectiveness of a combined exercise program and high-protein nutritional intervention in hospitalized older adults, using recommended sarcopenia assessments in a real-world clinical setting.

Trial registration and ethics

This trial has been registered at www.clinicaltrials.gov (NCT05413616). The trial received ethical approval from METC Oost-Nederland (NL80672.091.22).

Introduction

Background and rationale

The growing aging population in the Netherlands, expected to rise from 3.2 million in 2017 to 4.8 million in 2040, will increasingly impact hospital demographics. Already in 2018, nearly 42% of hospital admissions involved adults aged 65 and older, a percentage that is projected to grow [1]. Older adults are particularly vulnerable to hospitalization-related decline, notably in physical performance—defined as objectively measured whole-body mobility. This decline can begin as early as age 50 and progresses with age [2]. Importantly, reduced physical performance often precedes disability, making it an early marker of vulnerability in the disabling cascade [3]. Functional decline may occur within days of admission, with at least 30% of hospitalized older patients experiencing a decrease in activities of daily living (ADLs) [4, 5]. This loss of function is linked to poorer quality of life, prolonged hospital stays, institutionalization, readmissions, and increased mortality [6, 7].

Sarcopenia, characterized by the loss of muscle mass and function, affects an estimated 22–37% of hospitalized older adults and contributes to these negative outcomes [8-10]. Despite its prevalence and consequences, awareness among healthcare professionals remains limited [11]. Repeated periods of inactivity, such as bed rest during hospitalization, accelerate sarcopenia progression over the lifespan [12]. These insights underline the importance of early detection and timely intervention—ideally initiated during hospitalization—to prevent or mitigate sarcopenia and its associated complications.

It is known that adequate nutritional intake, particularly protein intake, is important for maintaining nutritional status during hospitalization [13]. Many studies recommend that the protein requirements for hospitalized patients are higher than those of healthy individuals. In the Netherlands, a protein intake between 1.2-1.5 g/kg body weight is considered optimal for hospitalized patients [13, 14]. Implementing an effective meal service has added value for improving protein and energy intake [15-17]. However, individual advice remains of great importance to meet individual needs.

Evidence suggests that high-quality protein supplementation has the potential to slow muscle loss, particularly among older adults with low habitual intake [12]. Moreover, in healthy individuals, timing, amount, and type of protein intake might play a role in optimizing physical performance [18, 19]. In addition to an adequate protein intake, increased physical activity prevents a hospitalization-associated decline in physical performance [20, 21].

Many adults do not reach the recommended physical activity of at least 150 minutes of moderately intensive weekly exercise [22], and hospitalization further impedes this. Studies have shown that most patients spend over 80%-99% of their hospital stay sedentary or lying in bed, and less than 1,000 steps per day were reported [23, 24]. Resistance exercise is the most effective intervention in maintaining muscle performance, whereas endurance training is effective in maintaining and improving maximum aerobic power [25]. However, a combination of different types of training seems to be the best strategy. Initially, resistance exercises targeting functional movements—such as standing up from a seated position or climbing stairs—are prioritized. Once adequate strength is developed, balance training is introduced to enhance postural stability, followed by endurance training to improve walking capacity, and sustain daily activities [26].

The effect of a combined nutritional intervention with exercise in healthy individuals and athletes has been studied before, but not in older hospitalized patients [27-31]. The older hospitalized population is heterogeneous and is a suitable target to offer a combined exercise program and high-protein nutritional intervention. Such an approach delivers a service that respects individual patient preferences, needs, and values, an important feature of high-quality patient-centered health care [32]. This study aims to improve physical performance in older hospitalized patients by implementing a combined exercise program and high-protein nutritional intervention, starting at hospital admission, and continuing for 12 weeks after baseline in the home setting. The primary research question is whether this combined intervention improves physical performance, as measured by the Timed Up and Go (TUG) test, compared to usual care.

We hypothesize that a combined exercise program and high-protein nutritional intervention (FITFOOD program), initiated at hospital admission and continued in home care, can be an effective strategy to improve physical performance in older patients compared to usual care.

Methods

Study design

The FITFOOD study will be performed as a multicenter randomized controlled trial in multiple wards of Radboud University Medical Center (Radboudumc) and Canisius Wilhelmina Hospital (CWZ) in Nijmegen, the Netherlands. The study is ongoing and had its first participant inclusion on 04-04-2024.

After inclusion, participants will be randomly assigned to either receive usual care or the FITFOOD intervention. The intervention comprises a combined exercise program and high-protein nutritional intervention (FITFOOD) for twelve weeks after study inclusion. The control group will receive usual care.

This study will be performed in accordance with the principles of the World Medical Association Declaration of Helsinki (69th WMA General Assembly, October 2018). Additionally, the study agrees with the Medical Research Involving Human Subjects Act and other guidelines, regulations, and Acts.

Study population and recruitment

Population

All Dutch-speaking, mentally competent, hospitalized patients ≥65 years within Radboudumc and CWZ on selected wards, living within 40km of the Radboudumc, will be screened for study eligibility.

Eligibility criteria

To be eligible to participate in this study, a subject patient must meet all the following criteria:

- Aged ≥65 years
- Living within 40km of the Raboudumc or CWZ, Nijmegen
- Admitted on one of the following hospital wards
- Radboudumc: Acute Admission (with transfer to another ward within the criteria), Gastroenterology and Hepatology, Internal Medicine, or Rheumatic Diseases
- CWZ: Acute Admission (with transfer to another ward within the criteria), Cardiology, Gastroenterology and Hepatology, Lung Disease, or Internal Medicine.
- Understanding and speaking the Dutch language
- Mentally competent
- Signed informed consent

A potential subject who meets any of the following criteria will be excluded from participation in this study:

- Complete use of tube feeding or parenteral nutrition
- Renal insufficiency (MDRD-GFR < 30ml/min)

Recruitment and consent

Eligible patients will be identified by researchers through screening of the electronic patient records. Eligibility will be confirmed by the involved nurse and

the patient will be asked whether they agree to a visit by a researcher. Patients who meet all inclusion and exclusion criteria and consent to the visit will receive verbal and written information about the study. The researcher will provide the participant information form and answer any questions the patient may have. Sufficient time will be given for the patient to consider participation.

If the patient agrees to participate, written informed consent will be obtained. Upon enrollment, a unique participant number will be assigned by a member of the research team, and randomization will be conducted using Castor EDC [33]. Participant data and the assigned number will be recorded by the researcher in a designated, protected document.

Sample size calculation

The sample size calculation is based on the primary outcome of this study: physical performance according to the TUG. The primary outcome of this study is the difference in TUG between the two groups, 12 weeks after hospital baseline.

Sample size calculation is based on the TUG score, with a difference of 0.7 seconds between groups estimated from a previous study in sarcopenic older adults. According to the following assumptions: a standard deviation of 1.2, a power of 80%, and an alpha of 0.05 (two-sided), 48 participants for each group are needed [34]. Considering the repeated measurement of a participant, we apply a correction with the factor $(1-(\rho^2))$ [40], and a total of 88 participants will be needed. The correlation between baseline and follow-up after 12 weeks (ρ) is estimated at 0.3.

After considering a dropout rate of 20%, a total of 106 participants should be included in a total of 53 per arm.

Treatment of subjects

Intervention

The FITFOOD intervention is developed in accordance with the MRC Framework for developing and evaluating complex interventions. This framework consists of four phases: (1) development of the intervention, (2) feasibility testing, (3) evaluation through a randomized controlled trial (RCT), and (4) implementation and dissemination of outcomes [35-37]. The first two phases, development and feasibility testing, have been completed. The current protocol outlines phase 3 of the framework, in which the intervention will be evaluated through a randomized controlled trial.

Existing research indicates that a combination of resistance and endurance training can enhance muscle mass and improve physical performance in hospitalized patients [38, 39]. Additionally, a personalized nutritional intervention—tailored to individual protein requirements, incorporating high-quality protein sources, and optimizing protein timing—can further promote muscle protein synthesis and physical performance [27-31]. Based on this evidence, the intervention group will receive a structured program integrating both targeted exercise and nutrition strategies.

Exercise intervention

The aim of the exercise intervention is to maintain or improve activities of daily living (ADLs) and prevent physical decline. The program starts during hospitalization and continues after discharge.

During hospitalization, a clinical physiotherapist will provide physiotherapy sessions starting immediately after study inclusion. Sessions will be delivered daily during the first week, and once weekly thereafter if the patient remains hospitalized. Each session lasts 30–45 minutes and includes:

- Goal setting (±10 minutes) using the Patient-Specific Complaints (PSK) to identify daily activity goals aligned with mobilization and discharge criteria [40-42];
- Functional training and exercises (10–25 minutes) tailored to patient capabilities and ward facilities;
- Instruction on unsupervised exercises (±10 minutes), to be performed independently between sessions.

Exercise intensity and content will be graded and progressively adjusted based on individual progress and goals.

After discharge, participants will primarily continue training independently. To support this transition, the hospital physiotherapist will transfer the exercise program and goals to the participant before discharge and advise follow-up with a primary care physiotherapist. Follow-up in primary care will look different according to the exercise program as instated in hospital, the needs of the participant and the expertise of the physiotherapist.

Nutritional Intervention

In addition to the exercise program, participants will receive a personalized nutritional intervention. This nutritional intervention aims to increase muscle protein synthesis by using optimal timing and distribution of protein intake and

high-quality protein to reach individual protein requirements. A clinical dietitian will perform a dietary history interview during the hospital stay to gain insight into the usual food intake of participants in the home setting to give accurate and personalized dietary advice participants should follow after hospital discharge [43]. The nutritional energy requirement will be calculated according to the WHO equation of 2001 [44]. Nutritional protein requirements are defined as 1.9 g/kg FFM, corresponding to 1.5 g/kg body weight [45], with an optimal high-quality protein distribution of at least two peaks a day [18, 19, 46-48]. Participants with lowered renal function (MDRD-GFR 30-60 ml/min) will receive a lower dose of 1.6g/kg FFM, equating to 1.3g/kg body mass. This ensures that protein consumption remains safe for all participants and aligns with the Dutch guideline on protein restriction in chronic kidney injury [49].

Vitamin D deficiency, which is defined as a risk factor for sarcopenia, is frequently seen in older adults [29, 50]. Therefore, standard high doses of vitamin D (i.e. ‡ 20 mg (800 IU)/d) for older adults are advised, according to the Health Council of the Netherlands [51].

Based on individual protein requirements and current dietary intake, participants in the intervention group will receive tailored dietary advice to optimize protein intake. To support this, two types of daily protein supplements are available. Depending on the participant's needs, one or both supplements will be provided. After each training session, participants will consume a protein drink containing 30 g of whey protein, 3.24 g of leucine, and 800 IU (20 µg) of vitamin D (Nutri Whey™ Isolate, FrieslandCampina, Amersfoort), taken within 60 minutes post-exercise [18, 47]. A second protein drink containing 25 g of whey protein and 2.7 g of leucine without added vitamin D, can be consumed approximately 30 minutes before bedtime [52-54]. Detailed nutritional information on the supplements is provided in Table 1.

Table 1 Nutritional information for the whey protein drinks used during the FITFOOD study. Theses supplements will be taken by patients every day after training or before bedtime.

	Per portion	
	After training	**Before bedtime**
Energy (kcal)	180	150
Total protein (g)	30	25
Leucine (g)	3.24	2.70
Lactose (g)	0.36	0.30
Vitamin D (mg)	20.0	0

The intervention period will start during hospitalization and continue up to 12 weeks after baseline. The dietitian and physiotherapist of Radboudumc or CWZ will start the intervention during hospital admittance. The participant will be advised to have at least one consultation with a physiotherapist and dietitian after hospitalization but is not obligated to do so.

Usual care

Participants in the hospital ward assigned to the control condition will receive the usual care. Usual care consists of physiotherapy for those who qualify for this care (according to the Dutch guidelines). Next to this, participants with a high risk of malnutrition (MUST score ≥2) will receive consultation from a dietitian. Meal service within the hospital is served according to personal needs.

Outcomes

Measurements include the primary measurement of TUG, and secondary outcomes are the Short Physical Performance Battery (SPPB), SARC-F questionnaire, handgrip strength, bioelectrical impedance analysis (BIA), PG-SGA, food diary, Activ8, SarQoL, EQ-5D-5L, clinical outcomes through electronic patient records, and cost-effectiveness through iMTA Medical Cost Questionnaire (iMCQ). Nutritional assessment measurements outcomes were performed according to the standard operating procedures as provided by the Nutritional Assessment Platform [55]. Measurement will take place during hospitalization (baseline T0), and after discharge 4 weeks after baseline (T1), 12 weeks after baseline (T2), and 24 weeks after baseline (T4), as shown in Figure 1.

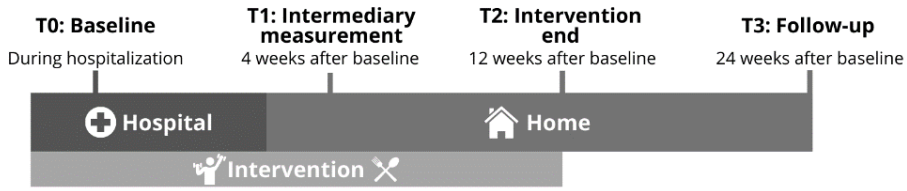

Figure 1 Timeline of intervention and study measurements.

For an overview of measurements performed at each time point, see Table 2.

Table 2 Overview of outcomes with the corresponding method for each time point.

	Method	T0	T1	T2	T3
Primary outcome					
Physical performance	TUG[1]	x	x	x	x
Secondary outcomes					
Physical performance	SPPB[2]	x	x	x	x
Risk for sarcopenia	SARC-F[3]	x	x	x	x
Muscle strength	Handgrip strength	x	x	x	x
Fat-free mass	BIA[4]	x	x	x	x
Nutritional status	PG-SGA[5]	x	x	x	x
Nutritional intake	Food diary	x	x	x	x
Movement	Activ8	x	x	x	x
Quality of life	SarQoL[6]	x	x	x	x
	EQ-5D-5L[7]	x	x	x	x
Clinical outcomes*	EPR[8]				x
Cost-effectiveness	iMCQ[9]	x		x	x

[1]TUG: Timed up and go; [2]SPPB: Short Physical Performance Battery; [3]SARC-F: Strength, Assistance with walking, Rise from a chair, Climb stairs and Falls, [4]BIA: Bioelectrical Impedance Analysis, [5]PG-SGA: Patient Generated-Subjective General Assessment; [6]SarQol: Sarcopenia & Quality of Life; [7]EQ-5D-5L: EuroQol 5D-5L; [8]EPR: Electronic patient record; [9]iMCQ: iMTA Medical Cost Questionnaire
*Length of hospital stay, re-admissions, complications, and mortality.

Timed Up and Go

Physical performance is the primary endpoint of this study. It is defined as "an objectively measured whole-body function related to mobility." To assess physical performance, we will use the Timed Up and Go (TUG) test, a reliable, cost-effective, safe, and time-efficient method for evaluating overall mobility [56]. Additionally, the TUG has been shown to predict mortality, further highlighting its clinical relevance [57].

The test will be conducted using a standard armchair with a backrest, and a marker (such as a piece of tape or another chair) will be placed 3 meters away from the front edge of the chair. Participants will begin the test seated with their back against the chair, arms resting on the armrests. Upon hearing the word "go," they will stand up, walk 3 meters to the marker, turn around, walk back, and sit down. Timing will start at "go" and stop once the participant is seated.

Risk for sarcopenia

The risk for sarcopenia is assessed using the Strength, Assistance with Walking, Rise from a Chair, Climb Stairs, and Falls (SARC-F) questionnaire. This questionnaire

is recommended by the European Working Group on Sarcopenia in Older People (EWGSOP) for assessing the risk of sarcopenia [58]. This tool helps identify participants at risk and track any changes in sarcopenia risk throughout the study.

Short Physical Performance Battery

The Short Physical Performance Battery (SPPB) combines three separate tests to gain insight into important factors of independence, mobility, and lower extremity function [59]. Participants receive points based on their performance in three assessments: gait speed, chair stand, and balance test. The total SPPB score is calculated by summing these points. A low SPPB is known to be associated with falls, long-term disability, and all-cause mortality [60-62].

Gait speed

Gait speed is measured by timing how long a participant takes to walk 4 meters. The test is performed twice, and the fastest recorded time is used for scoring. Participants may use assistive devices if needed.

Chair stand

For the chair stand test, participants must stand up and sit down from a chair five times while keeping their hands crossed over their chest. The time taken to complete the task is recorded, and points are assigned accordingly.

Balance test

The balance test evaluates a participant's ability to maintain stability in three progressively challenging positions for 10 seconds each. A standardized point system is used to objectively assess performance.

Muscle strength

Muscle strength will be assessed using the JAMAR hand dynamometer following a standardized protocol [63]. Participants will be seated in an upright position with their arms at a 90-degree angle and wrists in a neutral position (thumb side up). They will be instructed to squeeze the dynamometer as hard as possible, and each hand will be measured three times. Handgrip strength is a valid, non-invasive measure of muscle function and serves as a reliable predictor of overall muscle strength and nutritional status [64].

Fat-free mass

Fat-free mass (FFM) will be measured using Bioelectrical Impedance Analysis (BIA), a widely accepted method for assessing body composition. BIA has been shown

to be an accurate and practical alternative to computed tomography (CT) for identifying sarcopenia [65]. The BIA device operates by measuring the resistance of body tissues to an alternating current at 50kHz. FFM is then calculated based on a formula that incorporates resistance, height, weight, gender, and age [66-68].

Nutritional status

Nutritional status will be assessed using the Scored Patient-Generated Subjective Global Assessment (PG-SGA), a validated tool across various patient populations [69, 70]. The PG-SGA includes both a patient-reported section and an assessment by healthcare professionals. To ensure clarity and usability, the Dutch version of the PG-SGA will be used. This version has been deemed comprehensible and easy to use by participants, as well as relevant and practical by healthcare professionals [71].

Nutritional intake

Nutritional intake will be assessed using a three-day food diary, a method considered valid for older adults [72]. The primary focus will be on protein and energy intake. Participants will record the time, type, and quantity of all food and beverages consumed. The collected data will be analyzed using Evry (version 2.7.4.2, 2021), which calculates energy and nutrient intake based on the Dutch Food Composition Table 7.0 [73].

Movement

Movement will be measured using the Activ8 device, a compact, single-unit activity monitor equipped with a triaxial accelerometer. This device has been validated for assessing movement and body posture in the general population [74]. The Activ8 will be attached to the participant's thigh using an adhesive sticker and worn continuously for one week to record activity patterns. Data will be analyzed using Activ8 software to evaluate activity levels in metabolic equivalent of tasks.

Quality of life

SarQoL

Older hospitalized patients may be at risk for developing sarcopenia [REF]. The Sarcopenia & Quality of Life (SarQoL) questionnaire is a validated, consistent, and reliable tool designed to assess quality of life in relation to domains that may be affected by sarcopenia [75]. These domains include physical and mental health, locomotion, body composition, functionality, activities of daily living, leisure activities, and fears. The SarQoL has been translated and validated in Dutch, ensuring its applicability in this population [76].

EQ-5D-5L

Health-related quality of life will be assessed using the Dutch-validated EQ-5D-5L. This questionnaire evaluates five key dimensions of health: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression. Each dimension includes five response levels, ranging from no problems to extreme problems, allowing for a detailed description of individual health states [77]. Additionally, the EQ-5D-5L is well-suited for economic evaluations, as it incorporates a preference-elicitation method to assign value to different health states [78].

Clinical outcomes

All clinical outcomes will be assessed retrospectively using electronic patient record data, including the length of hospital stay, re-admissions within 24 weeks, complications, and mortality. Re-admissions and complications will be further confirmed via questionnaire, as hospital visits outside the study sites may not be recorded in accessible records. In line with the Dutch Association of Medical Specialists (FMS) definition, a complication is an unintended and undesirable event or condition occurring during or after medical intervention that significantly impacts the participant's health, necessitates a change in medical treatment, or causes irreversible damage. Complications will be categorized as infectious, decubitus, surgical (non-infectious), or other (e.g., cardiopulmonary).

Cost-effectiveness

Cost-effectiveness will be assessed through a cost-utility analysis (CUA) from a healthcare perspective, following the guidelines outlined in the "Richtlijn voor het uitvoeren van economische evaluaties in de gezondheidszorg" [79]. The CUA will be conducted concurrently with the controlled trial. First, healthcare costs will be measured, excluding costs related to work absence, as the study population consists primarily of older adults who are likely retired. Instead, the focus will be on medical consumption, assessed using the iMTA Medical Consumption Questionnaire (iMCQ), which evaluates healthcare use in the 12 weeks prior to the questionnaire. Clinical outcomes such as length of hospital stay, re-admission, and complications will also be considered to calculate healthcare costs based on reference prices [80].

Cost-effectiveness will be expressed in terms of cost per quality-adjusted life year (QALY), which compares the price difference between the intervention and control groups to the difference in quality of life experienced by the two groups. The Dutch version of the EQ-5D-5L will be used to measure quality of life at various time points, allowing the calculation of QALYs and the incremental cost per QALY.

Statistical analysis

Data will be checked for erroneous data and missing values. Descriptive statistics will describe the study population characteristics like age and sex, length of hospital stay, and hospital ward. Continuous variables will be presented as mean and standard deviation (SD) or median and interquartile range, depending on the distribution. Categorical variables will be presented as numbers and percentages. If significant differences exist between the two treatment groups, these differences may be added to the model as possible confounders.

The normality of the residuals will be checked using QQ plots. If the variable is skewed, we will perform a log transformation. An α level of $p < 0.05$ will be used to determine statistical significance based on two-sided testing. All analyses will be conducted according to the intention-to-treat principle. Data will be analyzed using R studio IDE.

Primary outcome

The primary outcome is the difference in physical performance, measured by the Timed Up and Go (TUG) test, between baseline (T0) and 12 weeks (T2) in the intervention and control groups. This will be analyzed using an analysis of covariance (ANCOVA), where TUG at T2 is the dependent variable, and treatment group and TUG at T0 are included as independent variables. This approach adjusts for baseline differences when comparing outcomes at follow-up.

In addition, the TUG outcome will also be analyzed using a linear mixed-effects model to evaluate progression over time (T0, T1, T2, T3). This model will include time, treatment group, and their interaction as fixed effects, and a random intercept for participants to account for repeated measures. This allows investigation of both within-group change and between-group differences across the full study period.

Secondary outcomes

Secondary study parameters will be analyzed using similar linear mixed-effects models, with time, treatment group, and their interaction as fixed effects, and a random intercept for participants. These models allow assessment of changes over time and group differences in the trajectory of each outcome

Clinical outcomes will be compared between intervention and control groups using independent samples t-tests if the data are continuous and normally distributed. For non-normally distributed or ordinal data, the Mann-Whitney U test will be used.

Discussion

This randomized controlled trial will study the effect of combined exercise program and high-protein nutritional intervention on physical performance in older hospitalized patients compared to usual care. Participants start the intervention during hospitalization and continue in the home setting for a total of 12 weeks after baseline.

The primary outcome of this study is the Timed Up and Go (TUG) test, chosen because it is a continuous measure of physical performance and an indicator of sarcopenia severity. Secondary outcomes include all recommended assessments for sarcopenia: SARC-F for screening, muscle mass for identifying probable sarcopenia, muscle strength for diagnosis, and physical performance for determining severity [58]. Additionally, nutritional status and intake, physical activity, quality of life, clinical outcomes, and cost-effectiveness will be evaluated to provide a comprehensive perspective on both clinical and patient-related effects of the intervention.

A previous feasibility study, linked to the current protocol, focused on hospitalized patients at risk for sarcopenia and evaluated the feasibility of a combined intervention, including an eHealth application. The study revealed limited feasibility in this specific population due to low recruitment and high dropout rates, primarily because the target group was highly vulnerable, which hindered participation and adherence to the intervention [81]. These findings highlighted the importance of early intervention, before patients become too frail to benefit, to help prevent further physical decline and the development of hospital-associated sarcopenia during admission [82]. Based on these insights, the target population for the current RCT was expanded to a broader group of hospitalized older adults aged 65 years or older, who may benefit from such a combined intervention. Due to limited usability in the hospital setting observed during the feasibility study, the eHealth application was not included in the current protocol.

A key strength of this study is that it includes hospitalized older adults without a specific diagnosis or risk of sarcopenia, which is a population in which sarcopenia still may be prevented. Beside this study evaluates the recommended assessment methods outlined in the European guidelines for sarcopenia [58]. The use of a comprehensive battery of tests offers valuable insights into participants' muscle strength, physical performance, and nutritional status. This approach enables a better understanding of when sarcopenia may emerge or progress following hospitalization, and how targeted interventions might help to prevent or delay this process.

A limitation of this protocol is the broad target population of hospitalized older adults, which may introduce heterogeneity in response to the intervention. There is a risk of including individuals who may not need treatment, potentially reducing observed effects. However, physiotherapists tailor the intervention to each participant's capabilities, which may mitigate this issue. Studying a broad population does increase the generalizability of findings.

Secondly, only one measurement will be conducted during hospitalization. As patients' health status can fluctuate from day to day during admission, the results of this baseline assessment may be influenced by the specific timing of the measurement. This may affect the precision and representativeness of outcomes such as muscle strength or physical performance, particularly in acutely ill or unstable patients.

Lastly, participants in the intervention group will be advised to follow up with a primary care physiotherapist. However, this is not mandatory, as financial compensation is not always available. As a result, not all participants will be able or willing to invest in primary care physiotherapy, which may lead to less supervision and guidance than ideal. Nevertheless, this reflects the current reimbursement system in Dutch healthcare and therefore offers a realistic picture of how exercise might be implemented in practice.

This study will provide valuable insights into the effects of a combined graded exercise program and high-protein nutritional intervention in hospitalized older adults. If the findings demonstrate that the intervention improves physical performance, muscle strength, muscle mass, and rehabilitation outcomes compared to usual care, it will support integrating the intervention into usual care for the broader hospitalized older population. If the results do not show any benefit, further investigation into adherence will be necessary. If adherence is low, additional support may be needed to assist patients who find it difficult to follow the intervention effectively. Alternatively, if adherence is high and the intervention still shows no improvement, it may indicate that the approach is ineffective for this population. This could be due to illness or ongoing treatments, which may limit the body's ability to respond to exercise and nutritional interventions. In that case, alternative strategies or timing of interventions might be needed to achieve meaningful improvements in this vulnerable group.

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Part III

Interprofessional collaboration

Chapter 7

Interprofessional management of (risk of) malnutrition and sarcopenia: a grounded theory study from the perspective of professionals

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Abstract

Background

As our global population ages, malnutrition and sarcopenia are increasingly prevalent. Given the multifactorial nature of these conditions, effective management of (risk of) malnutrition and sarcopenia necessitates interprofessional collaboration (IPC). This study aimed to understand primary and social care professionals' barriers, facilitators, preferences, and needs regarding interprofessional management of (risk of) malnutrition and sarcopenia in community-dwelling older adults.

Methods

We conducted a qualitative, Straussian, grounded theory study. We collected data using online semi-structured focus group interviews. A grounded theory data analysis was performed using open, axial, and selective coding, followed by developing a conceptual model.

Results

We conducted five online focus groups with 28 professionals from the primary and social care setting. We identified five selective codes: 1) Information exchange between professionals must be smooth, 2) Regular consultation on the tasks, responsibilities, and extent of IPC is needed; 3) Thorough involvement of older adults in IPC is preferred; 4) Coordination of interprofessional care around the older adult is needed; and 5) IPC must move beyond healthcare systems. Our conceptual model illustrates three interconnected dimensions in interprofessional collaboration: professionals, infrastructure, and older adults.

Conclusion

Based on insights from professionals, interprofessional collaboration requires synergy between professionals, infrastructure, and older adults. Professionals need both infrastructure elements and the engagement of older adults for successful interprofessional collaboration.

Trial registration and ethics

This study was conducted in accordance with the Declaration of Helsinki and received ethical approval from the Ethical Advisory Committee (HEAC) of Hanze University of Applied Sciences Groningen (document number HEAC.2022.030).

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Niek Koenders provides qualitative research training for healthcare professionals and contributed to this study as a qualitative research expert. The other authors declare no conflicts of interest.

Introduction

As our global population continues to age, the prevalence of malnutrition and sarcopenia among older adults in the community is on the rise, significantly impacting quality of life and daily functioning [1, 2]. Malnutrition refers to a state that arises from a lack of intake or uptake of nutrition [3]. Sarcopenia is a muscle disease that may result from physical inactivity, inflammation, and mitochondrial dysfunction but also from malnutrition[4]. Both conditions are characterized by reduced muscle mass and in the case of sarcopenia, also loss of muscle strength. Moreover, both conditions contribute to an elevated risk of falls and fractures, leading to impaired daily activities, reduced independence, mobility issues, diminished quality of life, the necessity for admission to long-term care facilities, and premature increased mortality[4, 5]. A combined intervention consisting of nutrition and physical activity efficiently addresses malnutrition and sarcopenia by targeting nutritional deficiencies while simultaneously promoting muscle quality and strength synergistically [6, 7]. This combined strategy requires the collaboration of professionals from diverse disciplines, each contributing their unique expertise and skills.

Interprofessional collaboration (IPC) is essential for achieving optimal care outcomes [8]. IPC involves different health or social care professions regularly coming together to provide services, characterized by shared accountability and interdependence between individuals, as well as clarity of roles and goals [9, 10]. This approach is more extensive than the more common multidisciplinary collaboration in healthcare, which often involves parallel efforts of professionals from different fields without integrated teamwork or shared goals [11].

Numerous studies indicate that IPC in healthcare enhances effectiveness, leading to increased patient satisfaction, better-informed patients, better adherence to medication, lower readmission rates, and reduced complications related to illness [12-15]. IPC also contributes to greater efficiency in the duration of treatment without altering the quality of care by decreasing the number of inpatient days, reducing (emergency) waiting times, facilitating quicker exchange of information, boosting productivity rates, and improving the accessibility, utilization, and flow of healthcare services [16-20]. Cohesive actions, information, and expertise from various disciplines are necessary to address the complex needs of patients effectively [21].

Despite the current evidence supporting the effectiveness of IPC and interventions that combine exercise and nutrition for addressing malnutrition and sarcopenia, the implementation of IPC in practice remains limited [22]. Professionals encounter

significant ideological, organizational, structural, and relational challenges when advocating for IPC [23]. There is some understanding of the barriers to collaboratively addressing malnutrition, such as insufficient knowledge and awareness, limited access to dietetic services in primary care settings, and poor communication among professionals [24-26]. However, information concerning IPC in the management of malnutrition and sarcopenia in primary care is still lacking. This underscores the current ambiguity of IPC in the context of the management of (risk of) malnutrition and sarcopenia among community-dwelling older adults.

Understanding professionals' perspectives is essential for successful IPC in the management of (risk of) malnutrition and sarcopenia. Therefore, we evaluated the barriers and facilitators encountered by professionals as well as their preferences and needs regarding interprofessional treatment of malnutrition and sarcopenia in community-dwelling older adults.

Methods

Study design

We conducted a qualitative study through focus groups using grounded theory methods as delineated by Strauss and Corbin [27]. This Straussian approach follows a systematic, interpretative process to produce a conceptual model through an iterative data analysis grounded in the perspectives and experiences of professionals working in the primary or social care setting, further indicated as 'professionals'. To ensure transparent and rigorous reporting of the study's findings, the researchers adhered to the 32-item checklist of the Consolidated Criteria for Reporting Qualitative Studies (COREQ) [28].

Eligibility criteria and recruitment

Professionals working in primary or social care who encountered (risk of) malnutrition and/or sarcopenia among community-dwelling older adults were eligible to participate. Proficiency in speaking, reading, and writing Dutch was required. We employed a purposive maximum variation sampling strategy to aim for diversity in profession and years of work experience, capturing a wide range of perspectives within each focus group. Researchers disseminated a call for participation through professional networks, and eligible participants expressed interest by contacting the researchers via email or telephone. We aimed for participants from various regions in the Netherlands, including the rural provinces of Drenthe and Friesland and the cities of Nijmegen and Amsterdam, enabling the

exploration of diverse collaboration contexts and practices. Informed consent, including permission to publish anonymized quotes and participant characteristics, was obtained from participants prior to each focus group session. No prior relationship was established with participants before the study commenced.

Data collection

Data were collected using online focus group sessions via Microsoft Teams (version range 1.6.00.6754-1.6.00.27573, Microsoft). Each focus group lasted two hours, including a 10-minute introduction and a 5-minute mid-session break. The focus groups comprised five to seven participants to maintain manageable online discussions. One researcher (SB) moderated the focus group sessions using an interview guide that was adapted between focus groups (Supporting information), a second researcher co-moderated (JJR) while third researcher was taking notes as documenter (SvE). Following each session, SB, JJR, and SvE discussed field notes and made necessary adjustments to the interview guide. The topics in the interview guide were derived from the Meta-Model of Interprofessional Development [29]. Questions comprised topics such as professionals' experiences with malnutrition and sarcopenia in older adults, their current collaboration practices, facilitators and barriers for IPC, and their vision of the ideal IPC. The questions also delved into the role of older adults in IPC. In addition to the interview questions, the concept of IPC was clarified after a short discussion on the concept among professionals to ensure a shared understanding of its definition. Focus groups were video recorded and transcribed verbatim by a third party (Marinka® Transcriberen). Data collection ended after reaching theoretical saturation, at which point no new selective codes emerged.

Reflexivity

The team's diverse expertise enriched the exploration of interprofessional management of malnutrition and sarcopenia. SB, a physiotherapist, offered insights from primary healthcare practice, while SvE, with a background in nutrition science, focused on considerations regarding nutrition assessment and treatment. JJR, a work and organizational psychologist, contributed insights into the dynamics influencing IPC. SB and SvE were PhD candidates, and JJR held a postdoctoral position. SB had experience conducting interviews and was trained in qualitative research and focus group moderation. In addition to SB, JJR, and SvE, the research team involved in the analysis consisted of individuals with diverse backgrounds, including nutrition and physical activity [MT], dietetics [MvdB, HJW], physiotherapy [NK, HD, PvdW], gerontology [HD], and qualitative research [NK], providing a comprehensive perspective on the analysis. All researchers work in the

fields of malnutrition, sarcopenia, and/or IPC and, therefore, may have preconceived notions about the importance of these concepts. Efforts were made to mitigate potential biases by promoting open discussions and critical reflections within the research team.

Data analysis

Grounded theory data analysis followed three steps: open coding, axial coding, and selective coding [27]. SB and SvE independently read, re-read, and coded the transcripts using open codes. Subsequently, they compared their codes, engaging in open and constructive dialogue until a consensus was reached. A constant comparative approach was employed to systematically compare participant responses across focus groups. Subsequently, axial codes were produced after analyzing the focus group sessions. After all focus groups had finished, SB and SvE created selective codes to organize the axial codes and identify connections in the data. Following the completion of the three stages of analysis by SB and SvE, all codes were reviewed within the research team to enhance mutual understanding and achieve consensus through five meetings with the research team. The first session focused on enhancing the open and axial codes. The second and third sessions were dedicated to discussing the axial and selective codes. The fourth and fifth sessions were dedicated to constructing the conceptual model.

Trustworthiness

Rigorous methodological practices contribute to enhancing the trustworthiness of the research findings. ATLAS.ti software (version 8.4, Scientific Software Development GmbH) facilitated data aggregation and analysis, promoting transparency and authenticity in code descriptions through participant quotes. Independent readings and coding enhanced thoroughness and addressed potential individual blind spots, strengthening the credibility of the interpretations. Furthermore, the constant comparison approach further bolstered credibility by systematically comparing data points and codes throughout the analysis process. This method ensured that interpretations were grounded in the data and allowed for the refinement of axial codes. The ongoing refinement of the interview guide, guided by insights from discussions between the focus group sessions, increased the depth of research findings by validating data collection methods and exemplified researchers' commitment to critical reflection on their biases and assumptions throughout the research process. Analytical memos were documented throughout the data analysis process to record decisions and interpretations. This enabled the research team to confirm the study's findings independently of the first authors' biases or influences, further enhancing the confirmability of the findings.

Results

Five online focus groups were conducted, involving a total of 28 participants representing four distinct regions across the Netherlands. Focus group sessions lasted 105 minutes on average (range 98-113 minutes). Theoretical saturation was achieved after the fifth focus group session. Although most contacted professionals initially expressed their willingness to participate, one individual who initially agreed failed to attend the session and did not respond to subsequent follow-up emails. Additionally, another professional was unable to attend on the agreed date due to scheduling conflicts, while a third had to cancel due to illness. Participant characteristics are detailed in Table 1.

Table 1 Participant characteristics

	Participants (n)
Total Participants	28
Sex	
Female	24
Male	4
Profession	
Dementia case manager	5
Dietitian	5
District nurse	5
General practitioner (GP)	2
GP practice assistant	4
(Geriatric) physiotherapist	5
Nurse practitioner	1
Social worker	1
Participants per region	
Friesland	5
Drenthe	13
Nijmegen	5
Amsterdam	5
Years of working experience in current expertise	
0-9	14
10-19	9
20-29	1
30-39	4

In our analysis, we identified five selective codes encapsulating the barriers, facilitators, preferences, and needs of professionals regarding IPC in managing (risk of) malnutrition and sarcopenia among community-dwelling older adults. The following sections will explore these selective codes and their associated axial codes in depth. Table 2 lists an overview of the selective and axial codes.

Table 2 Selective codes with axial codes. 'Professionals' are professionals who work in primary or social care. Abbreviations: EHR, Electronic health record; IPC, Interprofessional collaboration.

Selective code 1: Information exchange between professionals must be smooth
1A: Professionals experience non-interoperable EHRs as a barrier to IPC
1B: Professionals prefer to work in one shared EHR
1C: Professionals need different communication tools
1D: Professionals prefer to know other professionals in person
1E: Professionals prefer to have other professionals nearby
1F: Professionals need knowledge about malnutrition and sarcopenia to ensure smooth communication
Selective code 2: Regular consultation on the tasks, responsibilities, and extent of IPC is needed
2A: Professionals need structural meetings
2B: Professionals need agreements regarding tasks and responsibilities
2C: Professionals face the barrier that not all involved professionals can attend structural meetings
2D: Professionals prefer a balance in the content and extent of information exchange
2E: Professionals experience time constraints as a barrier to IPC
2F: Professionals think receiving financial compensation would facilitate regular interprofessional consultations
Selective code 3: Thorough involvement of older adults in IPC is preferred
3A: Professionals prefer that older adults can be self-determined in their care
3B: Professionals experience difficulties in engaging older adults as a barrier to IPC
3C: Professionals prefer shared decision-making with older adults regarding healthcare choices
Selective code 4: Coordination of interprofessional care around the older adult is needed
4A: Professionals need a coordinator in the team
4B: Professionals need the timely involvement of relevant other professionals in the healthcare process
4C: Professionals view the reluctance of older adults to engage other healthcare professionals as a barrier
Selective code 5: IPC must move beyond healthcare systems
5A: Professionals need organizations outside the healthcare sector to support IPC
5B: Professionals need informal caregivers and family to be involved in IPC
5C: Professionals think financial compensation from insurance to the older adult would facilitate IPC

Selective code 1: Information exchange between professionals must be smooth

Professionals seek an information exchange process that is seamless, uninterrupted, and free from obstacles, all with the overarching goal of enhancing IPC.

Axial code 1A: Professionals experience non-interoperable EHRs as a barrier to IPC

Professionals explained that the current non-interoperability of electronic health records (EHRs) complicates information exchange. Dietitians and physiotherapists emphasized the difficulties arising from using different systems that do not communicate with other EHRs, resulting in duplicated efforts and challenges in transitioning between platforms. However, it was recognized that interoperability between different EHRs could improve collaboration.

> *District nurse: "One of the biggest issues for me in collaboration is that the systems don't quite match up. We use an electronic health record, but I can't integrate the files of another electronic health record into it. So, I end up having to fill out a separate care plan, which is a bit of a hassle."*

Axial code 1B: Professionals prefer to work in one shared EHR

Professionals would prefer a shared EHR to facilitate shared care plans and goals. However, the lack of uniformity in EHRs among healthcare institutions was viewed as a barrier to effective communication. Despite challenges, professionals maintained a positive perspective on the concept of a shared EHR, listing advantages such as accessible contact, efficient communication, and time efficiency. Additionally, enabling patients to log into their health records was perceived as a positive development, allowing them access to information about their health.

> *Dietitian: "It becomes more challenging when you don't work with a shared system; coordinating requires speaking and exchanging secure emails. You may reach one person, but not necessarily colleagues. With a shared electronic health record, everyone can access it, including caregivers or partners. I find that very convenient."*

Axial code 1C: Professionals need different communication tools

Professionals seek to balance traditional and modern communication methods to ensure effective and efficient communication. Professionals pointed out various communication barriers, such as different work schedules, inconvenient phone calls, and challenges in scheduling face-to-face and online meetings. When it comes to exchanging critical information, professionals still prefer telephone

contact, considering it faster than sharing comprehensive reports. Nevertheless, professionals think sharing comprehensive EHRs is beneficial for future or further referencing of information. Additionally, professionals acknowledged the benefits of using digital communication tools, including online interactions and the use of apps for secure short messaging between professionals.

> *Dementia case manager: "I have noticed that the most effective way to communicate is through quick calls and emails. Occasionally, if it's not related to medical matters, you can shoot a message or drop by to schedule a meeting. I've found that works well, just a brief phone call."*

Axial code 1D: Professionals prefer to know other professionals in person

Professionals highlighted the importance of personal connections with other professionals, emphasizing their positive impact on building sustainable collaborations. However, they identified staff turnover as a significant barrier, and the collaboration with various healthcare institutions complicated the process of getting to know others well.

> *General practitioner: "It's about really knowing each other. Having those face-to-face interactions makes it easy to give a call, shoot a message, or even drop by. That personal connection is important to me. If I've spoken to someone even just once, it breaks down barriers."*

Axial code 1E: Professionals prefer to have other professionals nearby

Professionals preferred in-person, face-to-face interactions, citing it as facilitative for IPC and efficient communication. Working in the same building or sharing an office space was experienced as a practical way to establish direct lines of communication. Professionals already working with various disciplines within a single organization reported experiencing the benefits of these direct lines of communication, enabling quick and efficient interaction.

> *GP practice assistant: "I prefer to keep it informal and choose professionals who are close to me. So, those in the same building or with whom I collaborate well. People I can rely on, and I know that if there's anything, they'll give me a call."*

Axial code 1F: Professionals need knowledge about malnutrition and sarcopenia to ensure smooth communication

Professionals noted differences in knowledge levels concerning malnutrition and sarcopenia. Dementia case managers, district nurses, and practice assistants

acknowledge a knowledge deficit in these areas despite some reported specific training on this topic. Nonetheless, professionals expressed a need for further education in malnutrition and sarcopenia. The lack of understanding often challenges comprehending each other's reports. They stressed that improved knowledge could aid in the early detection of malnutrition and sarcopenia. Dietitians and physiotherapists were recognized for their expertise in malnutrition and sarcopenia and were identified as valuable resources for disseminating this knowledge.

Selective code 2: Regular consultation on the tasks, responsibilities, and extent of IPC is needed

Professionals acknowledged the importance of structural meetings for fostering effective communication and collaboration.

Axial code 2A: Professionals need structural meetings

Beyond their functional aspects, professionals acknowledged online or in-person team meetings as valuable networking opportunities, enhancing professional relationships and connectivity. Preferences for meeting frequency varied, with suggestions ranging from monthly to every eight weeks, emphasizing productivity when multiple disciplines can attend. Furthermore, there was a preference for increased involvement of dietitians, physiotherapists, and social care workers in team meetings because they are currently not always involved. Structural meetings were viewed as valuable opportunities for mutual learning and ensuring alignment among team members.

> *General practitioner: "Frequently, this [structural meetings] adds a valuable boost to the treatment, as everyone is once again on the same page with a particular client. Moreover, it's often an opportunity to gather insights into someone's working style, thought processes, and, oh, perhaps I should give him a ring sometime..."*

Axial code 2B: Professionals need agreements regarding tasks and responsibilities

Professionals underscored the significance of enhanced coordination and well-defined practical agreements regarding tasks and responsibilities. This need extends to establishing clear and effective protocols among professionals, ensuring precise work arrangements, and optimizing task distribution. Additionally, a preference was mentioned to streamline task allocation and coordinate meeting attendance for optimal collaboration.

> *Dementia case manager: "In one situation, I came into the picture, and the general practitioner had already brought in a dietitian. If you establish a*

connection with the dietitian like, 'Well, I'm involved now too,' maybe you should set clear agreements right away."

Axial code 2C: Professionals face the barrier that not all involved professionals can attend structural meetings

Professionals believed structural meetings were most productive when multiple professionals from diverse disciplines were involved. Low commitment due to heavy workloads and staff turnover were mentioned as barriers to attending those meetings. Planning meetings was seen as a complex task that demands seamless coordination among professionals from multiple organizations. It remained unclear who should undertake this responsibility, as multiple professionals would be capable of this task. Physiotherapists and dietitians were often absent at these structural meetings, suggesting that attendance could be more feasible if they received specific invitations tailored to meetings involving cases where their expertise is directly relevant.

Axial code 2D: Professionals prefer a balance in the content and extent of information exchange

Professionals emphasized that not every older adult with (risk of) malnutrition or sarcopenia should be discussed at every meeting. Focused discussions are preferred, only discussing those patients that require attention at that moment. Attention was also given to selectively sharing information between professionals by managing the flow of information. Sharing substantial amounts of information can lead to a flood of data, which means professionals cannot keep track of everything. Finding the appropriate equilibrium was considered crucial, as excessive sharing can overwhelm and hinder efficiency, while too little information leaves professionals uninformed about each other's treatment plans. Professionals prefer to develop a shared care plan, especially in complex cases. Additionally, professionals stressed the importance of considering various aspects of information exchange, including addressing critical health signals, making referrals to other professions, managing noncompliance, marking the start and end of treatment, and identifying instances where someone requires additional or specialized care.

Axial code 2E: Professionals experience time constraints as a barrier to IPC

Time constraints emerged as a significant barrier to IPC. High administrative burdens and busy schedules contribute to a shortage of time among professionals. IPC was perceived as potentially time-consuming, particularly when engaging older adults. However, professionals expressed a positive perspective on the efficiency of virtual collaboration, finding online discussions to be both time-saving and cost-saving.

Axial code 2F: Professionals think receiving financial compensation would facilitate regular interprofessional consultations

Professionals emphasized that receiving financial compensation would facilitate IPC. They noted disparities among disciplines regarding compensation currently exist, with physiotherapists, dietitians, general practitioners, and practice assistants often facing a lack of financial remuneration compared to other disciplines, such as dementia case managers, district nurses, and social care workers. Professionals identified diverse funding streams and the absence of financial compensation as significant barriers to effective IPC.

Selective code 3: Thorough involvement of older adults in IPC is preferred

Professionals advocated for actively involving older adults and preserving their self-determination while recognizing the complexities and challenges that may impede this goal.

Axial code 3A: Professionals prefer that older adults can be self-determined in their care

Professionals expressed a strong need for older adults to be self-determined and to be in charge of their healthcare decisions. Professionals acknowledged that preserving self-determination comes with difficulties due to factors like stress, cognitive issues, and mental challenges. Additionally, professionals stated safety is always the number one priority and may take precedence over self-determination in some instances.

Axial code 3B: Professionals experience difficulties in engaging older adults as a barrier to IPC

Professionals faced challenges in actively involving older adults, presenting a significant barrier to IPC. These challenges parallel the difficulties encountered in maintaining self-determination for older adults with dementia. Additionally, professionals mentioned factors such as the lack of accountability among older adults for their health, avoidance of seeking care, low comprehension, low health literacy, and a lack of motivation can further hinder engagement. Finally, professionals noted that engaging older adults is possible when sufficient time is available; however, this resource is often scarce.

> *District nurse: "I believe one's understanding, low literacy, and willingness are all factors [in engaging the older adults] when I look at my neighborhood."*

Axial code 3C: Professionals prefer shared decision-making with older adults regarding healthcare choices

Professionals emphasized the importance of ensuring that the need for care arises from, or aligns with, the older adults themselves rather than being solely influenced by their families. They advocate for engaging in conversations directly with older adults instead of discussing them among professionals or family, believing this approach would be appreciated by the older adults and improve treatment. Professionals stated that while shared decision-making is already a frequent practice in many disciplines, communication is essential to facilitate this collaborative decision-making process. A shared decision could also mean a person does not want to continue treatment or may not want to engage in shared decision-making, even if a professional would consider shared decision-making preferable.

> *General practitioner: "We consider what suits each person and how they view it. If someone doesn't want to participate, you can encourage or revisit the idea occasionally, but if they're not willing, that's where it ends. It's about making an individual plan, keeping in mind what's feasible and the person's preferences. We may have our opinions, but if the patient doesn't see it as an issue, we revisit it at a later time."*

Selective code 4: Coordination of interprofessional care around the older adult is needed

Professionals highlighted the importance of a designated coordinator to ensure clarity and timely involvement of other relevant professionals.

Axial code 4A: Professionals need a coordinator in the team

Professionals emphasized the need for a coordinator in the team. They noted that the involvement of multiple professionals in caring for an older adult often results in a lack of clarity for the individual receiving care. According to professionals, the absence of coordinated care can lead to an open-ended care process. Professionals believe that older adults value coordination, especially when they struggle to maintain an overview of their healthcare. Professionals, such as a general practitioner, dementia case manager, or district nurse, could potentially assume this role. Professionals also suggested that an informal caregiver could fulfill this coordinating function.

Axial code 4B: Professionals need the timely involvement of relevant other professionals in the healthcare process

The team of professionals needs to be expanded promptly to include relevant professionals for treating (risk of) malnutrition and sarcopenia. Physiotherapists

and dietitians expressed concerns about the delayed recognition of their potential value, often attributed to a lack of knowledge among other professionals and older adults. This delayed involvement of professionals is evident from the initial contact and the preliminary stages of malnutrition or sarcopenia, extending to potential relapses after treatment.

> *Dietitian: "Yesterday, I received a referral from a general practitioner stating that someone lost ten kilograms in the past year. The general practitioner had provided some nutritional drink bottles, but we weren't involved. It felt like things went wrong from the start. […] Sometimes we are involved too late."*

Axial code 4C: Professionals view the reluctance of older adults to engage other healthcare professionals as a barrier

Professionals perceive a lack of awareness among older adults regarding the added value and roles provided by various disciplines. This was particularly seen by physiotherapists, dietitians, and dementia case managers. Notably, professionals emphasized that dietitians face challenges due to an unfavorable image among older adults. Furthermore, professionals explained that older adults are motivated to maintain independence for as long as possible. This desire for independence may lead older adults to resist involvement from other professionals, posing a barrier to IPC.

> *GP practice assistant: "I encounter individuals with resistance, especially the 88-year-olds who are like, 'I've always managed on my own, so I don't want any help.' They don't allow themselves the luxury of a physiotherapist. It's not that they refuse to exercise; it's more like, 'I've always handled things on my own."*

Selective code 5: IPC must move beyond healthcare systems

Professionals emphasize the need for support from organizations outside the healthcare sector to enhance and facilitate collaboration.

Axial code 5A: Professionals need organizations outside the healthcare sector to support IPC

Professionals emphasized the importance of support from organizations outside the healthcare sector to facilitate IPC. Social care workers were highlighted as valuable allies, particularly in addressing lifestyle improvements and social aspects. They have the time and expertise to gain the trust of older adults. It was mentioned that this trust and sense of rapport could facilitate the acceptance of other professionals relevant to managing malnutrition and sarcopenia. Additionally, daycare and

domestic assistance could play a role in encouraging physical activity and promoting healthy eating habits among older adults, according to professionals. However, professionals pointed out that daycare facilities used to have the older adults spend their day there cooking a nutritious meal together for the group. Professionals have expressed that daycare facilities used to involve older adults living at home cooking nutritious meals together as a group. However, government regulations and financial constraints hinder communal cooking in daycare facilities. This results in the provision of pre-cooked and less nutritious meals, which may be less optimal for older people at risk for malnutrition and sarcopenia. Professionals expressed the preference to engage the local government in initiatives focused on preventing malnutrition and sarcopenia. This includes providing information and creating opportunities for older adults to develop and maintain a healthy lifestyle.

Axial code 5B: Professionals need informal caregivers and family to be involved in IPC

Professionals emphasized the vital role of involving informal caregivers and families in IPC. They stressed the importance of discussing the wishes and goals of the older adult and their family members. Informal caregivers and family members were recognized for their essential role in motivating the older adult, particularly during and after treatment, especially in cases where dementia is involved.

Axial code 5C: Professionals think financial compensation from insurance to the older adult would facilitate IPC

Professionals advocated financial compensation through healthcare insurance in facilitating the interprofessional management of older adults at risk of malnutrition or sarcopenia. Professionals expressed disappointment that financial factors often significantly influence older adults' healthcare decisions. Some individuals feel compelled to prioritize financial considerations when making healthcare choices, and in some instances, older adults decline care due to financial constraints. The discontinuation of interventions due to limited or no reimbursement from healthcare insurers was acknowledged as a substantial barrier. Insufficient financial support poses challenges for both older adults and healthcare providers, affecting the accessibility of essential care. The lack of adequate financial support was especially highlighted concerning treatment by a dietitian or physiotherapist.

> *Dementia case manager: "There are sometimes financial considerations at play, preventing patients from seeking help. They might not mention it initially, but through further inquiry, you may discover that. For instance,*

someone might not have supplementary insurance and want to know the cost beforehand. That can also be a hindering factor for effective collaboration."

Conceptual model

The conceptual model was derived from the findings of this study. Selective codes (depicted in Figure 1A) and underlying axial codes (shown in Figure 1B) were categorized under three main dimensions: professionals, infrastructure, and older adults, represented by ellipses. Overlapping areas illustrate interdependencies and interconnectedness among these dimensions. The term 'professionals' refers to professionals from various disciplines in health and social care. The term 'infrastructure' encompasses diverse factors and organizations that influence IPC, including technical and social aspects such as time and financial resources. The term 'older adults' represents the patients or clients undergoing management of (risk of) malnutrition and/or sarcopenia.

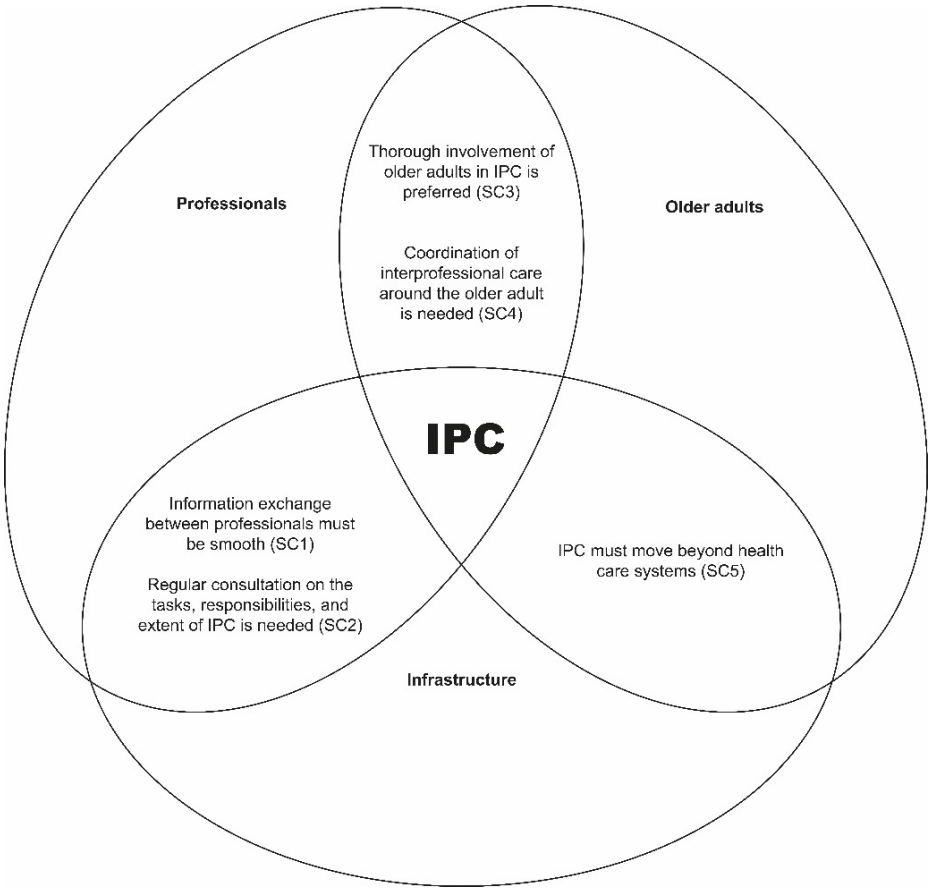

Figure 1A Conceptual model of interprofessional collaboration in the management of (risk of) malnutrition and sarcopenia: a professional's perspective. Interconnectedness of selective codes among the dimensions of professionals, infrastructure, and older adults.

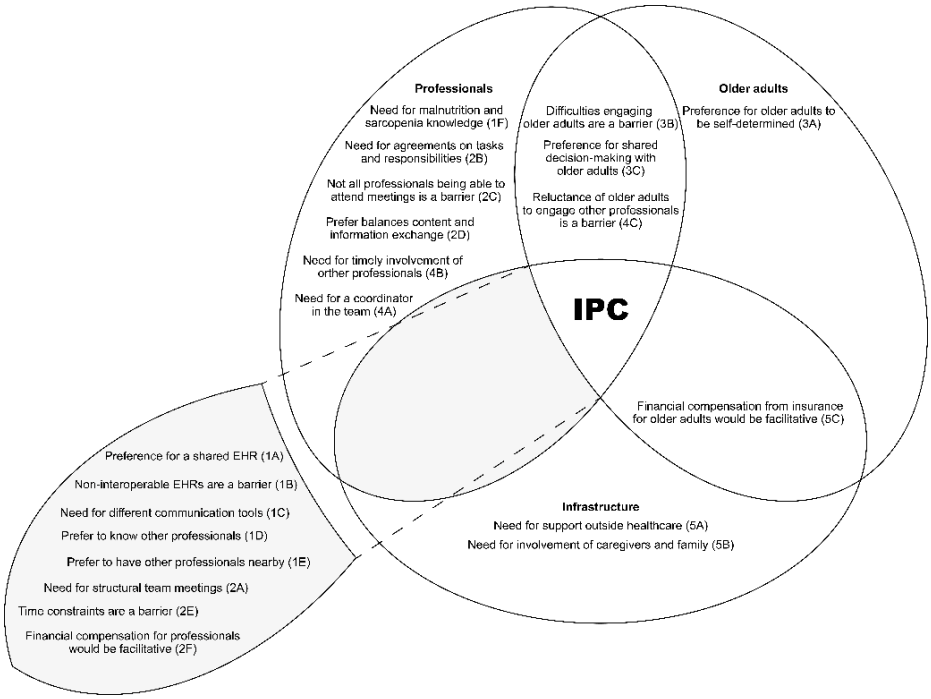

Figure 1B Conceptual model of interprofessional collaboration in the management of (risk of) malnutrition and sarcopenia: a professional's perspective. Interconnectedness of axial codes among the dimensions of professionals, infrastructure, and older adults.

Discussion

In this qualitative study, we aimed to understand the barriers, facilitators, preferences, and needs encountered by professionals regarding the interprofessional management of (risk of) malnutrition and sarcopenia in community-dwelling older adults. The insights gained from professionals indicated that achieving IPC requires synergy among professionals, infrastructure, and older adults.

Within the dimension of professionals, the presence of a coordinator, clear agreements on tasks and responsibilities, and sufficient knowledge of malnutrition and sarcopenia are needed, according to professionals. Additionally, professionals prefer a balance in the exchange of information but face barriers such as the inability of all professionals to attend structural meetings. Regarding the interconnection between the dimensions of professionals and infrastructure, professionals addressed non-interoperable EHRs and time constraints as barriers to IPC. They expressed a preference for a shared EHR system, emphasized the value of in-person connections, and preferred to have other professionals nearby. Financial compensation for professionals was perceived as a facilitating factor for IPC. Professionals also recognized the value of both traditional and modern communication tools and stressed the need for structural meetings to facilitate collaboration. In the dimension of infrastructure, professionals underscored the need to involve informal caregivers, families, and external organizations such as insurance companies to facilitate IPC. Regarding the interconnection between infrastructure and older adults, professionals recognized financial compensation from insurance to older adults as facilitative for IPC. Finally, professionals expressed a preference for older adults to be self-determined and to be in charge of their healthcare decisions.

Our study aligns with previously established findings on IPC in a primary care setting. Facilitators mentioned in previous research, such as organizing regular meetings, employing clear communication routines or information channels, working at the same location, and establishing relationships, were corroborated by our findings [30, 31]. Professionals in our study further underscored these facilitators by emphasizing the positive impact of knowing each other in person, having other professionals nearby, regular acquaintance with other professionals, using facilitative communication tools, and the importance of clear protocols. Research has shown that regular interpersonal contact among team members influences the sense of belonging of professionals, positively impacting their intentions to exchange knowledge [32, 33]. Therefore, fostering an environment that facilitates

regular interaction, and clear communication can contribute not only to effective IPC but also to the willingness of team members to share valuable knowledge.

Our findings validate time constraints as a barrier to effective IPC in primary care, as described in the literature [29, 34]. Professionals in our study echoed these barriers, particularly regarding structural team meeting attendance. Acknowledging that efficient communication positively impacts available time, addressing communication processes becomes crucial to alleviate time-related challenges. Strategies such as flexible scheduling or incorporating virtual meeting options may prove essential. Flexible scheduling allows professionals to join and leave meetings when needed. Using flexible scheduling for face-to-face and virtual meetings would offer solutions to strengthen team dynamics and overcome time-related challenges while preserving the benefits of regular face-to-face interactions. Furthermore, professionals emphasized the need for enhanced coordination and clear agreements regarding tasks and responsibilities. Clarity of goals, team roles, and responsibilities is not only essential for effective IPC but is also consistently emphasized in the definitions of interprofessional work across various clinical settings and in different national contexts [35].

Moreover, according to our findings, financial compensation for the professional and the older adult with malnutrition and/or sarcopenia can further support IPC. Professionals may find it challenging to collaborate during their own time, which is now often necessary. Older adults with malnutrition or sarcopenia frequently face inadequate compensation from health insurers for services provided by physiotherapists or dietitians, leading to reluctance to involve these professionals in their care team. These observations are in line with the literature identifying financial support and supportive policies as facilitators of IPC [31, 36]. The current health and social care payment models are often fragmented or based on fee-for-service systems [37, 38]. Such models can create conflicting financial incentives that discourage collaboration between professionals and limit comprehensive care. Integrated payment models, which streamline payments across providers and encourage shared responsibility, are suggested as promising solutions to enhance care coordination and improve patient outcomes [39, 40].

Professionals' preference for shared decision-making with older adults aligns with the interprofessional communication competency outlined by the Interprofessional Education Collaborative (IPEC) [41]. This competency emphasizes adapting communication strategies to accommodate diverse patient populations, including those facing cognitive impairments or limited health literacy. Acknowledging and

addressing these challenges in patient communication aligns with the overarching goal of providing patient-centered care, ensuring that communication methods are tailored to older adults' unique needs and circumstances.

While our study primarily highlighted organizational and structural barriers to IPC, a recent study on primary healthcare centers in Qatar also identified cultural barriers, including 'fear culture' and professional hierarchies [36]. Concerns about adverse consequences when reporting errors were noted to discourage open communication among professionals. These findings reflect differences in organizational structures and cultural norms between the two contexts. Qatar's healthcare system may have more pronounced hierarchical structures, which could contribute to these cultural barriers. In contrast, the context of our study may have involved fewer cultural differences and hierarchical structures, which explains why cultural barriers were not prominent in our findings. It is important to remain mindful that barriers to IPC can vary significantly across different healthcare systems and cultural environments.

Strengths and limitations

We employed a rigorous grounded theory methodology to strengthen our research. Two independent researchers coded the data, ensuring the reliability of our findings and minimizing interpretation bias.

Another strength of our study is the inclusion of professionals from diverse disciplines and regions, with a sample demographic that accurately reflects real-world settings. A significant proportion of female participants and individuals with 0-9 years of work experience in their current expertise were included in our study. This demographic profile closely mirrors the typical workforce in the care for older adults, which is predominantly female on a global scale [42]. For instance, in the Netherlands, approximately 80% of those employed in health and social care are female [43]. Several factors contribute to the prevalence of individuals with less experience in their current roles, including frequent role transitions due to additional training and a notable representation of younger professionals in the health and social care sectors [44].

Furthermore, the strategic time gaps between focus groups allowed for the iterative refinement of questions, facilitating a nuanced exploration of axial and selective codes. The focus group format's efficiency, enriched with symbolic interactionism principles, encouraged lively discussions and idea generation. These exchanges enhanced the depth and richness of discussions by making participants attribute meaning and interpretations to shared ideas, words, and interactions.

Nevertheless, we recognize certain limitations inherent to our study. Firstly, although focus groups are a proper method for this grounded theory research, they could have been expanded to include more types of methods, such as individual interviews, team observations or participant diaries. These could have further enriched the data. Secondly, all participating professionals may have had a baseline interest in IPC as they voluntarily participated in a focus group on this subject. We cannot rule out the possibility of missing results and insights from professionals less interested in IPC through selective sampling. This might explain why only one social care worker participated, as they may not have been drawn to the initial call for participation even though an invitation for study participation was specifically given to welfare organizations. The abundance of participating healthcare professionals naturally caused focus groups to shift towards a health-focused viewpoint. However, including participants with a strong motivation for IPC is likely to have contributed to the generation of rich data [45]. Thirdly, despite our efforts to maintain objectivity and engage in self-reflection, we acknowledge that researchers inevitably brought their perspectives and biases to this qualitative study. To address this, we employed researcher triangulation during the analysis, involving a diverse team to enhance the study's robustness and minimize the impact of individual prejudices and assumptions throughout the research process.

Implications for clinical practice and future research

The conceptual model emphasizes the importance of synergy among multiple dimensions to achieve successful IPC in managing malnutrition and sarcopenia. To achieve this, an interprofessional team should establish explicit protocols and agreements to ensure effective communication and information exchange. Improving infrastructure, such as implementing interoperable or shared EHRs and regular team meetings, is essential for facilitating the exchange of knowledge and information. Additionally, involving social workers, informal caregivers, and local governments can provide valuable support to the interprofessional team and older adults. Furthermore, older adults must be involved in their healthcare decisions despite challenges such as cognitive issues and low health literacy. Professionals can encourage this involvement by inviting patients and their support networks to participate actively in the decision-making process, considering their individual needs and circumstances.

Moving forward, research efforts should prioritize understanding and enhancing the practical implementation of IPC to address (risk of) malnutrition and sarcopenia among community-dwelling older adults. Gathering insights into the wishes and needs of older adults is essential to ensure that IPC truly centers around the

patient's perspective. Additionally, assessing the feasibility and effectiveness of implementing IPC in real-world settings is also imperative. One potential approach to achieve these goals is by first co-designing an interprofessional care pathway tailored to address the specific needs of older adults with malnutrition and sarcopenia, and professionals needed for IPC. Subsequently, implementing and evaluating its impact. Such research pursuits can offer valuable insights into enhancing the quality of care, improving job satisfaction among healthcare professionals, managing healthcare costs, and improving the health outcomes of older adults with (risk of) malnutrition and sarcopenia.

Conclusion

Based on insights from professionals, interprofessional collaboration requires synergy between professionals, infrastructure, and older adults. Professionals need both infrastructure elements and the engagement of older adults for successful interprofessional collaboration. Regarding the interconnection between the professionals' and infrastructure dimensions, professionals addressed non-interoperable electronic health records and time constraints as barriers to interprofessional collaboration. Professionals expressed a preference for a shared electronic health record, emphasized the value of in-person connections, and preferred to have other professionals nearby. Financial compensation for professionals was perceived as a facilitator for interprofessional collaboration. Professionals also recognized the value of both traditional and modern communication tools and stressed the need for structural meetings. Concerning the interconnection between infrastructure and older adults, professionals noted that financial compensation from insurance for older adults would facilitate interprofessional collaboration.

This study contributes to a deeper understanding of interprofessional collaboration in primary care settings and offers valuable insights for professionals, researchers, and policymakers.

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Supporting information

COREQ (COnsolidated criteria for REporting Qualitative research) Checklist

Table I COnsolidated criteria for REporting Qualitative research Checklist. Developed from: Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. International Journal for Quality in Health Care. 2007. Volume 19, Number 6: pp. 349 – 357

Topic	Item No.	Guide questions/Description	Reported on page No.
Domain 1: Research team and reflexivity			
Personal characteristics			
Interviewer/facilitator	1	Which author/s conducted the interview or focus group?	6
Credentials	2	What were the researcher's credentials? E.g. PhD, MD	6-7
Occupation	3	What was their occupation at the time of the study?	6-7
Gender	4	Was the researcher male or female?	N/A
Experience and training	5	What experience or training did the researcher have?	6-7
Relationship with participants			
Relationship established	6	Was a relationship established prior to study commencement?	5
Participant knowledge of the interviewer	7	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	N/A
Interviewer characteristics	8	What characteristics were reported about the inter viewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	6-7
Domain 2: Study design			
Theoretical framework			
Methodological orientation and Theory	9	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	5
Participant selection			
Sampling	10	How were participants selected? e.g. purposive, convenience, consecutive, snowball	5
Method of approach	11	How were participants approached? e.g. face-to-face, telephone, mail, email	5
Sample size	12	How many participants were in the study?	8
Non-participation	13	How many people refused to participate or dropped out? Reasons?	8

Table I Continued

Topic	Item No.	Guide questions/Description	Reported on page No.
Setting			
Setting of data collection	14	Where was the data collected? e.g. home, clinic, workplace	6
Presence of non-participants	15	Was anyone else present besides the participants and researchers?	N/A
Description of sample	16	What are the important characteristics of the sample? e.g. demographic data, date	8 + Table 1
Data collection			
Interview guide	17	Were questions, prompts, guides provided by the authors? Was it pilot tested?	Supporting information
Repeat interviews	18	Were repeat inter views carried out? If yes, how many?	N/A
Audio/visual recording	19	Did the research use audio or visual recording to collect the data?	6
Field notes	20	Were field notes made during and/or after the interview or focus group?	6
Duration	21	What was the duration of the inter views or focus group?	8
Data saturation	22	Was data saturation discussed?	6
Transcripts returned	23	Were transcripts returned to participants for comment and/or correction?	N/A
Domain 3: analysis and findings			
Data analysis			
Number of data coders	24	How many data coders coded the data?	7
Description of the coding tree	25	Did authors provide a description of the coding tree?	N/A
Derivation of themes	26	Were themes identified in advance or derived from the data?	7
Software	27	What software, if applicable, was used to manage the data?	7-8
Participant checking	28	Did participants provide feedback on the findings?	N/A
Reporting			
Quotations presented	29	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	8-18
Data and findings consistent	30	Was there consistency between the data presented and the findings?	8-18
Clarity of major themes	31	Were major themes clearly presented in the findings?	8-18
Clarity of minor themes	32	Is there a description of diverse cases or discussion of minor themes?	8-18

Interview Guide version 1

Opening question

How does your work bring you into contact with malnutrition and sarcopenia in older adults living at home?

Introductory questions

- Can you describe your current collaboration with other professionals regarding the treatment of malnutrition and sarcopenia in older adults living at home?
  - What methods are employed to identify malnutrition and sarcopenia?
  - How do you go about coordinating the content of the treatment?
  - How are the treatment goals for the patient typically established?
  - What measures are in place to monitor the progress of the treatment?
- How is the involvement of the older adult managed in this collaboration concerning malnutrition and sarcopenia?

Main questions

- How do you define interprofessional collaboration?
- When we talk about interprofessional collaboration, we are not just referring to referral and task allocation, as seen in multiprofessional collaboration, but also the substantive alignment to optimize care together. How do you view this collaborative approach to optimize care?
- Could you outline your role within interprofessional collaboration concerning sarcopenia and malnutrition and how it relates to other professionals?
- From your perspective, what does the ideal situation for interprofessional collaboration in treating sarcopenia and malnutrition in older adults living at home look like?
  - What decisions would you prefer to make collaboratively, and what approach would you favor in making these decisions?
  - To what extent do you believe each team member should be involved in formulating treatment goals for a patient within an interprofessional team?
  - How much consensus do you think should be reached on care decisions within an interprofessional team, both procedurally and regarding patient care?
  - What factors facilitate the coordination of treatment with other professionals, such as required knowledge, information exchange, or mutual agreements?
  - What impedes this coordination, taking into account factors like motivation, competence, or opportunities for interprofessional collaboration?
- How are malnutrition and sarcopenia presently identified in older adults living at home? (Is there variation between the two conditions?)
- What strategies aid in the early identification of malnutrition and sarcopenia? (Do these differ between the two conditions?)
- To what extent are there barriers to involving the older adult in treatment decisions?
- What strategies do you employ to engage the older adult? (This could include considerations of insight and knowledge related to malnutrition/sarcopenia)

Concluding questions

As we wrap up our discussion, we have two final questions. These may overlap with our previous conversation.

- How can we best encourage collaboration among healthcare providers?
- In your experience, what approaches are effective in fostering collaboration with the older adult during treatment?
- Is there anything we have not covered that you feel is important to discuss?

Interview guide final version

Opening questions

How does your work bring you into contact with malnutrition and sarcopenia in older adults living at home?

Introductory questions

- Can you describe your current collaboration with other professionals regarding the treatment of malnutrition and sarcopenia in older adults living at home?
  - o How are the treatment goals for the patient typically determined?
  - o How do you go about coordinating the content of the treatment?
- To what extent are malnutrition and sarcopenia areas of expertise within your professional field? And to what extent are they areas of focus for other professional groups?

Main questions

- Which professionals identify malnutrition and sarcopenia?
- What facilitates the coordination of treatment with other professionals? (This could involve necessary knowledge, information exchange, or mutual agreements)
- What hinders this mutual coordination? (Consider factors like motivation, competence, or opportunities for interprofessional collaboration)
- When we talk about interprofessional collaboration, we are not just referring to referral and task allocation, as seen in multiprofessional collaboration, but also the substantive alignment to optimize care together. What does the ideal situation for interprofessional collaboration in the treatment of sarcopenia and malnutrition in older adults living at home look like for you?
  - o What decisions would you like to make collaboratively, and how would you prefer to make these decisions?
  - o To what extent should each member of an interprofessional team be involved in establishing treatment goals for a patient?
  - o How much agreement should there be on care decisions within an interprofessional team? (Both procedurally and regarding patient care)
- To what extent are the reports accessible to each other? And to what extent are they understandable?
- Concerning the role of the older adult in interprofessional collaboration:
  - o What decisions can the older adults make for themselves?
  - o To what extent are there barriers to involving the older adult in decisions regarding interprofessional treatment?
  - o What helps you engage the older adult? (Consider factors like insight and knowledge about malnutrition/sarcopenia)
  - o What aspects of information exchange could the older adult be responsible for?

Concluding questions

As we wrap up our discussion, we have two final questions. These may overlap with our previous conversation.

- How can we best enhance collaboration among healthcare providers and with the older adults at home?
- Is there anything we have not covered that you feel is important to discuss?

Chapter 8

Understanding the needs and wishes of older adults in interprofessional treatment for malnutrition and sarcopenia: a grounded theory study

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Abstract

Background

Malnutrition and sarcopenia impact the physical health and quality of life of community-dwelling older adults. Managing these conditions requires integrating nutritional and exercise interventions delivered by professionals from diverse backgrounds. Interprofessional collaboration holds promise for providing integrated, person-centered care to older adults. However, to tailor such care, it is essential to understand the needs and wishes of older adults, which remain underexplored. This study aimed to understand the needs and wishes of community-dwelling older adults regarding interprofessional treatment for (risk of) malnutrition and sarcopenia. Methods: We conducted a grounded theory study. Data collection involved semi-structured interviews and focus groups with community-dwelling older adults who are undergoing treatment or have been treated for (risk of) malnutrition and/or sarcopenia. We systematically analyzed the data using open, axial, and selective coding and developed a conceptual model.

Methods

We conducted a grounded theory study. Data collection involved semi-structured interviews and focus groups with community-dwelling older adults who are undergoing treatment or have been treated for (risk of) malnutrition and/or sarcopenia. We systematically analyzed the data using open, axial, and selective coding and developed a conceptual model.

Results

Interviews and focus groups were conducted with 18 older adults. Three selective codes were identified: 1) older adults need to be involved in their interprofessional treatment, 2) older adults need healthcare professionals to be well-informed about their interprofessional treatment, and 3) older adults need collaboration amongst involved healthcare professionals in interprofessional treatment. Our conceptual model addresses the needs and wishes of older adults in relation to interprofessional collaboration. Older adults' needs highlight what is missing, while their wishes offer ways to fulfill these needs.

Conclusion

Older adults' need for involvement in interprofessional treatment can be met by engaging them actively in healthcare decisions and as partners to healthcare professionals. The need for well-informed healthcare professionals can be fulfilled by ensuring accessible healthcare information, the prevention of conflicting advice,

and the prevention of repeating medical history. Finally, the need for collaboration among healthcare professionals can be fulfilled by healthcare professionals communicating openly and directly and working closely together.

Trial registration and ethics

This study was not subject to the Dutch Medical Research Involving Human Subjects Act (WMO). It was conducted in accordance with the Declaration of Helsinki and received approval from the Ethical Advisory Committee (HEAC) of Hanze University of Applied Sciences Groningen (document number HEAC.2022.030).

The study was supported by a research grant from ZonMw (InterGAIN, project no. 10270022120003).

Niek Koenders provides qualitative research training for healthcare professionals and contributed to this study as a qualitative research expert. He reports personal fees from Stichting Revalidatie Geneeskunde & Wetenschap, unrelated to the submitted work. The other author(s) declare no conflicts of interest.

Introduction

With the global population aged 60 years and older projected to double from 2015 levels by 2050 [1], the number of older adults at risk of or affected by malnutrition and sarcopenia is expected to increase substantially. Currently, the prevalence rates for malnutrition and sarcopenia among community-dwelling older adults are estimated at 7% and 13%, respectively [2, 3]. Malnutrition and sarcopenia are common among older adults and significantly impact physical health, independent functioning, overall quality of life, and mortality [4-6]. Malnutrition results from inadequate nutrition intake or uptake, altering body composition and body cell mass [7]. Sarcopenia is a muscle disease that may result from physical inactivity, inflammation, mitochondrial dysfunction, and malnutrition [8, 9]. Both conditions are characterized by reduced muscle mass and, in the case of sarcopenia, also loss of muscle strength [8, 10]. Effective treatment of these conditions requires a combination of nutritional and exercise interventions [6, 11, 12].

Given the multifaceted nature of these conditions, multiple areas of expertise and skills, as well as a collaborative effort from diverse professionals across various disciplines, are needed to address the complex needs of older adults with, or at risk of, malnutrition and sarcopenia [6, 11].

Interprofessional collaboration (IPC) offers a promising approach to integrated, person-centered care for addressing (risk of) malnutrition and sarcopenia. IPC involves different health or social care professionals working together to provide health services and is characterized by shared accountability, interdependence between individuals, and clarity of roles and goals [13]. The older adult is actively involved in the care process but is not a formal interprofessional team member. Unlike other forms of non-integrated collaboration in healthcare, in which professionals often work in parallel without coordinated efforts or shared objectives, IPC ensures a cohesive, team-based approach through joint treatment plans and a designated contact person to address the complex needs of older adults [14, 15]. So far, the perspectives of older adults remain underexplored, leaving it unknown how community-dwelling older adults view interprofessional treatment for (risk of) malnutrition and sarcopenia.

IPC centers around patient involvement, ensuring that older adults and their caregivers actively participate in healthcare. IPC can increase patient satisfaction and lead to better-informed patients [16-19]. Poor patient involvement, in contrast, is linked to worse health outcomes [20]. The World Health Organization (WHO)

emphasizes that patient involvement improves patient safety in primary care and, therefore, must be encouraged [21]. Understanding how older adults prefer to be engaged is essential for improving their healthcare outcomes, aligning with global healthcare initiatives, and enhancing person-centered care [20].

Despite the benefits of IPC, research has predominantly focused on professionals' perspectives, often neglecting the viewpoints of those who directly receive care. To our knowledge, no existing models link end-user needs and wishes with IPC. This oversight highlights the importance of qualitative studies to better understand the experiences and preferences of community-dwelling older adults with, or at risk of, malnutrition and/or sarcopenia. Understanding these perspectives is essential, as it can significantly impact the quality of person-centered care [22, 23]. Therefore, this study aimed to understand the needs and wishes of community-dwelling older adults regarding interprofessional treatment for (risk of) malnutrition and sarcopenia.

Methods

Study design

We conducted a qualitative study using semi-structured interviews and focus groups. Grounded theory, as described by Strauss and Corbin, was used to construct theory from the data [24]. This methodical, interpretive process was chosen to enhance understanding of older adults' perspectives and generate theory informed by their experiences. We developed a conceptual model through iterative data analysis to show the interconnectedness of the data [24]. By using both semi-structured interviews and focus groups, we captured in-depth individual insights and group dynamics, offering a comprehensive understanding of the older adults' perspectives. We adhered to the 32-item Consolidated Criteria for Reporting Qualitative Studies (COREQ) checklist to ensure transparent and rigorous reporting of the study's findings (Supporting information) [25].

Definition of "need" and "wish"

In this study, a "need" is defined as a felt state of deprivation that signals a fundamental requirement that cannot be repressed or replaced by another need [26, 27]. In contrast, a "wish" refers to a desire for a future outcome shaped by factors like value, expectancy, and practicality. A wish can emerge from anticipated consequences, outcomes, or actions [26, 28, 29]. Unlike needs, wishes are flexible. As priorities change, wishes can be replaced by other wishes, reflecting aspirational goals rather than necessities [26]. A wish represents the fulfillment of a

need and can manifest in various forms, reflecting individual differences in desires and preferences.

Eligibility criteria and recruitment

Participants were required to meet several criteria: being 65 years or older, living in the community and falling under the care of a general practitioner (GP), receiving treatment or having previously been treated for (risk of) malnutrition and/or sarcopenia, and being able to speak and read Dutch. Older adults with severe cognitive impairments that prevented them from making informed decisions were excluded. A qualified healthcare professional (HCP) evaluated potential participants, using their expertise to assess whether they met the inclusion criteria and could participate.

We used our direct and indirect professional networks and social media to reach out to professionals who work with older adults experiencing (or being at risk of) malnutrition or sarcopenia to assist in recruiting participants for the interviews and focus groups. Older adults who expressed interest were provided with informational leaflets and given the option to contact us via telephone or email. Alternatively, they could provide consent for their healthcare provider to share their contact details with the researchers.

We employed a purposive maximum variation sampling strategy to select participants for interviews and focus groups, ensuring diversity in gender, age, and the geographic living locations of the older adults. Recruitment spanned various regions in the Netherlands, covering the rural areas of Drenthe and Friesland and the cities of Nijmegen and Amsterdam. This approach facilitated a comprehensive understanding of diverse contexts across the country, where context refers to the various factors influencing participants' experiences, including their geographical location (urban vs. rural), social circumstances, and healthcare environment. These contexts shape how older adults interact with healthcare systems, experience conditions like malnutrition and sarcopenia, and perceive their treatment [30].

Before participating in the interview or focus group, all participants gave written informed consent, including permission to publish anonymized quotes and participant characteristics.

Data collection

We conducted face-to-face interviews and focus groups between March and November 2023. We developed interview guides for the interviews and the focus

groups (Supporting information). Both guides were created using the I-change model [31]. As preparation, we conducted a pilot interview with an older adult from the target group, and both guides were modified accordingly. For example, questions were rephrased to be more precise and more understandable for older adults, and some topics that did not generate in-depth responses were revised or expanded.

Interviews were held in the participants' living environment or at their chosen location. The older adult was informed that an interview would last a maximum of one hour. One researcher, SB, conducted all interviews.

Focus groups were conducted in a designated meeting room, with each session scheduled for two hours, including time for arrival and post-discussion. One researcher, SB, moderated both focus groups. In the first focus group, researcher JJR co-moderated, and SvE was responsible for taking field notes as a documenter. For the second focus group, due to the smaller group size and our prior experience, only two researchers were involved, with SvE serving as both co-moderator and documenter. Following each session, SB, JJR, and SvE discussed field notes and made necessary adjustments to the interview guide. The guide for the final focus group session was adjusted based on the outcomes of the interviews and the first focus group (Supporting information).

All interviews and focus groups were audio recorded, transcribed verbatim by a third party (Marinka® Transcriberen), and subsequently analyzed using ATLAS. ti software (version 8.4, Scientific Software Development GmbH). Data collection ended after reaching theoretical saturation, at which point no new selective codes emerged.

Reflexivity

The team's diverse expertise enriched the exploration of the needs and wishes of older adults surrounding IPC. SB, drawing on expertise in physiotherapy, provided perspectives from primary healthcare practice. SvE, with a background in nutrition science, emphasized dietary considerations. JJR, as a work and organizational psychologist, offered insights into IPC. SB and SvE were PhD candidates throughout the study, and JJR held a postdoctoral position. SB had experience conducting interviews and was trained in qualitative research and focus group moderation. In addition to SB, JJR, and SvE, the research team encompassed individuals with diverse backgrounds in dietetics [MvdB, HJW], nursing [EF], nutrition and physical activity [MT], physiotherapy [NK, HD, PvdW], person-centered and integrated care [SdR], gerontology [HD], and qualitative research [NK]. Additionally, a representative of the older population [AGB] was involved, providing a comprehensive perspective on the analysis.

Data analysis

We performed a grounded theory analysis involving three steps: open, axial, and selective coding [24]. SB and SvE independently read, re-read, and coded the transcripts using open codes. After this, they compared their open codes, engaging in open and constructive dialogue until consensus was reached. A constant comparative approach was employed to compare participant responses across interviews and focus groups. As a next step, axial codes were constructed. After all interviews and focus groups had finished, SB and SvE created selective codes to cluster the axial codes and identify connections in the data. Following the completion of the three stages of analysis by SB and SvE, all codes were reviewed within the research team to enhance mutual understanding and achieve consensus through four meetings with the entire research team. The first session focused on improving the open and axial codes. The second session was dedicated to discussing the axial and selective codes. The third and fourth sessions were devoted to constructing the conceptual model. The final axial and selective codes and the conceptual model were refined throughout the reporting process and subsequent manuscript drafts.

Trustworthiness

ATLAS.ti software (version 8.4, Scientific Software Development GmbH) facilitated data aggregation and analysis, promoting transparency in code descriptions through participant quotes. The constant comparison method strengthened the study's credibility by continuously comparing data and codes throughout the analysis. This method ensured that interpretations were grounded in the data and allowed for the refinement of axial codes. The ongoing improvement of the interview guides exemplified researchers' commitment to reflect on the research methods and findings throughout the research process. Analytical memos were documented throughout the data analysis to record decisions and interpretations. This enabled the research team to confirm the study's findings independently of the first authors' biases or influences, further enhancing the confirmability of the findings.

Results

Eleven interviews were conducted in Amsterdam and Drenthe, and two focus groups with seven participants were held in Nijmegen and Friesland. In Nijmegen, two older adults who had agreed to participate previously could not join the focus group at the location due to health issues. In Friesland, one older adult initially agreed to participate in a focus group but ultimately decided not to join, as he did not wish to participate in a group setting with multiple people. In Amsterdam,

two other older adults preferred one-on-one interviews over group settings, so individual interviews were conducted instead of a focus group.

In one of the focus groups, a participant's partner attended, and in another, a family member was present. The partner, actively involved in the participant's care, contributed to the focus group discussion to provide support and add context to the participant's experiences. The older adult in question requested this support, preferring to have assistance during the conversation. The partner provided informed consent, allowing us to use the input in the analysis. However, the family member just supported the other participant and did not provide data for analysis. Participant characteristics are detailed in Table 1.

Table 1 Participant characteristics

	Participants (n)
Interviews	
Total of participants	11
Sex	
Female	8
Male	3
Age in years	
65-69	1
70-74	1
75-79	5
80-84	0
85-89	4
Region	
Drenthe	8
Amsterdam	3
Focus groups	
Total of participants	7
Sex	
Female	4
Male	3
Age in years	
75-79	1
80-84	2
85-89	4
Region	
Nijmegen	2
Friesland	5

The interviews lasted an average of 39 minutes, ranging from 23 to 56 minutes. The focus groups lasted 76 and 77 minutes. Theoretical saturation was reached after the second focus group session, marking the end of data collection.

Beyond the findings related to IPC, several nuanced experiences and needs of older adults emerged that go beyond the immediate focus of IPC. These insights are presented in a dedicated context paragraph, offering a more comprehensive view of older adults' healthcare experiences. Following this broader context, seven axial codes and three selective codes were identified through analysis. These codes outline the needs and wishes of community-dwelling older adults regarding IPC in treating (risk of) malnutrition and sarcopenia. Finally, the conceptual model integrates these findings.

Context

Older adults expressed a need for clear and understandable communication about their health and medical information. They preferred various communication channels to suit different situations and personal preferences, including telephone, in-person interactions, and digital platforms. Autonomy was highlighted as necessary, both in making healthcare decisions and in practical matters like transportation. Older adults emphasized the importance of autonomy and self-determination in managing their health. While they want access to comprehensive medical records and clearly explained care plans, they also expressed concerns about potential anxiety when reviewing these records.

Many older adults recognize the convenience of online access to their medical records, which helps them monitor aspects of their health, such as medication. However, despite these advantages, there remains a hesitation among older adults to engage with their primary care physicians online. Older adults highlight the ongoing need for in-person interactions with their HCPs.

Selective and axial codes

Selective code 1: Older adults need to be involved in their interprofessional treatment

Older adults feel that they need to be actively involved in their treatment decisions and treated as equal conversation partners during discussions with their HCPs.

1A: Older adults should be actively involved in their healthcare decisions

Older adults expressed a desire to actively take part in decision-making related to their healthcare, mainly when it involves treatment options and the selection

of their care team. They highlighted the importance of shared decision-making, in which patients' preferences and insights are considered when HCPs decide on their behalf.

Older adults value being consulted on treatment choices, providing input into which HCPs are on their care team, and discussing care planning and medication. While older adults appreciate this involvement, many prefer receiving clear summaries of formal multi- or interdisciplinary meetings rather than attending them directly. Ultimately, older adults want their preferences respected and have an active voice in decision-making while trusting HCPs' guidance and expertise.

> *Participant (P3): "They [general practitioner and physical therapist] have to. They shouldn't just do anything without consulting me. I wouldn't like that. I don't want to be left out."*

1B: Older adults should be engaged as partners to their HCPs

Older adults emphasized that beyond decision-making, they want to be treated as equal partners in their healthcare, desiring mutual respect and engagement from their professionals.

They seek healthcare interactions where their opinions are heard, valued, and incorporated into care decisions, reinforcing a sense of equality in the relationship.

Older adults stressed the need for HCPs to listen to and acknowledge their unique perspectives. They felt that HCPs sometimes dominated the conversation, relying on their specialized knowledge and making older adults feel insignificant in decision-making. Older adults described situations where they felt treated as "just a number" rather than individuals with valid input. Participants expressed a need for collaborative, respectful conversations with their HCPs, where their voices are genuinely valued, and their input plays a meaningful role in care decisions.

> *Participant (P1): "For the patients, it is much better. Listen to the patients. Not like: I'm [a doctor] more educated, and you [the patient] are just a number. That's how it goes. That doesn't cross my mind. That is often the case these days. Not all doctors, but you have certain types who are so arrogant. They are so arrogant in healthcare. That bothers me."*

Selective code 2: Older adults need HCPs to be well-informed about their interprofessional treatment

Older adults need their HCPs to be well-informed, which can be achieved by making their medical information accessible to the professionals involved. Older adults hope this will prevent them from repeating their medical history to different HCPs. Accessible information would also diminish the conflicting advice they sometimes receive from HCPs.

2A: Older adults wish for their medical information to be accessible to involved HCPs

Older adults expressed diverse perspectives on sharing their medical information. For some, the convenience of sharing treatment details between HCPs is paramount. They find it practical and reassuring when all involved professionals have access to their complete medical history, facilitating seamless care coordination and ensuring that new HCPs are informed from the start. They appreciate it when HCPs are well-informed about their treatments across different settings, indicating an efficient and well-coordinated healthcare system.

However, older adults have concerns about privacy and the extent of information sharing. Some older adults have specific preferences about what information should be shared and with whom. For instance, they may prefer that sensitive information, such as emotional well-being, is not shared without explicit consent. They also desire control over who can access their information, indicating that not all details should be available to every provider but only what is relevant to their care.

> *Participant (P4): "At my age, what secrets do you have? I think it's good when you become ill that they know what medications I'm on, what therapies I have."*

2B: Older adults should not have to repeat their medical history to different HCPs

Older adults expressed frustration with repeatedly recounting their medical history to different HCPs. As they often work with multiple specialists focused on various aspects of their care, they find it annoying and burdensome to share the same information repeatedly because of insufficient communication among HCPs.

> *Participant (P1): "Because you have to tell them [dietitian and the geriatrics department] everything about what's going on..."Partner of participant (P1): "They are unaware of each other's existence, so to speak."*

2C: Older adults should not receive conflicting advice from their HCPs

Older adults reported receiving contradictory medical advice from different HCPs, which disrupts their treatment strategies and causes significant frustration. They specifically wish HCPs to refrain from offering advice outside their expertise to prevent inconsistencies with specialist recommendations. Older adults desire better coordination among HCPs to ensure that recommendations are aligned and accurate, avoiding unclear, false, or conflicting advice.

> *Participant (P9): "She's a nephrologist for the kidneys. She's not for the muscles. So, I received advice that I thought wouldn't work. And the physiotherapist also said, 'Don't bother with that; it's not practical.' I wasn't happy with that advice [from the nephrologist] either; that's not how it works."*

Selective code 3: Older adults need collaboration amongst involved HCPs in interprofessional treatment

Older adults expressed a need for their HCPs to collaborate and communicate with each other. This is especially important when older adults are experiencing critical illness or are unable to care for themselves.

3A: HCPs should work closely together

Older adults mentioned they find it comforting when HCPs collaborate as a team rather than in isolation, particularly during medical emergencies. Older adults emphasized the importance of improved agreement and cooperation between healthcare entities, such as pharmacists, general practitioners, and hospitals, regarding medication use. Insufficient communication in these areas has led to errors, highlighting the need for better coordination. Older adults appreciate HCPs working together seamlessly to ensure comprehensive and well-coordinated care, though they recognize that time constraints might limit this.

> *Participant (P2): "It gives trust that there are HCPs who are not just here for themselves but are trying to work as a team. That doesn't mean they have to contact each other every week; that's nonsense, of course, because it's not necessary at all. But, if necessary, I can say, 'Get in touch with them,' and they do. [...] It gives the most confidence because you are always dealing with adults who know the ins and outs and have a piece of background information you normally don't give or can't give."*

3B: HCPs should communicate openly and directly with each other

Older adults expressed that communication with their HCPs enhances their security and confidence. They desire seamless communication among professionals and want to be informed about these interactions without direct involvement. Effective communication is essential to them when HCPs have different opinions about their care. They also mentioned a greater need for inter-provider communication during serious illness.

> *Participant (P10): "I like hearing that they [my general practitioner and dietitian] consult each other. My general practitioner, who was unsatisfied with something, consulted my dietitian; I thought that was very good. Because certain things are different for me than for someone else."*

Conceptual model

Our conceptual model visualizes the needs and wishes of community-dwelling older adults regarding interprofessional treatment for (risk of) malnutrition and sarcopenia (Figure 1). Older adults are at the model's center, emphasizing their central role in a person-centered approach to care. The model consists of two layers: the inner circle represents needs, derived from the selective codes, and the outer circle represents wishes, derived from the axial codes. Needs define the fundamental requirements of older adults in the context of interprofessional treatment for malnutrition and sarcopenia, while wishes specify ways to fulfill these needs.

Figure 1 Conceptual model of interprofessional treatment of (risk of) malnutrition and sarcopenia: needs and wishes of community-dwelling older adults. HCPs: Healthcare professionals.

Discussion

This study aimed to understand the needs and wishes of community-dwelling older adults regarding interprofessional treatment for (risk of) malnutrition and sarcopenia. Our conceptual model illustrates the needs and wishes of older adults with (risk of) malnutrition or sarcopenia. Older adults' needs reflect their perception of what is missing in interprofessional treatment, while their wishes suggest how they believe these needs could be fulfilled. The older adults' need to be involved in interprofessional treatment can be fulfilled by being actively involved in healthcare decisions and by being engaged as partners with their HCPs. The older adults' need for well-informed HCPs can be fulfilled by making healthcare information accessible to HCPs, the prevention of conflicting advice among HCPs, and the prevention of repeating medical history to HCPs. Lastly, the older adults' need for collaboration among HCPs can be fulfilled by HCPs communicating openly and directly and by HCPs working closely together.

Our study shows that older adults support data sharing among involved HCPs in their interprofessional treatment for malnutrition and sarcopenia. They appreciate having their complete medical history accessible to all HCPs, as it minimizes the need to recount their health information repeatedly and promotes consistency in treatment. However, older adults are also concerned about privacy. A previous study reported that older adults want to share health-related information but worry about losing control over their personal information and the risk of family members micromanaging when they can see all their medical information [32]. Although acceptance of data sharing tends to increase as health needs grow, privacy concerns remain paramount, especially among more independent older adults [32].

Our study aligns with the findings of a previous meta-ethnography, which shows that older adults consider strong interprofessional communication essential for integrated primary care [33]. In that study, if older adults encountered conflicting advice or inadequate follow-up, they interpreted this as a breakdown in communication between HCPs. Older adults are particularly concerned about whether HCPs communicate openly with each other. Our study and the meta-ethnography show that older adults feel more secure and confident when HCPs maintain open and direct communication.

In our study, older adults expressed a desire for autonomy in their healthcare, emphasizing the need to be treated as partners in interprofessional treatment for malnutrition and sarcopenia. It is common for HCPs or family members to underestimate the older adult's capacity to make autonomous decisions regarding their

health, which can be detrimental to the feeling of self-control [34]. The desire for participation aligns with the Self-Determination Theory (SDT) component of autonomy [35]. Patients are more motivated to participate in decision-making when they feel they have control over their treatment choices and align with their values and preferences. Older adults in our study highlighted the need to have their preferences and values respected. By fostering a sense of agency and involving older adults as partners in their care, HCPs can enhance motivation and patient engagement.

Our study showed that older adults desire active decision-making. However, previous research specified that their involvement should focus on a 'caring relationship,' 'person-centered approach,' and 'receiving information' rather than on 'active participation in decision-making.' [36] This shift may reflect evolving perspectives on healthcare autonomy between 2007 and 2024. According to the Attribution Theory, active involvement in healthcare can enhance older adults' sense of control and self-esteem [37]. When older adults are involved in decision-making and see positive results, they often feel that their efforts led to success, which boosts their self-esteem. However, when excluded from such decisions, they may attribute failures to external factors beyond their control, leading to frustration and disengagement.

The desire for active decision-making also aligns closely with the principles of shared decision-making (SDM), a component of person-centered care in which HCPs and patients work together to make healthcare choices [38]. In SDM, HCPs share the best available evidence, presenting treatment options, risks, and benefits, while patients are encouraged to voice their values and preferences. Traditionally, SDM models have focused on a single patient-provider relationship. However, as healthcare becomes more complex and interprofessional, the concept of SDM has expanded to incorporate additional stakeholders, such as family members and other HCPs, shifting towards interprofessional shared decision-making (IP-SDM) [39]. Integrating IP-SDM could improve decision-making quality, strengthen patient-provider partnerships, and foster more coordinated, responsive care that aligns with patients' comprehensive needs.

Older adults often experience multiple health conditions, with malnutrition and sarcopenia commonly appearing alongside other issues. Although we aimed to focus on these conditions, discussions frequently included care for other comorbidities. This overlap suggests that older adults perceive their health as interconnected rather than divided by individual conditions, reinforcing the importance of interprofessional treatment approaches for malnutrition and sarcopenia.

Strengths and limitations

A strength of this study is its use of a rigorously grounded theory methodology. Two researchers independently coded data, and a diverse group of experts interpreted the findings, enhancing the study's trustworthiness. Researchers used the time between interviews and focus groups to analyze transcripts and refine the interview guide, allowing for deeper exploration of participants' sentiments. Collaborative discussion sessions among all researchers contributed significantly to understanding older adults' nuanced needs and wishes, which informed the thorough development of the conceptual model.

However, some limitations need to be acknowledged. Firstly, older adults in this study were unfamiliar with interprofessional care. Researchers had to explain the principle of interprofessional care during interviews and focus groups. While this ensured a basic understanding, more detailed insights might have been gathered if participants had prior knowledge or experience with IPC in their healthcare. Nonetheless, IPC for malnutrition and sarcopenia is rarely implemented in primary care, making it challenging to find suitable candidates with direct experience. Secondly, although the study's minimum age requirement was 65 years, most participants were 75 years and older. This reflects the increasing prevalence of (risk of) malnutrition and sarcopenia with age, but the preferences of these older adults may differ from those of relatively younger participants. This demographic focus could limit the transferability of the findings to younger older adults.

Implications for clinical practice and future research

The results of this study provide valuable insights into the needs of older adults in the interprofessional treatment of malnutrition and sarcopenia, which HCPs, policymakers, and researchers should consider.

For HCPs, these findings underscore the potential benefits of integrating older adults' preferences into care practices through a structured interprofessional approach. Coordinated care that addresses interconnected health issues, such as malnutrition and sarcopenia, alongside other comorbidities, is essential. Interprofessional shared decision-making (IP-SDM) allows for unified treatment planning with the older adult and improves decision quality, reduces conflicting advice, and strengthens the partnership between patients and providers. This ensures older adults feel actively involved and respected in their care, leading to better health outcomes.

Policymakers should integrate older adults' insights into policies that support person-centered and interprofessional care models. These policies should incorporate clear

protocols for interprofessional communication, shared data access, and privacy protection. As privacy is a significant concern for older adults, policies should balance data sharing to facilitate seamless care with respect for patient autonomy and data control.

Additionally, researchers should build on these results by testing their applicability in practice and exploring further areas of IPC to improve care for older adults with (risk of) malnutrition and sarcopenia. Designing and implementing a structured interprofessional care pathway for these conditions could minimize the risk of conflicting advice and make it easier for older adults to navigate complex care networks. Moreover, interprofessional care pathways can improve treatment continuity and consistency, ensuring that older adults receive comprehensive, coordinated care tailored to their needs.

Conclusion

This study contributes to a deeper understanding of the needs and wishes of community-dwelling older adults regarding interprofessional treatment for (risk of) malnutrition and sarcopenia. Older adults' needs reflect their perception of what is missing in interprofessional treatment, while their wishes suggest how they believe these needs could be fulfilled. Older adults' need for involvement in interprofessional treatment can be met by engaging older adults actively in healthcare decisions and as partners with healthcare professionals. The need for well-informed healthcare professionals can be fulfilled by ensuring accessible healthcare information, the prevention of conflicting advice, and the prevention of repeating medical history. Finally, the need for collaboration among healthcare professionals can be fulfilled by healthcare professionals communicating openly and directly and working closely together.

This study provides valuable insights for healthcare professionals, researchers, and policymakers to support person-centered interprofessional care for malnutrition and sarcopenia.

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Supporting information

COREQ (COnsolidated criteria for REporting Qualitative research) Checklist

Table I COnsolidated criteria for REporting Qualitative research Checklist. Developed from: Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. International Journal for Quality in Health Care. 2007. Volume 19, Number 6: pp. 349 – 357

Topic	Item No.	Guide questions/Description	Reported on page No.
Domain 1: Research team and reflexivity			
Personal characteristics			
Interviewer/facilitator	1	Which author/s conducted the interview or focus group?	6
Credentials	2	What were the researcher's credentials? E.g. PhD, MD	6-7
Occupation	3	What was their occupation at the time of the study?	6-7
Gender	4	Was the researcher male or female?	N/A
Experience and training	5	What experience or training did the researcher have?	6-7
Relationship with participants			
Relationship established	6	Was a relationship established prior to study commencement?	5
Participant knowledge of the interviewer	7	What did the participants know about the researcher? e.g. personal goals, reasons for doing the research	N/A
Interviewer characteristics	8	What characteristics were reported about the inter viewer/facilitator? e.g. Bias, assumptions, reasons and interests in the research topic	6-7
Domain 2: Study design			
Theoretical framework			
Methodological orientation and Theory	9	What methodological orientation was stated to underpin the study? e.g. grounded theory, discourse analysis, ethnography, phenomenology, content analysis	5
Participant selection			
Sampling	10	How were participants selected? e.g. purposive, convenience, consecutive, snowball	5
Method of approach	11	How were participants approached? e.g. face-to-face, telephone, mail, email	5
Sample size	12	How many participants were in the study?	8
Non-participation	13	How many people refused to participate or dropped out? Reasons?	8

Table I Continued

Topic	Item No.	Guide questions/Description	Reported on page No.
Setting			
Setting of data collection	14	Where was the data collected? e.g. home, clinic, workplace	6
Presence of non-participants	15	Was anyone else present besides the participants and researchers?	N/A
Description of sample	16	What are the important characteristics of the sample? e.g. demographic data, date	8 + Table 1
Data collection			
Interview guide	17	Were questions, prompts, guides provided by the authors? Was it pilot tested?	Supporting information
Repeat interviews	18	Were repeat inter views carried out? If yes, how many?	N/A
Audio/visual recording	19	Did the research use audio or visual recording to collect the data?	6
Field notes	20	Were field notes made during and/or after the interview or focus group?	6
Duration	21	What was the duration of the inter views or focus group?	8
Data saturation	22	Was data saturation discussed?	6
Transcripts returned	23	Were transcripts returned to participants for comment and/or correction?	N/A
Domain 3: analysis and findings			
Data analysis			
Number of data coders	24	How many data coders coded the data?	7
Description of the coding tree	25	Did authors provide a description of the coding tree?	N/A
Derivation of themes	26	Were themes identified in advance or derived from the data?	7
Software	27	What software, if applicable, was used to manage the data?	7-8
Participant checking	28	Did participants provide feedback on the findings?	N/A
Reporting			
Quotations presented	29	Were participant quotations presented to illustrate the themes/findings? Was each quotation identified? e.g. participant number	8-18
Data and findings consistent	30	Was there consistency between the data presented and the findings?	8-18
Clarity of major themes	31	Were major themes clearly presented in the findings?	8-18
Clarity of minor themes	32	Is there a description of diverse cases or discussion of minor themes?	8-18

Interview Guide Interviews

Opening question

- Please tell me a little about who you are (e.g., background, hobbies)?

Diagnosis of malnutrition and/or sarcopenia

- We are conducting this research to learn your thoughts about how healthcare professionals work together during your treatment. You went to a dietitian and/or physiotherapist. Could you tell us about your experience with this?

Additional questions

- How did you come to see the dietitian or physical therapist?
- What symptoms made you visit the physical therapist or dietitian?
  - Have you had unintentional weight loss? Do you have/do you have thinner arms/legs? Do/did you have/have less energy?
  - Do you have/have you had less muscle strength? For example, did you have more difficulty getting out of a chair, climbing stairs, or lifting a shopping bag?

Interprofessional collaboration around the treatment of malnutrition and sarcopenia

- Which other professionals have you (had) contact with about your complaints? (E.g., family doctor, doctor's office assistant, dietician, physical therapist, district nurse, welfare worker, hospital care professional).

Additional questions

- What did you talk about with this healthcare professional(s)?
  - With which healthcare professionals did you have the most contact?
  - What did you like or dislike about the contact? (For example, the content, duration, timing, or referral process.)
- Did you feel like something was missing during these contacts? If yes, what was missing? (For example, information, advice, a healthcare professional, or a type of treatment.)
- Which healthcare professionals treated you for your symptoms?
  - What did the treatments involve? (For example, a combination of nutrition and exercise.)
  - What were you satisfied with?
  - What were you less satisfied with or not satisfied with at all?
- What did you think of the collaboration between the healthcare professionals?
  - Could you give an example where you noticed little or no collaboration? (For instance, conflicting advice, misunderstandings, repeating questions, or having to tell the same story multiple times.)
  - Could you give an example where you noticed good collaboration? (For instance, professionals sharing information, being well-informed, being on the same page or giving consistent advice.)
  - Which health care professional arranged the most, in your opinion? What did you notice about that? What did you think about that?
  - Healthcare professionals can make decisions about your care together. But sometimes, one healthcare professional wants to decide more than another. How was that in your situation?
  - What did you think about that?
  - When do you think it is important for healthcare professionals to work together? Why do you think so?

Role community-dwelling older adults

- How would you like to cooperate with healthcare professionals? (E.g., receive information only, think along, participate in consultations, make your own choices)

Additional questions

- In what way would you prefer to receive information? (E.g. verbal, via e-mail, electronic file) At what times would this work best for you?
  - What decisions would you like to make for yourself?
  - What do you need to be able to make these choices yourself?

Wrap-up

- Do you have anything to add to what we have discussed? [...] Then I will stop the recording now.
- May I contact you if I have any further questions about what was discussed in this conversation? [..]
- Are you interested in the outcome of this investigation? *If yes, record the details about which and how we may reach the participant.*
- Thank you for your participation.

Memory aid for follow-up questions, asking for clarification, and follow-up questions

- Questions to ask through:
  - You mentioned [...]:
  - Could you tell me more about that?
- Questions to clarify:
  - You mentioned [...]:
  - What exactly do you mean by that?
  - Could you elaborate on this?
  - Could you give me an example?
- Follow-up questions:
  - You mentioned reason x; are there any other reasons?

Interview Guide Focus Groups (Version 1)

General opening question

- How did you find out that you were experiencing unintentional weight loss and/or loss of muscle strength?

Introductory questions

- Different healthcare professionals, such as dieticians, physiotherapists, general practitioners, district nurses, etc., may be involved in treating weight and muscle loss. Would you like to explain what type of healthcare professionals are/were involved in your treatment?
- Could you indicate to what extent these healthcare professionals had mutual contact around your treatment?
- In what way would you like to be involved in the contact between health care professionals?

Main questions

- To what extent did you miss anything during the contact? If yes, could you indicate what you missed? (E.g., certain information or advice, a healthcare professional, type of treatment)
- Could you indicate how you experienced the contact between healthcare professionals?
  - o If there is little contact between them: Could you give an example where you noticed little contact? (E.g., conflicting information/advice, misunderstandings, having to tell the same story more often)
  - o If there is a lot of contact: Could you give an example where you noticed a lot of contact between healthcare professionals? (Informed healthcare professionals, same information/advice)
- From your experience, which type of healthcare professional arranged the most? By what did you notice that? How did you experience that?
- In what situation do you think it is essential for healthcare professionals to have a lot of contact? Would you care to elaborate on that?
- To what extent did you consult with this healthcare professional(s)?
- In what way do you prefer to receive information from your healthcare professional? (E.g., verbal, via e-mail, electronic record) At what times?
- What do you want to make your own choices about during your treatment?
- What do you need to be able to make these choices yourself?

Concluding question

- Is there anything you would like to add to what we discussed during this group discussion?

Interview Guide Focus Groups (Version 2)

General opening question

- Treatment around losing weight and muscle strength may involve different healthcare professionals.
  - For example, the dietician, physical therapist, family doctor, district nurse, etc.
  - Which healthcare professionals have you been in contact with?

Introductory question

- How do you feel about the care you receive from these healthcare professionals?

Main questions

- Participants in previous interviews mentioned that they appreciate it when healthcare professionals communicate with each other. This allows healthcare professionals to be aware of different healthcare professional's advice and treatment goals. What do you think healthcare professionals should have contact about?
- In what situation do you think it is essential for healthcare professionals to have contact with each other? Could you elaborate?
- You can receive information during an in-person appointment via phone or electronic record. In what way do you prefer to receive information from your healthcare professional (at what times?)?
- Participants in previous group discussions indicated they need personal contact with healthcare professionals. How is that for you? What do you find important in contact with healthcare professionals?
- To what extent do you want to be involved in choices in your treatment?
  - What choices would you like to make for yourself?
  - What do you need to make these choices independently?
  - Do you need information on specific topics to make these choices?
  - If yes, what topics would you like information about?
- Have you missed anything in your contact with healthcare professionals? If yes, could you explain what you missed? (E.g., certain information or advice, a healthcare professional, type of treatment)

Concluding question

- Is there anything you would like to add to what we discussed during this group discussion?

Chapter 9

General discussion

Through this thesis, we aimed to improve the care of older adults, specifically those at risk for sarcopenia and malnutrition. To achieve this, we evaluated diagnostic tools, developed interventions, and explored the perspectives of professionals and older adults regarding interprofessional collaboration for this population. In this chapter we reflect on the main findings, their strengths and limitations, and their implications for future healthcare and research.

Part I: Diagnosis, assessment, and evaluation

In Part I, we aimed to assess and evaluate the psychometric properties of tests and tools used for people with (risk of) sarcopenia.

Main findings and implications

There is a need for disease-specific physical performance, screening, and diagnostic tests for people with sarcopenia, which are validated specifically for this population. For physical performance tests, our review showed that although reliability was generally acceptable, most tests lacked sufficient validity and responsiveness and were rarely evaluated in sarcopenic populations. This limits their usefulness for clinical decision-making and monitoring treatment effects. In our cross-sectional study of hospitalized patients, the SARC-F questionnaire demonstrated limited diagnostic accuracy for identifying sarcopenia in clinical practice. A more objective measure, such as handgrip strength, emerged as a more reliable alternative and should be considered as the first-line test to identify sarcopenia in this setting. We believe it is important to use outcome measures that are both psychometrically sound and appropriate for the target population and setting [1]. For preventive purposes, it may also be relevant to apply different cutoffs across age groups, as early signs of weakness in younger individuals could indicate a trajectory of decline [2]. The absence of validated and responsive tools undermines accurate diagnosis, severity grading, and monitoring of sarcopenia over time in clinical practice. Early detection and timely intervention are essential, but only meaningful if supported by appropriate measurement tools.

Strengths and limitations

A key strength of this part of the thesis is its direct alignment with the European Working Group on Sarcopenia in Older People guideline [3]. By focusing on the measurement outcomes described in this guideline, the results of this study can inform future global revisions. Methodologically, the systematic review applied the GRADE approach to ensure transparent evaluation of evidence quality, while the

clinical study used standardized procedures and involved trained professionals to enhance the reliability and practical relevance of the results [4].

While both studies contribute to our understanding of sarcopenia (risk) assessment, several overarching limitations should be noted. First, generalizability is limited due to the specific populations studied: community-dwelling older adults in one study and hospitalized patients in the other. In both cases, the representation of individuals with confirmed sarcopenia was lower than expected, which may affect the applicability of findings to the sarcopenic population. Additionally, both studies mainly relied on cross-sectional data, which limits the ability to assess changes over time and may introduce inaccuracy in the measurements due to natural fluctuations or temporary conditions.

Gaps in knowledge and future research

The global prevalence of sarcopenia varies based on the classification used, ranging from 10% to 27% [5]. The differences in guidelines on sarcopenia around the world hinder the comparability of research and implementation of standard operating procedures regarding sarcopenia screening, diagnosis, assessment, and evaluation. The Global Leadership Initiative in Sarcopenia (GLIS) is working towards a global working definition with standardized measurement outcomes, indicating three concepts of sarcopenia: muscle mass, muscle strength, and muscle-specific strength [6]. GLIS research should yield a core set of tests with strong psychometric properties that are widely applicable and can be tailored to the individuals being assessed and their specific setting. Our findings contribute to this effort by identifying which tests are psychometrically sound and suitable for clinical use. A standardized core outcome set should be implemented worldwide by hospitals and primary care, with possibly different cutoff values depending on the population.

Apart from traditional measurement outcomes, the use of patient-reported outcome measures (PROMs), potential biomarkers, and wearable technology may offer new solutions for identifying and monitoring sarcopenia. PROMs such as the SarQoL [7-10], ARMQoL [11], and PROMIS Physical Function [12] provide insight into how sarcopenia or loss of muscle mass and muscle strength impact quality of life and physical abilities [13]. The use of biomarkers may be implemented in the future. Inflammatory markers, hormones, and metabolites could serve as indicators for early detection and monitoring of sarcopenia progression. However, the currently available biomarkers are not specific enough and lack standardized cutoff values, which limits their ability to provide valuable information on sarcopenia [14]. Finally, advancements in wearable technology could provide new avenues for early

detection and continuous monitoring of physical activity. Devices equipped with inertial sensors can assess gait parameters, enabling the identification of subtle changes in gait speed and patterns associated with sarcopenia [15].

To better detect and monitor sarcopenia, future efforts should focus on integrating diverse measurement outcomes, including physical tests, patient-reported outcomes, biomarkers, and wearable technology. This combined approach may offer more accurate predictions of sarcopenia progression and support earlier, more personalized interventions. Validating these tools and embedding them in clinical practice and primary care will be key to improving care worldwide.

Part II: Interventions

In Part II, we aimed to evaluate the feasibility, effectiveness, and (re)design of a research protocol for exercise and nutrition interventions.

Main findings and implications.

Our research demonstrates that protein supplementation can effectively increase protein intake during prehabilitation, supporting its use alongside dietetic guidance. However, a combined exercise and nutrition intervention in hospitalized patients at risk for sarcopenia faced considerable barriers, such as patients' physical and mental limitations, motivation, and competing priorities. These challenges result in low recruitment and high dropout rates, underscoring the need to carefully consider patient capacity, motivation, and timing when designing complex interventions [16]. Based on these insights, we adapted the protocol to focus on a broader population of hospitalized older adults, aiming to improve feasibility and applicability. The findings of this part of the thesis highlight the importance of patient-centered, flexible approaches and iterative refinement of interventions to optimize engagement in this vulnerable group.

Strengths and limitations

This part of the thesis provides a comprehensive and transparent account of the design, implementation, and adaptation of nutritional and physical activity interventions for (older) hospitalized patients. It includes a detailed assessment of adherence to nutritional intervention using validated methods, which is rarely described in research. The intervention studies are grounded in multidisciplinary collaboration and reflect real-world clinical practice, increasing their relevance and translational value. The structured reporting of the protocol, challenges in

the feasibility study, and refinements offers practical insights that can support researchers and clinicians in designing feasible, patient-centered interventions.

At the same time, several limitations may affect the interpretation and generalizability of the findings. The study populations are specific to people with illnesses, during or around hospital stay; this may not reflect the broader population of older adults [17, 18]. Selection bias is likely in studies where participation depended on patients' physical condition or motivation to change their lifestyle [19]. Additionally, contextual factors such as existing healthcare support, mental and physical health, and other ongoing interventions can influence outcomes.

Gaps in knowledge and future research

The effectiveness of a combined exercise and nutritional intervention in hospitalized older patients has not yet been shown and will be elucidated after analysis of the FITFOOD study. This hospitalized population has not been researched enough and differs from the community-dwelling population in the number of comorbidities present [20].

The International Conference on Frailty and Sarcopenia Research & Geroscience Task Force recommends exercise as an effective non-pharmacological treatment for multifactorial geriatric syndromes such as sarcopenia. Resistance and power training two to three times per week, supplemented with functional, balance, and gait exercises, are considered key components. We believe exercise should be recognized by both healthcare professionals and patients as a legitimate form of treatment, relevant to both prevention and disease management [21].

Beyond physical exercise, amino acids from dietary protein play a crucial role in stimulating muscle protein synthesis [22]. However, the optimal protein dose required to maximize this process remains unclear. While earlier consensus suggested that healthy older adults need approximately 20g of protein per serving to stimulate maximal muscle protein synthesis, anabolic resistance in aging muscle indicates that higher doses may be necessary. Some recommendations suggest up to 40g per serving [23]. This assumption remains debated, but recent studies in healthy active males indicate that the anabolic response to a high post-exercise protein intake can be prolonged beyond this level, thereby questioning the existence of a strict upper limit to protein utilization for muscle building in a single meal [24]. This finding also indicates that evenly distributing protein intake across multiple meals may offer greater flexibility in meeting nutritional recommendations while still supporting optimal muscle protein synthesis. It is unsure whether this also applies to older of less healthy persons.

Current recommendations for nutrition and exercise are partially personalized, with a focus on achieving individual protein requirements, food preferences, exercise type, and intensity. Besides, we believe these interventions should also be aligned with the lived experiences, preferences, and broader needs of specific patient populations. This requires consideration of psychosocial factors, motivational drivers, and contextual barriers that influence adherence and outcomes. Currently, there is no medication for the treatment of sarcopenia. However, recent advancements suggest promising potential therapies. For instance, GDF15 antagonists have shown the ability to alleviate muscle atrophy in early studies [25, 26]. Additionally, a combination of the diabetes drug metformin and the dementia medication galantamine has demonstrated encouraging results in improving muscle quality [27]. While these novel therapies are still in the research and development phase, primarily in mouse models, they hold promise for future clinical applications. If successful, they could play a crucial role not only in treating sarcopenia but also in addressing other muscle-related conditions, such as cancer cachexia and muscle myopathies.

In summary, gaps remain in our understanding of effective interventions for sarcopenia, especially in hospitalized older adults who face not only decreased muscle strength and mass but also multiple comorbidities. This research is still ongoing. While exercise and nutrition interventions show promise, the most effective approach for this vulnerable population has yet to be fully established. Emerging pharmacological treatments may complement exercise and nutrition strategies in the future, but they are unlikely to surpass the fundamental contribution of these non-pharmacological interventions. Closing these gaps through ongoing and future research is essential for developing evidence-based, personalized approaches to prevent and treat sarcopenia, ultimately improving outcomes for (hospitalized) older adults at risk.

Part III: Interprofessional collaboration

In Part III, we aimed to explore the perspectives of healthcare professionals and older adults at risk for sarcopenia and malnutrition on interprofessional collaboration.

Main findings and implications

We identified three key dimensions of interprofessional collaboration that professionals consider crucial: the healthcare professionals themselves, the supporting infrastructure, and the involvement of older adults. Successful

collaboration depends on improvements within each of these dimensions as well as on their integration. Older adults emphasize the importance of active involvement as partners in their own care, receiving consistent and accessible information, and avoiding the need to repeat their medical history. To achieve this, healthcare professionals must communicate openly, coordinate closely, and provide clear, unified guidance.

Our findings highlight the need for a well-structured approach to interprofessional collaboration in caring for older adults at risk of sarcopenia and malnutrition. Since these conditions often overlap and treatment is multifactorial, their management requires multiple healthcare providers to be involved [28]. Healthcare systems should facilitate this by improving information exchange across care settings, clarifying roles and responsibilities, and ensuring that older adults receive understandable and consistent information. Assigning a coordinating professional, whose background may vary depending on the patient's needs, can strengthen collaboration and provide structure. Enhancing these elements will promote patient-centered care, reduce fragmentation, and improve overall healthcare efficiency.

Strengths and limitations

A major strength of this part of the thesis is that we rigorously applied grounded theory methodology [29]. Two independent researchers coded all data, enhancing the reliability of the findings and reducing interpretation bias. We followed an iterative process in both studies, enabling reflection and analysis between interviews or focus groups and allowing for deeper exploration of participants' views. Additionally, we held collaborative discussions across various research disciplines, which enriched our analysis and fostered a more comprehensive understanding of participants' nuanced perspectives.

Multiple limitations apply to this part of the study. Selection bias is likely, as participants probably had a pre-existing interest or experience with interprofessional collaboration, which could have influenced both their decision to participate and their responses in interviews or focus groups. Although interviews and focus groups were conducted across various regions of the Netherlands, research in this field tends to attract predominantly highly educated older adults. This limits the generalizability of our findings to the broader older adult population. Additionally, we did not collect data on participants' educational backgrounds, making it difficult to characterize the demographic profile of those involved fully.

Gaps in knowledge and future research

The InterGAIN project has developed an interprofessional care pathway tailored to the Dutch healthcare system, enabling early recognition of reduced intrinsic capacity in primary care. Intrinsic capacity refers to an individual's physical and mental abilities, shifting the focus from deficits to capabilities and potentially increasing older adults' motivation to engage in health-promoting behavior. Malnutrition and sarcopenia both contribute to and result from reduced intrinsic capacity. Building on this concept, the World Health Organization's Integrated Care for Older People (ICOPE) framework promotes person-centered care, yet in practice its assessment tools still primarily measure deficits, creating a mismatch between its holistic intentions and operationalization [30].

Future research on interprofessional collaboration in sarcopenia and malnutrition healthcare should move beyond understanding stakeholder perspectives to implement effective collaboration. While this thesis has explored the perspectives of professionals and older adults, the next step is to focus on implementation research to translate this knowledge into practice. Implementation studies should investigate practical strategies for fostering collaboration, optimizing communication between professionals, and embedding interprofessional collaboration into existing healthcare systems [31]. Additionally, research should assess the impact of interprofessional collaboration on patient outcomes, healthcare efficiency, and professional satisfaction, as well as identify key barriers and facilitators in real-world settings to improve implementation continually.

Overall conclusion

This thesis shows that improving care for older adults at risk of sarcopenia and malnutrition requires an integrated approach in which diagnostic accuracy, effective interventions, and interprofessional collaboration reinforce each other. Addressing just one of these domains is not sufficient. Without alignment between identification, treatment, and organization of care, opportunities for timely and effective support are missed.

First, diagnostic tools must meet high psychometric standards to ensure reliable identification and evaluation of sarcopenia. The use of valid and reliable diagnostics not only supports clinical decision-making but also raises awareness among healthcare professionals and patients about the importance of recognizing sarcopenia. This awareness is essential, as it forms the foundation for motivation

to address the condition. In this context, education and training of healthcare professionals are crucial to ensure they understand the significance and impact of sarcopenia and can effectively communicate this to patients. Without this recognition and engagement from healthcare providers, patients are unlikely to appreciate the need for intervention or to be motivated to initiate and maintain behavioral changes. Our findings show that in hospital settings, opportunities for lifestyle interventions in patients at risk for sarcopenia are constrained, as patients are often too ill, lack capacity or motivation because of the acute condition for which they are hospitalized. This highlights the need to shift intervention efforts for patients at risk for sarcopenia towards primary care and home settings

After hospital discharge, opportunities for intervention may be more feasible; however, without a structured transition, patients are at risk of being lost to follow-up. A clear referral pathway is crucial. When patients are motivated and it is evident which healthcare professionals should be involved, direct referral to primary care is appropriate. In other cases, referral to a lifestyle care portal can be valuable. This hospital-based service offers a broader assessment of the patient's context. It can facilitate shared decision-making about next steps, even in patients with limited health, digital literacy, or low intrinsic motivation. The lifestyle coach helps patients set personalized health goals and can refer them to appropriate services, such as dietitians, physiotherapists, or community-based initiatives like neighborhood sports coaches. Such infrastructure supports a smooth transition from hospital to community care and promotes the adoption of sustainable lifestyle changes.

Older adults face significant challenges in managing lifestyle changes independently and require coordinated support from multiple healthcare professionals. Interprofessional collaboration is vital, especially in the context of sarcopenia and malnutrition where effective interventions cross disciplinary boundaries. Despite its importance, current practice still shows considerable room for improvement. Professionals say improvements are required across the dimensions of the professionals, infrastructure, and older adults. Both professionals and older adults emphasize the need for clearer communication, better coordination, and active involvement of older adults in their care. To address these challenges, integrated care centers could be established more widely where multiple disciplines, such as dietitians, physiotherapists, geriatricians, and nurses, work closely together within the same setting. Such centers could facilitate interprofessional collaboration, streamlined care pathways, shared electronic patient records, and shared decision-making, creating a more seamless and patient-centered approach that better supports older adults in sustaining lifestyle changes over time.

Ultimately, improving outcomes for older adults with sarcopenia (risk) requires strengthening screening, diagnostic testing, interventions, and interprofessional collaboration in practice. Focusing on any one of these domains in isolation will limit progress and reduce the potential impact on patients. Scientific insights must be translated into practical, integrated care solutions. To achieve this, healthcare professionals, policymakers, and researchers must join forces and act decisively to ensure that advances in knowledge lead to meaningful improvements in care delivery and patient well-being.

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Appendix

Summary

Sarcopenia, defined as the loss of muscle mass and strength, and malnutrition, an imbalance in energy or nutrient intake that adversely affects body composition, are common conditions among older adults. These conditions are associated with difficulties in daily activities, loss of independence, reduced quality of life, and increased mortality risk.

This thesis investigated how care for older adults at risk for sarcopenia or malnutrition can be improved. We evaluated the effectiveness of existing tests for patients with or at risk for sarcopenia in various settings, assessed exercise and nutrition interventions, and explored the perspectives of healthcare providers and older adults on interprofessional collaboration.

In **part I,** we evaluated the psychometric properties of tests and tools used for people (at risk of) sarcopenia.

Chapter 2 presents a systematic review of the psychometric properties of four physical performance tests commonly used in community-dwelling older adults: the Short Physical Performance Battery, the Timed Up and Go test, the 4-meter gait speed test, and the 400-meter walk test. The review included 50 studies comprising data from 19,266 participants aged 63 to 84 years. Psychometric properties were assessed using the COSMIN guideline, and the quality of evidence was rated according to the GRADE approach. While the reliability of these tests was generally rated as sufficient, other key properties, such as measurement error, criterion and construct validity, and responsiveness, were often rated as insufficient, even though the quality of the underlying evidence was moderate to high. Overall, most physical performance tests showed limited psychometric quality beyond reliability, indicating that their use for assessing sarcopenia severity or monitoring changes in physical performance in community-dwelling older adults should be interpreted with caution.

Chapter 3 reports a cross-sectional diagnostic accuracy study conducted among 255 hospitalized patients aged 50 years and older. Sarcopenia status was determined according to European diagnostic criteria, based on assessments including the SARC-F questionnaire, handgrip strength measurement, and bioelectrical impedance analysis of fat-free mass. The SARC-F questionnaire showed moderate sensitivity (59%), specificity (75%), and an area under the curve (AUC) of 0.67 for identifying sarcopenia, indicating limited diagnostic accuracy. In contrast, handgrip

strength demonstrated excellent diagnostic performance with 100% sensitivity, 88% specificity, and an AUC of 0.94. These findings support handgrip strength as a reliable and objective first-line screening tool for sarcopenia in hospitalized older adults, while SARC-F is less suitable as a standalone instrument.

In **part II**, we evaluated the feasibility, effectiveness, and (re)design of a research protocol for exercise and nutrition interventions.

Chapter 4 presents an evaluation of the efficacy of and adherence to a nutritional intervention in the context of the multimodal Fit4Surgery prehabilitation program for patients with colorectal (n = 35) or esophageal cancer (n = 29). The intervention consisted of dietary counseling combined with daily whey protein supplementation (30 g), targeting a total protein intake of at least 1.5 g/kg body weight per day. Mean daily protein intake increased from 1.20 ± 0.39 g/kg at baseline to 1.61 ± 0.41 g/kg after prehabilitation ($p < 0.001$), with the largest increase observed during the evening snack. In total, 56.3% of patients achieved the protein intake target. Adherence to the intervention was associated with body weight, BMI, physical performance, and baseline protein intake. These findings show that nutritional counseling and protein supplementation effectively improve protein intake in patients undergoing multimodal prehabilitation.

Chapter 5 presents a pilot feasibility study of a randomized controlled trial, evaluating a combined exercise and nutrition intervention in hospitalized patients at risk of sarcopenia (FITFOOD study). Of the 115 eligible patients, 14 participated (recruitment rate 12%), and the dropout rate was 50%. The intervention included a functional exercise program that combined strength and aerobic training, along with a high-protein diet and daily protein supplementation. Feasibility was assessed using quantitative data and qualitative insights from a focus group and interviews. Results showed that most patients were unable or unwilling to participate fully due to health concerns, limited mobility, or lack of motivation during acute illness. These findings indicate that a combined lifestyle intervention is difficult to implement in these vulnerable patients at risk for sarcopenia during hospitalization.

Chapter 6 presents the study protocol of the randomized controlled FITFOOD trial, investigating the effects of the combined exercise program and high-protein nutritional intervention in hospitalized older adults. Building on the findings of **Chapter 5**, the study was adapted to target a broader population. The trial aims to evaluate the effects on physical performance and other sarcopenia-related outcomes in older patients.

In **part III**, we explored the perspectives of healthcare professionals and older adults at risk for sarcopenia and malnutrition on interprofessional collaboration.

Chapter 7 reports qualitative research with 28 primary and social care professionals exploring barriers, facilitators, and needs related to interprofessional collaboration in managing (risk of) malnutrition and sarcopenia among community-dwelling older adults. Using grounded theory, analysis of focus groups identified three interconnected dimensions essential for successful collaboration: professionals, infrastructure, and older adults. Key elements include smooth information exchange, clear task division, thorough patient involvement, coordinated care, and collaboration beyond traditional healthcare systems.

Chapter 8 presents qualitative research with 18 community-dwelling older adults who have experienced treatment for (risk of) malnutrition and sarcopenia. Through interviews and focus groups analyzed with grounded theory, three primary needs emerged: active involvement in treatment decisions, well-informed healthcare professionals providing consistent information, and effective collaboration among healthcare providers. The study emphasizes the importance of engaging older adults as partners in care, providing accessible and coherent information, and promoting open communication among professionals.

This thesis evaluated tools for sarcopenia screening, diagnosis, and severity assessment, examined the feasibility of combined exercise and nutrition interventions to improve nutritional intake and physical performance, and explored the perspectives of healthcare professionals and older adults on interprofessional collaboration for treatment of sarcopenia and malnutrition. Improving care for older adults at risk of sarcopenia and malnutrition requires accurate, context-specific diagnostics, tailored and feasible interventions, and strong collaboration among healthcare professionals and patients. Addressing these components is crucial for improving outcomes and quality of life in this vulnerable population.

Samenvatting

Sarcopenie, het verlies van spiermassa en spierkracht, en ondervoeding, een tekort of disbalans in voedingsstoffen dat de lichaamssamenstelling negatief beïnvloedt, komen vaak voor bij ouderen. Deze aandoeningen leiden tot problemen in het dagelijks functioneren, verlies van zelfstandigheid, een verminderde kwaliteit van leven en een verhoogd sterfterisico.

In dit proefschrift onderzochten we hoe de zorg voor ouderen met een verhoogd risico op sarcopenie of ondervoeding verbeterd kan worden. We evalueerden hoe goed bestaande testen voor (het risico op) sarcopenie werken, onderzochten de haalbaarheid van gecombineerde beweeg- en voedingsinterventies, en verkenden de perspectieven van zorgverleners en ouderen op interprofessionele samenwerking.

In **deel I** beoordeelden we de betrouwbaarheid en bruikbaarheid van testen en meetinstrumenten die worden ingezet bij mensen met (een risico op) sarcopenie.

In Hoofdstuk 2 geven we een systematisch overzicht van vier fysieke prestatietesten die vaak worden gebruikt bij zelfstandig wonende ouderen: de Short Physical Performance Battery, de Timed Up and Go-test, de 4-meter loopsnelheidstest en de 400-meter looptest. We analyseerden 50 studies met in totaal 19.266 deelnemers van 63 tot 84 jaar. Hoewel de betrouwbaarheid van deze testen over het algemeen voldoende was, bleken andere belangrijke eigenschappen zoals meetfout (de onnauwkeurigheid van de test), validiteit (de mate waarin de test meet wat het moet meten), en responsiviteit (het vermogen om veranderingen in de tijd op te sporen) vaak onvoldoende, ondanks dat het onderliggende bewijs van matige tot hoge kwaliteit was. Over het geheel genomen toonden de meeste fysieke prestatietesten beperkte psychometrische kwaliteit buiten de betrouwbaarheid. Dit betekent dat de resultaten van deze testen bij het vaststellen van de ernst van sarcopenie of het volgen van fysieke veranderingen bij zelfstandig wonende ouderen voorzichtig geïnterpreteerd moeten worden.

In Hoofdstuk 3 beschrijven we een onderzoek onder 255 opgenomen patiënten van 50 jaar en ouder, waarin we onderzochten hoe goed verschillende methoden sarcopenie opsporen. De aanwezigheid van sarcopenie werd vastgesteld volgens de Europese diagnostische criteria, op basis van de SARC-F vragenlijst, handknijpkrachtmetingen en een bio-elektrische impedantieanalyse van de vetvrije massa. De SARC-F vragenlijst had een matige gevoeligheid (59%) en specificiteit (75%), met een zogenaamde 'gebied onder de curve' (AUC) van 0,67.

*

Dit getal geeft aan hoe goed een test het onderscheid kan maken tussen mensen met en zonder sarcopenie, waarbij 1 perfect is en 0,5 niet beter dan toeval. Handknijpkracht presteerde beter, met een gevoeligheid van 100%, specificiteit van 88%, en een AUC van 0,94. Dit maakt handknijpkracht een betrouwbare en objectieve eerste test om sarcopenie te herkennen bij opgenomen ouderen, terwijl SARC-F als screeningsinstrument minder geschikt is om hiervoor te gebruiken in deze populatie.

In **deel II** onderzochten we de haalbaarheid, effectiviteit en het (her)ontwerp van een onderzoeksprotocol voor beweeg- en voedingsinterventies.

In **Hoofdstuk 4** evalueren we de effectiviteit en de mate waarin patiënten zich aan de voedingsinterventie hielden binnen de Fit4Surgery studie. We evalueerden de resultaten van patiënten met dikke darm- (n = 35) of slokdarmkanker (n = 29). De voedingsinterventie bestond uit voedingsadvies door de diëtist, gecombineerd met een dagelijks supplement van 30 gram wei-eiwit, met als doel een eiwitinname van minimaal 1,5 gram per kilogram lichaamsgewicht per dag. We zagen dat de gemiddelde dagelijkse eiwitinname steeg van 1,20 ± 0,39 gram per kilogram lichaamsgewicht bij aanvang naar 1,61 ± 0,41 gram na de interventie ($p < 0,001$); vlak voor de operatie, vooral door een toename tijdens de avondsnack. In totaal behaalde 56,3% van de patiënten het eiwitdoel. Hoe goed patiënten zich aan de interventie hielden, hing samen met het lichaamsgewicht, BMI, fysieke prestaties en de eiwitinname aan het begin van de interventie. Onze bevindingen tonen aan dat voedingsadvies door de diëtist en eiwitsupplementen effectief zijn om de eiwitinname te verhogen bij patiënten die zich voorbereiden op een operatie.

In Hoofdstuk 5 beschrijven we een haalbaarheidsstudie, waarbij we gecombineerde leefstijlinterventie bij opgenomen patiënten met een verhoogd risico op sarcopenie onderzochten (FITFOOD studie). Van de 115 in aanmerking komende patiënten deden 14 mee (wervingspercentage 12%), waarvan de helft tussentijds stopte (uitvalpercentage 50%). De interventie bestond uit een beweegprogramma met kracht- en cardiotraining, gecombineerd met een eiwitrijk dieet en dagelijkse eiwitsupplementen. We beoordeelden de haalbaarheid met kwantitatieve gegevens en kwalitatieve inzichten uit een focusgroep en interviews. Uit de resultaten bleek dat de meeste patiënten vanwege gezondheidsproblemen, beperkte mobiliteit of gebrek aan motivatie tijdens hun acute ziekte niet volledig konden of wilden deelnemen. Deze bevindingen laten zien dat het lastig is om dergelijke leefstijlinterventies tijdens ziekenhuisopname succesvol uit te voeren bij een kwetsbare patiënten met een risico op sarcopenie.

De bevindingen uit **Hoofdstuk 5** zijn gebruikt om het studieprotocol aan te passen, zoals beschreven in **Hoofdstuk 6**. Dit hoofdstuk beschrijft het protocol van de lopende gerandomiseerde gecontroleerde FITFOOD-studie, waarin de effecten van een gecombineerde beweeg- en eiwitrijke voedingsinterventie bij opgenomen ouderen worden onderzocht. Het studieprotocol is aangepast om een bredere patiëntengroep te omvatten. De studie heeft als doel de effecten op fysieke prestaties en andere voor sarcopenie relevante uitkomsten te evalueren bij oudere ziekenhuispatiënten.

In **deel III** onderzochten we de perspectieven van zorgprofessionals en ouderen met een verhoogd risico op sarcopenie en ondervoeding op interprofessionele samenwerking.

In **Hoofdstuk 7** onderzoeken we kwalitatief de barrières, mogelijkheden en behoeften rondom interprofessionele samenwerking van zorgprofessionals. We spraken hiervoor met 28 zorg- en welzijnsprofessionals uit de eerstelijns- en sociale zorg die werken met zelfstandig wonende ouderen met (risico op) ondervoeding en sarcopenie. Uit de analyse van focusgroepen bleek dat succesvolle samenwerking afhankelijk is van een samenspel tussen professionals, infrastructuur en ouderen. Belangrijke voorwaarden zijn een soepele informatie-uitwisseling, duidelijke taakverdeling, actieve betrokkenheid van de patiënt, gecoördineerde zorg en samenwerking die verder gaat dan de traditionele zorgsystemen.

In **Hoofdstuk 8** onderzoeken we de behoeften en wensen rondom interprofessionele samenwerking van 18 zelfstandig wonende ouderen. Deze ouderen ondergingen behandeling voor (risico op) ondervoeding en sarcopenie en deden mee aan interviews en focusgroepen. Drie hoofdbehoeften kwamen naar voren: actieve betrokkenheid bij behandelbeslissingen, goed geïnformeerde zorgverleners die consistente en begrijpelijke informatie verstrekken, en effectieve samenwerking tussen zorgverleners. Dit onderzoek benadrukt het belang van het betrekken van ouderen als partners in hun zorg, het waarborgen van toegankelijke en samenhangende informatie, en het stimuleren van open communicatie tussen professionals.

Dit proefschrift beoordeelde methoden voor het opsporen, diagnosticeren en inschatten van de ernst van sarcopenie. Daarnaast onderzochten we de haalbaarheid van gecombineerde beweeg- en voedingsinterventies om de voedingsinname en fysieke prestaties te verbeteren bij klinische patiënten. Tot slot verkenden we de perspectieven van zorgverleners en ouderen op interprofessionele samenwerking. Verbetering van de zorg voor ouderen met een verhoogd risico op sarcopenie

en ondervoeding vraagt om nauwkeurige en context specifieke diagnostiek, interventies die zijn afgestemd op de behoeften en mogelijkheden van patiënten, en goede samenwerking tussen zorgverleners en patiënten. Alleen met aandacht voor al deze aspecten kunnen we de uitkomsten en kwaliteit van leven van deze kwetsbare groep daadwerkelijk verbeteren.

Research data management

Ethics and privacy

This thesis is based on literature research (**Chapter 2**), medical-scientific research involving human participants (**Chapters 3-6**), and qualitative research (**Chapters 7 and 8**). All studies were conducted in accordance with relevant national and international legislation and regulations, guidelines, codes of conduct and Radboudumc policy.

A statement that the study described in **Chapter 3** was not subject to the Dutch Medical Research Involving Human Subjects Act (WMO), was obtained from the recognized Medical Ethics Review Committee 'METC Oost-Nederland' (reference number: 2024-17001).

The studies described in **Chapters 4, 5, and 6** were subjected to the Medical Research Involving Human Subjects Act (WMO). The recognized Medical Ethics Review Committee 'METC Oost-Nederland' has given approval to conduct these studies (reference numbers: NL73777.091.20 (**Chapter 4**) and NL80672.091.22 (**Chapters 5 & 6**).

The studies described in **Chapters 7 and 8** were not subject to the Dutch Medical Research Involving Human Subjects Act (WMO) and received approval from the Ethical Advisory Committee (HEAC) of the Hanze University of Applied Sciences Groningen (HEAC.2022.030).

For the studies of **Chapters 3-8**, informed consent was obtained from participants to collect and process their data for this research project. Consent was not obtained for sharing and reuse of the (pseudonymized) data for future research in **Chapters 3, 4, and 6**. Reusing the data of Chapter 5 for future research is only possible after a renewed permission by the participants.

The privacy of the participants in the studies of **Chapters 3-8** was warranted by the use of pseudonymization. The pseudonymization key was stored on a secured network drive that was only accessible to members of the project who needed access to it because of their role within the project. The pseudonymization key was stored separately from the research data.

Data collection and storage

To ensure the interpretability of data, all file names, primary and secondary data, metadata, descriptive files, and program code and scripts used for study analyses are stored in the department's shared drive.

Data for **Chapter 2** was collected from manuscripts and transferred to Microsoft Excel for processing.

Data for **Chapters 3-6** were and are collected through an electronic Case Report Form (eCRF) using Castor EDC. Pseudonymized data were stored on the Dietetics department server of Canisius Wilhelmina Hospital (**Chapter 3**) or Radboudumc (**Chapters 5-6)** and in Castor EDC and are only accessible by project members. Hardcopy data is stored in locked department cabinets.

Data from interviews in **Chapters 7 and 8** were recorded and stored pseudonymized on the ResearchDrive of Hanze University of Applied Sciences Groningen.

Availability of data

The studies described in **Chapters 2, 4, 5, 7, and 8** were published with open access. **Chapter 3** is not yet published but has been submitted to an open access journal. **Chapter 6** is a protocol and will remain unpublished until the results of the trial are complete.

Chapter 2 is based on existing data which was obtained from published literature.

The data underlying **Chapter 3** are not suitable for reuse because consent for reuse was not obtained. The data used for **Chapter 3** are not owned by Radboudumc but by Canisius Wilhelmina Hospital. The data are archived by Canisius Wilhelmina Hospital. Questions about the data can be addressed to m.bello@cwz.nl.

The data underlying **Chapter 4** were collected in the context of the Fit4Surgery study. Question regarding the data can be directed to bureau@fit4surgery.nl.

Because permission to share the data from **Chapter 5** for other research was not obtained, the data are archived with closed access in the Data Acquisition Collection of the Radboud Data Repository (DOI: 10.34973/b4h7-mg42). Upon completion of the study described in the protocol in **Chapter 6**, the corresponding data will also be made available there.

Data collection for the project described in **Chapter 7 and 8** is still ongoing. In addition, the data used for **Chapter 7 and 8** are not owned by Radboudumc. The data are archived by Hanze University of Applied Sciences Groningen. Questions about the data can be addressed to s.d.boxum@pl.hanze.nl or ha.jager@pl.hanze.nl. When the project is completed, the processed and anonymized datasets will be archived in DataverseNL.

The study data **from Chapters 3, 4, and 5** will be archived for 15 years after the conclusion of each study. Data from **Chapters 7 and 8** will be archived for 10 years following study completion.

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List of publications

This thesis

Adherence to and efficacy of the nutritional intervention in multimodal prehabilitation in colorectal and esophageal cancer patients
S.H. van Exter*, L. D. Drager*, M. J. M. D. van Asseldonk, D. Strijker, N. D. van der Schoot, B. van den Heuvel, S. Verlaan & M. G. A. van den Berg
Nutrients, 2023 (15-9), p. 2133,
DOI: 10.3390/nu15092133

Interprofessional management of (risk of) malnutrition and sarcopenia: a grounded theory study from the perspective of professionals
S.D. Boxum*, **S. H. van Exter***, J. J. Reinders, N. Koenders, H. Drenth, M. G. A. van den Berg, M. Tieland, S. L. W. Spoorenberg, E. J. Finnema, P. J. van der Wees & H. Jager-Wittenaar
Journal of Multidisciplinary Healthcare, 2024 (17), p. 4677-4692,
DOI: 10.2147/jmdh.S474090

A systematic review of the psychometric properties of physical performance tests for sarcopenia in community-dwelling older adults
S. H. van Exter, N. Koenders, P. van der Wees & M. G. A. van den Berg
Age and Ageing, 2024 (53-6), p. afae113,
DOI: 10.1093/ageing/afae113

Lessons learned from a combined, personalized lifestyle intervention in hospitalized patients at risk for sarcopenia: a feasibility study
S. H. van Exter, N. Koenders, P. J. van der Wees, J. P. H. Drenth & M. G. A. van den Berg
Disability and Rehabilitation, 2024, p.1-8,
DOI: 10.1080/09638288.2024.2426685

Understanding the Needs and Wishes of Older Adults in Interprofessional Treatment for Malnutrition and Sarcopenia: A Grounded Theory Study
S. Boxum*, **S. H. Van Exter***, J.-J. Reinders, H. Drenth, M. G.A. Van den Berg, M. Tieland, A. Geluk-Bleumink, S. L. W. Spoorenberg, E. Finnema, P. J. Van der Wees, N. Koenders and H. Jager-Wittenaar
Journal of Multidisciplinary Healthcare, 2025 (18), p. 1433-1444,
DOI: 10.2147/jmdh.S507567

Other publications

Resting energy expenditure measured by indirect calorimetry in mechanically ventilated patients during ICU stay and post-ICU hospitalization
Moonen, H., A. J. H. Hermans, A. E. Bos, I. Snaterse, E. Stikkelman, F. J. L. van Zanten, **S. H. van Exter**, M. C. G. van de Poll & A. R. H. van Zanten.
Journal of Critical Care, 2023 (78), p. 154361,
DOI: 10.1016/j.jcrc.2023.154361

De invloed van voeding en beweging op sarcopenie
S.H. van Exter & M.G.A. van den Berg
Voedingskennis.nl, 2022, https://voedingskennis.bsl.nl/artikel/20115867/sarcopenie-de-invloed-van-voeding-en-beweging/

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Ook wil ik de verschillende coauteurs die bijgedragen hebben aan de hoofdstukken van dit proefschrift bedanken: **Harriët, Jan-Jaap** en het volledige **InterGAIN-team**, evenals **Luuk, Monique, Sjors** en de andere coauteurs van **Fit4Surgery**. Dank voor de fijne samenwerking en de waardevolle expertise waarvan ik veel heb mogen leren.

Dank aan alle collega's die hebben bijgedragen aan de FITFOOD-studie, van **diëtisten** en **fysiotherapeuten** tot **verpleegkundigen** en **artsen**. Dankzij jullie inzet konden de screenings succesvol plaatsvinden, de de interventies worden gerealiseerd, en de patiënten worden begeleid.

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*

Curriculum Vitae

Sabien Hannah van Exter werd geboren op 3 oktober 1997 in Leiderdorp. Zij groeide op met haar ouders Mirjam en Martin, haar zus Roos en haar broer Emiel. In 2016 behaalde zij haar vwo-diploma aan het Da Vinci College in Leiden. Aansluitend volgde zij de bacheloropleiding *Voeding en Gezondheid* aan Wageningen Universiteit en de master *Nutrition and Health*, met de specialisatie *Molecular Nutrition and Toxicology*, die zij in 2021 afrondde.

Tijdens haar opleiding ontwikkelde zij een sterke interesse in humane gezondheid en nam zij onder andere deel aan een interdisciplinair project met studenten Geneeskunde en Biotechnologie. Haar MSc-stage op de Intensive Care afdeling van het ziekenhuis Gelderse Vallei bevestigde haar interesse voor de raakvlakken tussen voeding en ziekte.

Na haar verhuizing naar Nijmegen startte zij in 2021 haar promotietraject aan het Radboudumc, dat zij in 2025 afrondde. Ze werkte hierbij onder begeleiding van promotoren prof. dr. JPH Drenth en prof. dr. P.J. van der Wees, en copromotoren dr. M.G.A. van den Berg en dr. N. Koenders. Haar onderzoek richtte zich op de beoordeling, leefstijlinterventies en interprofessionele zorg rondom sarcopenie bij ouderen. De resultaten van dit onderzoek zijn gebundeld in dit proefschrift.

Portfolio

Department: Gastro-enterology and Hepatology, Dietetics
PhD period: 15/11/2021 – 14/11/2025
PhD Supervisor(s): prof. dr. J.P.H. Drenth, prof. dr. P.J. van der Wees
PhD Co-supervisor(s): dr. M.G.A. van den Berg, dr. N. Koenders

Training activities	Hours
Courses	
• Radboudumc - eBROK course (for Radboudumc researchers working with human subjects) (2021)	26.00
• Writing without stress (2022)	1.50
• RIHS - Introduction course for PhD candidates (2022)	15.00
• Literature Review for your PhD: how to search & where to publish (2022)	4.00
• RU - Achieving your Goals and performing more successfully in your PhD (2022)	28.00
• Data visualisation (2022)	15.00
• Radboudumc - Scientific integrity (2023)	20.00
• Active Bystander Training (2023)	1.50
• Zelfinzicht, de sleutel voor je loopbaan (2023)	0.40
• Career development for PhD candidates & postdocs "The next step in my career" (2024)	19.00
• RU - Analysing longitudinal and multilevel data using R (2025)	96.00
• Science Journalism and Communication (2025)	40.00
Seminars	
• Preserving muscle mass: the role of protein and physical activity' (2022)	1.50
• Impact van voeding op gezondheid en milieu (2022)	1.50
• Workshop Adobe Illustrator (2023)	2.00
• Research Integrity Round: Artificial Intelligence and Research Integrity: a good marriage? (2024)	1.50
• CoP Perioperatieve Gezondheid (2025)	2.00
• Meet the expert (2025)	2.00
Conferences	
• Congress Sarcopenia, Cachexia and Wasting Disorders (2021)	7.00
• RIHS PhD Retreat (2022)	16.00
• PhD retreat RIHS (2022)	16.00
• Nationaal Voedingscongres (2023)	7.50
• ESPEN (2023)	28.00
• PhD Retreat (2023)	16.00
• ICFSR (2024)	26.00
• International Conference on Frailty and Sarcopenia Research (poster) (2024)	26.00
• ICFSR (2025)	25.00
• International Conference on Frailty and Sarcopenia Research (poster tour) (2025)	26.00
Other	
• Intervision (2021-2025)	28.00
• Journal Club (2021-2025)	200.00

Teaching activities	
Lecturing	
• Research into practice (2022)	4.00
• Seminar and practical (2022)	4.00
• Research into practice (2023)	3.00
• Research into practice (2024)	2.00
• MSc Thesis Support (2025)	10.00
Supervision of internships / other	
• BSc student supervision (2021)	10.00
• MSc Student Intern Supervision (2022-2025)	792.00
Total	**1523.40**

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