Høgskulen på Vestlandet

Masteroppgave

MAFYS602-O-2022-VÅR-FLOWassign

Predefinert informasjon

Startdato:	09-05-2022 09:00	**Termin:**	2022 VÅR
Sluttdato:	16-05-2022 14:00	**Vurderingsform:**	Norsk 6-trinns skala (A-F)
Eksamensform:	Masteroppgave		
Flowkode:	203 MAFYS602 1 O 2022 VÅR		
Intern sensor:	(Anonymisert)		

Deltaker

Kandidatnr.:	408

Informasjon fra deltaker

Antall ord *:	6802

Egenerklæring *: Ja

Jeg bekrefter at jeg har registrert oppgavetittelen på norsk og engelsk i StudentWeb og vet at denne vil stå på vitnemålet mitt *: Ja

Jeg godkjenner avtalen om publisering av masteroppgaven min *

Ja

Er masteroppgaven skrevet som del av et større forskningsprosjekt ved HVL? *

Nei

Er masteroppgaven skrevet ved bedrift/virksomhet i næringsliv eller offentlig sektor? *

Nei

Høgskulen på Vestlandet

MASTEROPPGAVE

The effect of resistance training and to which extent resistance training interventions are reported in randomized controlled trials for older adults with sarcopenia.
A systematic review using the Consensus on Exercise Reporting Template (CERT)

Effekt av styrketrening og i hvilken grad styrketreningsintervensjoner rapporteres i randomiserte kontrollerte studier for eldre med sarkopeni.
En systematisk oversikt med bruk av Consensus on Exercise Reporting Template (CERT)

Marie Heines Pettersen og Karoline Marx
Kandidatnummer: 402 og 408

Master i klinisk fysioterapi
Fordypning i muskel-skjelett, ortopediske og revmatiske helseproblem

Høgskulen på Vestlandet, Bergen
Fakultet for helse- og sosialvitenskap
Institutt for helse og funksjon

Innleveringsdato: 16.05.22
Antall ord: 6802

Jeg bekrefter at arbeidet er selvstendig utarbeidet, og at referanser/kildehenvisninger til alle kilder som er brukt i arbeidet er oppgitt, *jf. Forskrift om studium og eksamen ved Høgskulen på Vestlandet, § 12-1.*

PREFACE

The completion of this thesis marks the end of our two-year master education. Two years of learning and educational discussions, but also two years of Zoom-meetings and social distancing. Despite Covid-19, these two years have given us new friendships and knowledge, about the trade of physiotherapy and about methodological considerations in research.

Working with this thesis we have learned a lot about ourselves and our ability to cooperate. We have experienced the importance of communication, structuring and prioritization. We now better understand the work behind the evidence-based practice we as physiotherapists proudly takes part in, and we hope to contribute with further knowledge for our profession in the future. It has been a challenging process, but one we are grateful to have experienced.

We would like to thank our fellow students for making the best out of a suboptimal situation, and staying positive and engaged, both behind the screen and in the classroom. We hope to continue our fruitful discussions and look forward to meeting all of you again. We would also like to thank the hole stab at HVL for thinking on their feet and trying to find the best solutions, when Covid threw some curveballs.

We would like to thank Trond Arve Pettersen for thorough proof reading of the thesis.

Last, but not least, we would like to thank our supervisor Bård Bogen, PhD, for guiding us through the process, and for contributing with insightful knowledge and educational discussions.

Karoline Marx and Marie Heines Pettersen

Note:

This systematic review is intended to be published in British Medical Journal Open (BMJ Open) Sports and Exercise Medicine. The authors guidelines can be found in appendix 7. We have chosen to include figures in the main text to increase readability. When submitting the systematic review to BMJ Open, figures will be submitted separately in accordance with the authors guidelines.

ABSTRACT

Objectives: This systematic review aims to synthesize the available literature on the effect of resistance training interventions on sarcopenia parameters (muscle quality/quantity, muscle strength and physical function), and critically evaluate to which extent these report their interventions.

Material and Methods: Systematic literature searches were conducted in five databases (Medline Ovid, EMBASE Ovid, Cochrane Library, CINAHL and PEDro) for randomized controlled trials assessing the effect of resistance training on sarcopenia parameters among older adults aged 65 years and above with sarcopenia, published from 2010 to October 21, 2021. The searches included the key words and synonyms of "sarcopenia" and "resistance training". The two authors independently screened and performed data extraction from each included study. The revised Cochrane risk-of-bias tool (RoB2) was used to assess study quality, and the Consensus on Exercising Reporting Template (CERT) was used to evaluate how well the studies reported the interventions. Review Manager 5.4 (RevMan 5.4) was used to conduct systematic analysis. A 95 percent confidence interval (CI) was calculated as the effects measure and reported as standardized mean differences (SMD). To calculate overall effect sizes, inverse variances were used as a statistical method, and random effect models ($I^2 > 50\%$) were conducted as an analysis model.

Results: This systematic review included 10 studies (total publications) (414 older adults with sarcopenia). The meta-analysis showed significant differences in muscle strength in favor of the intervention group [quadriceps femoris strength, SMD = 0.69, 95% CI 0.39 to 0.98, $p < 0.0001$, $I^2 = 79\%$]. The results also showed difference in hand grip strength [SMD = 0.51, 95% CI -0.04 to 1.06, $p < 0.07$, $I^2 = 75\%$] and muscle mass [SMD = 0.21, 95% CI -0.03 to 0.46, $p < 0.08$, $I^2 = 0\%$] in favor of the intervention group, but these results were not statistically significant. The overall reporting of interventions in the included studies were poor, with the mean number of reported intervention items 8.2 out of 19 possible.

Conclusion: Resistance training is beneficial in improving sarcopenia parameters in older adults (65 years or older); however, the reporting of the interventions lacks details to support easier replication in clinical practice.

ABSTRAKT NORSK

Hensikt: Målet med denne systematiske oversikten er å undersøke effekten av styrketrening på de ulike sarkopeni-parameterne (muskelkvalitet/kvantitet, muskelstyrke og fysisk funksjon), samt å kritisk evaluere i hvilken grad randomiserte kontrollerte studier rapporterer styrketreningsintervensjoner.
Materiale og metode: Det ble gjennomført systematiske litteratursøk etter randomiserte kontrollerte studier som vurderer effekt av styrketrening på sarkopeni-parametere hos eldre (≥ 65 år) med sarkopeni, publisert fra 2010 til oktober 2021 i fem databaser (Medline Ovid, EMBASE Ovid, Cochrane Library, CINAHL and PEDro). Søkene inkluderte søkeord og synonymer for «sarcopenia» og «resistance training». De to forfatterne leste, vurderte og gjennomførte dataekstraksjon individuelt. Cochrane risk-of-bias tool (RoB2) ble benyttet for å vurdere studienes kvalitet, og Consensus on Exercising Reporting Template (CERT) ble benyttet for å evaluere grad av rapportering av intervensjoner. Review Manager 5.4 (RevMan 5.4) ble benyttet for gjennomføring av statistisk analyse. Et 95 prosent konfidensintervall (CI) ble kalkulert som effektestimat og rapportert som standardisert gjennomsnittlig forskjell (SMD). Invers variansmetode ble benyttet for å beregne effektivitet, og en random-effects modell ble benyttet som analysemetode ($I^2 > 50\%$).
Resultat: Denne systematiske oversikten inkluderte 10 studier (totale publikasjoner) (414 eldre voksne med sarkopeni). Meta-analysen viste signifikant forandring i muskelstyrke [quadriceps femoris styrke, SMD = 0.69, 95% CI 0.39 to 0.98, $p < 0.0001$, $I^2 = 79\%$] i favør av intervensjonsgruppen. Resultatene viste samtidig en forskjell i håndgrepsstyrke [SMD = 0.51, 95% CI -0.04 to 1.06, $p < 0.07$, $I^2 = 75\%$] og muskelmasse [SMD = 0.21, 95% CI -0.03 to 0.46, $p < 0.08$, $I^2 = 0\%$] i favør av intervensjonsgruppen, men disse resultatene var ikke statistisk signifikante. Rapporteringen av intervensjoner i de inkluderte studiene var generelt mangelfull, med en gjennomsnittlig poengsum på 8.2 av 19 mulige poeng.
Konklusjon: Styrketrening har en fordelaktig effekt på sarkopeni-parametrene blant eldre voksne med sarkopeni (≥ 65 år); men rapporteringen av intervensjonene mangler detaljer for å øke overførbarhet til klinisk praksis.

Table of contents

1. INTRODUCTION 6

1.1 Background *6*

1.2 Clinical definition and causes of sarcopenia *7*

1.3 Interventions for sarcopenia *8*

1.4 Resistance training and dosage *8*

1.5 Aim of the review *8*

2. MATERIAL AND METHODS 9

2.1 Theoretical perspective *9*

2.2 Literature Search *9*

2.3 Study Selection *10*

2.4 Data Extraction *10*

2.5 Risk of Bias Assessment *10*

2.6 Exercise Reporting Standards *11*

2.7 Statistical analysis *11*

2.8 Ethical considerations *12*

3. RESULTS 14

3.1 Study selection *14*

3.2 Study Characteristics: *14*

3.3 Quality assessment *15*

3.4 Data synthesis and analysis of sarcopenia parameters *18*

3.5 Results: CERT *19*

4. DISCUSSION 22

4.1 Discussion of results *22*

4.2 CERT *23*

4.2.1 General considerations 23

4.2.2 Individual progression 23

4.2.3 Supervision and motivation strategies 24

4.2.4 Fidelity, adherence, and adverse events 24

4.2.5 Implications for research and future directions 24

4.2 Discussion of method *25*

4.2.1 Limitations of our study 25

4.2.2 Discussion of included studies 25

5. CONCLUSION 27

REFERENCES 28

Overview of figures

Figure 1: PRISMA 2020, Flow diagram of the study selection 13
Figure 2: Forest plot, Muscle quantity (mass), between-group effect 18
Figure 3: Forest plot, Muscle strength, quadriceps femoris strength (knee extension), between-group effect 19
Figure 4: Forest plot, Muscle strength, hand grip, between-group effect 19

Overview of tables

Table 1: PICO 9
Table 2: Eligibility criteria 10
Table 3: Methodological quality assessment (RoB2) 15
Table 4: Study characteristics 16
Table 5: Critical evaluation of intervention reporting (CERT) 20
Table 6: Intervention characteristics and critical evaluation score 21

Overview of appendix

Appendix 1: Search strategy
Appendix 2: Pre-specified scoring guide, CERT
Appendix 3: Excluded studies and reason for exclusion
Appendix 4: Revised Cochrane Risk of Bias tool (RoB2)
Appendix 5: CERT complete scoring
Appendix 6: PRISMA checklist for systematic reviews
Appendix 7: Authors guidelines (BMJ Open)

1. INTRODUCTION

1.1 Background

Aging is an inevitable process, carrying several physiological changes for the individuals. These changes include decline of muscle fiber number and size, as well as reduction in muscle strength and physical function. Age-related loss of muscle mass, muscle strength and physical function is often referred to as sarcopenia. New evidence shows that sarcopenia is a result of negative muscle changes that occur throughout a lifetime.[1] Combined with age-related lifestyle characteristics, such as inactivity and malnutrition, and comorbidity, the process may escalate, accelerating functional decline and loss of independence in older adults.[2]

The prevalence in community-dwelling populations is estimated to be 1-29 percent, and 14-33 percent in long-term care facilities.[3] Such figures are, however, inaccurate, as calculating incidences and prevalence are difficult due to differences in diagnostic criteria and definitions across the world.2 4

In 2010, the European Working Group of Sarcopenia in Older People (EWGSOP)[5] established the first working consensus on the age-related syndrome known as sarcopenia, characterized by loss of both muscle mass and muscle function (muscle strength and/or physical performance). This consensus was later updated in 2018 (EWGSOP2) with low muscle strength as the key characteristic of the syndrome.[1]

The establishment of the sarcopenia parameters in 2010 marked a big change, adding muscle function to the former definition that was based only on detection of low muscle mass. Then, the 2018 consensus emphasized muscle strength, recognizing that strength is a better predictor of adverse outcomes and the most reliable measure for muscle function.[1] Muscle strength is defined as the maximal force that can be generated by a specific muscle or muscle group.[6] Muscle quantity (mass) and muscle quality are also impaired in sarcopenia, with muscle quality describing micro- and macroscopic aspects of muscle architecture and composition. The final sarcopenia parameter, physical performance, was earlier considered part of the core definition, but is now proposed by EWGSOP2[1] to rather be an indicator of severity. Physical performance is by EWGSOP2 defined as an objectively measured whole-body function related to locomotion.

Summarized in an operational definition, sarcopenia is probable when low muscle strength is detected. The diagnosis is confirmed by the presence of low muscle quantity and/or quality. When all the sarcopenia parameters, including also low physical performance, are detected, the condition is considered severe.[1]

The consequences of sarcopenia for the individual can be severe, as the reduction of strength and functional capability associated with the condition can lead to a number of adverse health outcomes including: functional decline and disability, increased use of healthcare, hospitalization and institutionalization[4], reduced quality of life[7], and premature death.[8] This in turn leads to a substantial burden on healthcare and society.4 9 In 2004 the annual health care expenditure relating to sarcopenia in the US was estimated at approximately $18.5 billion.[10] Based on the demographic changes the world is facing, which

will see an increase in the older population and the oldest old, the burden of sarcopenia on socioeconomic resources are projected to rise.[11]

1.2 Clinical definition and causes of sarcopenia

Sarcopenia was first introduced in 1988, and was recognized as a disease by WHO and included in the International Classification of Diseases (ICD code M62.8) in 2016[12]. It is accepted as a complex geriatric syndrome across the world, with different diagnostic criteria established in different regions.[13]

A distinction is made between different categories of sarcopenia and sarcopenia-like conditions. Depending on the cause, sarcopenia is considered "primary" when there is no other cause, other than age itself, or "secondary" if other causal factors than age are evident. These causes could be systemic diseases, e.g., malignancy or organ failure[5]. EWGSOP2[1] identifies different stages or subcategories of sarcopenia, from acute to chronic, depending on being related to an acute illness or injury, or being a progressive condition, respectively. Furthermore, sarcopenia is often seen in relation to other health issues, e.g., obesity and osteoporosis. Sarcopenic obesity is the condition where reduced lean body mass is combined with excess adiposity. Obesity exacerbates sarcopenia, increases the infiltration of fat into muscle, lowers physical function, and increases risk of premature death[1]. Osteosarcopenia is the combination of sarcopenia and osteoporosis. Like obesity, osteoporosis aggravates the negative consequences of sarcopenia.[14]

Risk factors for developing sarcopenia, other than aging itself, include physical inactivity, inflammation, and malnutrition.[11] The metabolism in muscle tissue deteriorates with age and is further exacerbated with inactivity and muscles being disengaged.[15] Muscle tissue responds to biomechanical loading with increase in density and strength. A sedentary lifestyle and inadequate loading will therefore lead to muscle atrophy and decreased muscle function.[16]

Low intake of vitamin D, protein and calcium is also associated with low muscle mass. Although protein synthesis and skeletal muscle mass are regulated by several factors, including physical activity, dietary-derived amino acids play a fundamental role for muscle protein synthesis.[15] New evidence also suggests a link between low vitamin D level and impaired neuromuscular function and low muscle mass among older adults. According to Kirk[16], supplementing vitamin D as a part of nutrition can enhance lean body mass, strength and function in sarcopenic older adults.

Gianoudis et. al[17] states that age-related loss in muscle mass may also be related to increases in visceral and intermuscular fat, mediated by an increase in pro-inflammatory cytokines. This is due to the cytokines being released from adipose tissue, with a decrease in anti-inflammatory markers, potentially having a catabolic effect on muscles by impairing muscle protein synthesis. Understanding that sarcopenia is a complex and multicausal diagnosis is essential for suitable treatment of the syndrome. We acknowledge the potential value of pharmacological and nutritional interventions, but will not focus on such interventions in this systematic review.

1.3 Interventions for sarcopenia

Habitual exercise has shown to be beneficial for preventing sarcopenia in elderly individuals.[18] Although there is consensus on the positive effects of physical exercise, an umbrella review from 2020[19] underlines that the poor description of exercise intervention in studies is limiting the extent to which such findings can be used to guide clinical practice.

Most intervention studies focus on mixed exercise interventions, combining aerobic, balance and strength training.[18 19] Progressive resistance training is one of four training modalities recommended for older people as part of a balanced exercise program.[20] As muscle strength is considered the defining factor for sarcopenia, and with grip strength and lower limb strength being the outcome measures recommended by EWGSOP2[1], it would seem appropriate to target both upper and lower limbs through both functional exercises and isolated resistance exercises. The value of adding aerobic and balance exercises to counteract sarcopenia is yet to be established. Although these training modalities may improve general physical performance, they may not specifically impact the sarcopenia parameters.[19]

1.4 Resistance training and dosage

This review will focus mainly on intervention studies where resistance training is the primary intervention, as ACSM views this as one of the most important modalities to "offset aging". Resistance training is also considered the only training modality that can counteract the skeletal muscle atrophy and decreased muscle strength associated with aging and sarcopenia.[20 21] ACSM defines resistance training as an exercise modality for improving muscular fitness by activating a muscle or muscle group against an external load. Furthermore, they establish five basic principles of resistance training: progressive overload, specificity, periodization, and prioritization, and the principle of specific adaptation to imposed demands (SAID-principle). Understanding and embedding these core principles are crucial to optimize exercise prescription.[22]

SAID-principle, as a result of progressive overload, can be obtained with the appropriate dosage. In resistance exercises, as in other training modalities, dosage can be summarized by the acronym FITT-VP: Frequency, Intensity, Time, Type, Volume, and Progression and Pattern. As the physiologic capacities of the body expand, the initial training stimulus may be too low, and the workload must increase (progression) to maintain overload.[23]

1.5 Aim of the review

Recognizing the adverse health outcomes associated with sarcopenia, as well as the considerable financial burden, it is essential to find ways to target this problem in clinical practice. There is consensus that exercise is an effective method of treating the individual components of sarcopenia[24], including muscle mass and quality[25], muscle strength[26] and physical function.[27] However, Moore et al.,[19] states that using resistance exercises in the treatment of sarcopenia has not yet been matured into a set of concrete, evidence-based clinical practice guidelines. Further, they emphasize that the poor description of the exercise interventions in experimental studies is limiting the extent to which the study findings can be used to guide clinical practice. This view is shared by Glasziou with others[28], stating that providing additional detail could improve the uptake of trial results in clinical practice.

This systematic review aims to assess the effect of resistance training and critically evaluate the extent to which resistance training interventions are reported in randomized controlled trials exploring the effect of resistance training on older adults with sarcopenia.

2. MATERIAL AND METHODS

This review follows The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines[29], and the protocol was registered in the Open Science Framework, https://osf.io/5mtqw, on January 15, 2022, with the following registration code: 5MTQW.

2.1 Theoretical perspective

This work is rooted in the natural sciences and in biomedicine. Traditionally, this assumed that one could assign values to naturally occurring phenomena and analyze the values statistically. It was further assumed that one could interpret the values objectively, regardless of context. Over the years, such a strict positivist approach has softened, and although quantification and objectivity are still ideals, the preconceptions and biases of the researcher are acknowledged.[30]

Further, this work is done within a framework of evidence-based practice, where accumulated research is synthesized to give clinicians the best possible basis for implementation in their practice. It is, however, important to recognize that such approach inevitably leads to loss of important information, for example the older adults' personal experiences with the resistance training.[31]

2.2 Literature Search

A comprehensive, electronic search was conducted in five databases (Medline Ovid, EMBASE Ovid, Cochrane Library, CINAHL and PEDro) on October 21, 2021, with date restriction from January 1, 2010. The date restriction coincides with the EWGSOP publication of the first consensus.[5] Details of the search strategy are available in appendix 1. The following search words were used, corresponding to PICO, see table 1: *PICO,* Population: Sarcopenia; Intervention: Resistance training; Comparison: All/None; Outcome: Any. The search was restricted to intervention studies using SIGN[32], and not RCT-filter.

Table 1: PICO

Population (P)	Intervention (I)	Comparison (C)	Outcome (O)
Elderly with sarcopenia (≥65 y/o)	Resistance training	All/None	Any

All potential references were imported into Endnote 20[33] and duplicates removed, first by using the duplicate function and then by manual screening. The remaining references were exported to Rayyan, a software that assists in categorizing papers and makes screening possible for several authors.[34] Titles and abstracts were independently screened for eligibility by the two authors. The full text of each eligible study was then independently examined according to the inclusion and exclusion criteria, see table 2: *Eligibility criteria*.

Reference lists of the included studies were manually searched, and citation searches through Google Scholar were conducted on January 14, 2022, to identify any further articles for inclusion. In the event of disagreement between the authors, a third person was consulted to reach consensus.

Table 2: Eligibility criteria

Inclusion	Exclusion
Elderly with sarcopenia (≥65 y/o)	Other primary diagnoses
Intervention: Resistance training as primary intervention	Nutrition or other training modalities other than resistance training as primary intervention
Outcome: muscle mass, muscle strength, physical function	No sarcopenia parameters assessed
Study design: RCT	

2.3 Study Selection

Studies were included if they met the following criteria: (1) the study was a randomized controlled trial (RCT); (2) resistance training was listed as the primary intervention; (3) the participants were 65 years of age or above; (4) at least one sarcopenia parameter (muscle mass (quality or quantity), muscle strength, and/or physical function) were reported as outcome measure. If nutrition interventions were included, these had to be the same for the intervention group and the control group. There were no restrictions set on type of sarcopenia, e.g., osteosarcopenia or sarcopenic obesity. There was no absolute definition set on diagnostic criteria for sarcopenia, but all the included studies defined their participants as sarcopenic.

2.4 Data Extraction

Data extraction was done using a Microsoft Office Excel spreadsheet. The two authors independently extracted and gathered the relevant data, being: (1) research design; (2) demographic details; (3) sarcopenia criteria; (4) sample size (including age/sex); (5) intervention details; (6) control group; (7) outcome measures and tools; (8) result. If data was missing and could not be obtained by additional search, or additional information was needed, several attempts of contacting the authors of the studies were made.

2.5 Risk of Bias Assessment

A risk of bias assessment was conducted independently by each of the two authors using the revised Cochrane risk-of-bias tool (RoB2).[35] Before performing the critical evaluation of the studies, the two authors familiarized with the guidance document to be able to correctly apply RoB2 to the studies. The authors started by independently evaluating two articles, then discussed any discrepancies or issues. Afterwards, the remaining articles were independently screened. Any discrepancies were discussed, and a third person was consulted when necessary.

RoB2 is specifically designed for assessing RCTs and addresses five bias domains: (1) randomization, (2) deviations from intended interventions, (3) missing outcome data, (4) measurement of the outcome, and (5) selection of the reported result.[35] The studies were classified as either “low risk of bias”, “some concerns”, or “high risk of bias”. Studies were registered as “low risk of bias” when the study had overall low risk of bias across domains, “some concerns” when the study was considered to have some concerns in at least two domains, and “high risk of bias” if the study was considered to have high risk of bias in at least two domains.

Publication bias was not assessed, nor was sensitivity analysis performed.

2.6 Exercise Reporting Standards

The exercise intervention reporting as a whole was evaluated using the Consensus on Exercise Reporting Template (CERT).[36] In the same way as for the RoB2 screening, the authors started by scoring two trials independently, then discussing any discrepancies. Afterwards, the remaining articles were separately scored based on a pre-prepared guide, which was made in advance in order to aid consistency in scoring between the authors, see appendix 2. The included articles were scored 0 or 1 for all 16 items, and the reasons for scoring were documented.

CERT has been specifically designed to help in structuring intervention reporting exercise programs across all study designs. The template can also be used to evaluate the completeness of exercise descriptions, which may help clinicians in understanding to what extent such exercise programs are fit for implementation in practice.[36] The checklist consists of 16 items, with a maximum score of 19 points, and is considered the minimum data set necessary to report exercise interventions. The checklist is divided into seven categories; WHAT (materials), WHO (provider), HOW (delivery), WHERE (location), WHEN HOW MUCH (dosage), TAILORING (what, how) and HOW WELL (planned, actual).

2.7 Statistical analysis

All available data were analyzed using the Review Manager (RevMan 5.4).[37] If the necessary data (post-test results, and standard deviation for post-test results) was not available, the study was excluded from the meta-analysis and the result rather presented in narrative. In the statistical analysis, the intervention group was compared to the control group if the study was a three- or four-armed trial.

For each outcome, e.g., muscle strength, heterogeneity across studies was assessed using I^2 statistics. To calculate overall effect sizes, inverse variances were used as a statistical method, and random effect models (I^2 > 50%) were conducted as an analysis model due to the expected high heterogeneity. A 95 percent confidence interval (CI) was calculated as the effects measure and was due to the variance in outcome tools and scales in the included studies, reported as standardized mean differences (SMD). All data were continuous variables, and using a threshold of $p \leq 0.05$ for when a result was statistically significant.

We contacted the authors of the included studies if we could not extract valid mean values or standard deviations from the paper. If the authors did not reply, we excluded their studies

from the meta-analysis. The results from these studies were then rather presented narratively.

2.8 Ethical considerations

We do not have first-hand knowledge about the execution of the included trials or the adherence to the trial protocols. Nevertheless, all publications referred to the trial protocol as being approved by an ethics committee, and no control groups received interventions known to be harmful to the participants.

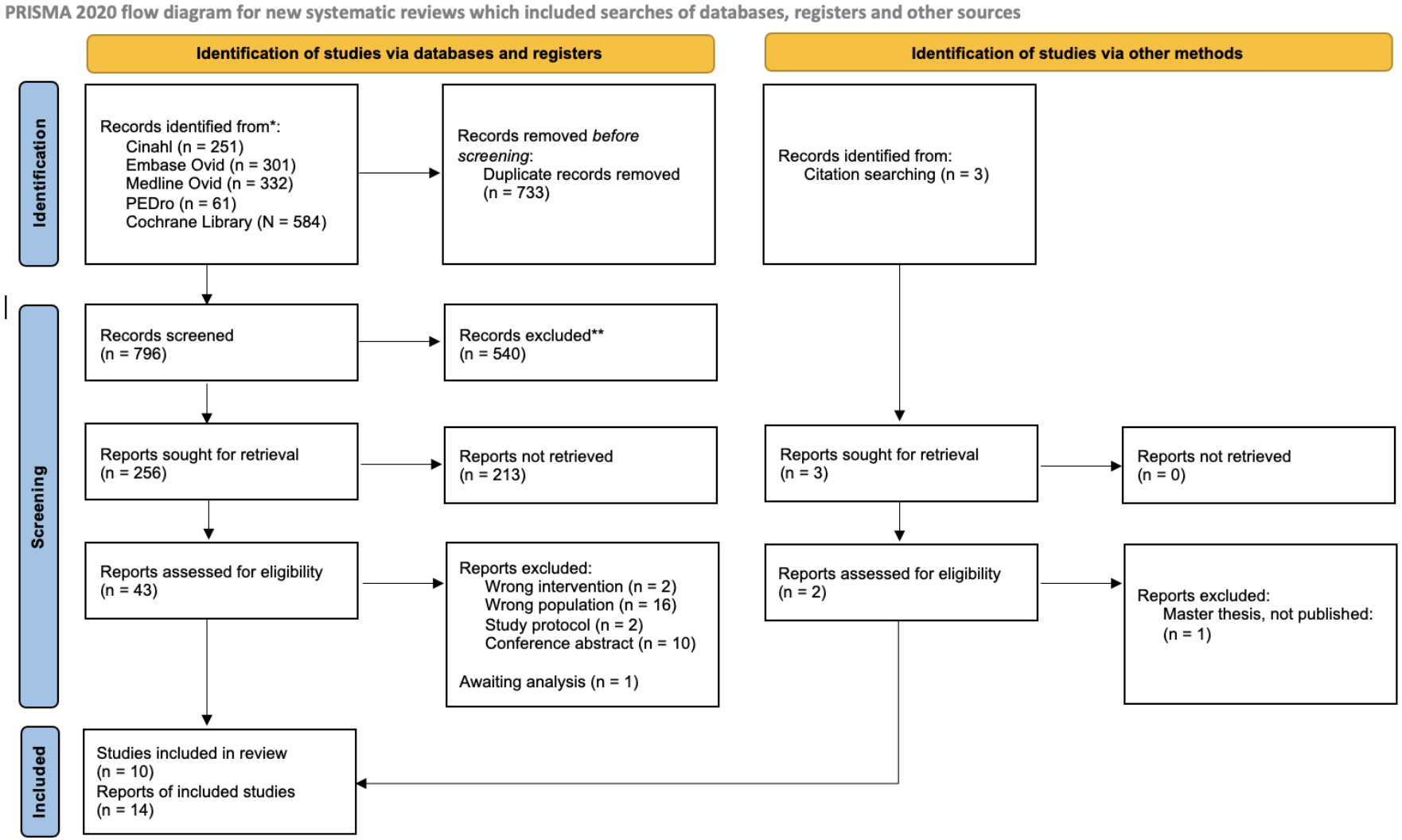

Figure 1: PRISMA 2020, Flow diagram of the study selection

3. RESULTS

3.1 Study selection

The process of study selection is shown as a PRISMA flow diagram in figure 1. We identified 1529 records from databases and three records from citation search. After screening of abstracts and titles, 43 articles were assessed for eligibility in full text, of which 14 reports were included. These 14 reports included a total of 10 intervention studies, and five reports addressed the same study, FrOST (10a, b, c, d, e). All included studies assessed the sarcopenia parameters; all trials assessed muscle strength; eight studies measured muscle mass; two trials considered muscle quality; and eight trials studied physical function. We found only one article not published in English, Sola Serrabou, et al. [38], which is awaiting analysis. A list of the studies excluded during the full text assessment, with reason, is provided in appendix 3.

3.2 Study Characteristics:

Table 4 shows characteristics and details of the included studies. The studies were published between 2016 and 2021, and were conducted in Brazil (9), China/Taiwan (3, 4), Germany (10), Iran (1) Italy (7), Japan (6), Korea (5, 8) and Spain (2). Two studies were four-armed (3, 6), one study was three-armed (2), and seven studies were two-armed (1, 4, 5, 7, 8, 9, 10).

A total of 462 older adults with sarcopenia were recruited for the 10 trials, and 414 of these completed the trials. Sample sizes ranged from 26 to 72. The mean age ranged from 64 to 81.9 y/o. Two studies included both men and women (2, 3), one study included only men (10), while the other studies covered only women (1, 4, 5, 6, 7, 8, 9). One study recruited participants from nursing homes (2), one from senior citizen centers (8), and the rest of the studies recruited community-dwelling older adults.

Diagnosis of sarcopenia

Four of the included studies defined their participants as sarcopenic based on the EWGSOP criteria (2, 7, 8, 10), while two studies used the criteria set by Asian Working Group of Sarcopenia (AWGS)[13] (4, 5). Four studies did not specify which working group criteria they used, but all of them set cut-off points based on low SMI (skeletal muscle mass index) or grip strength (1, 3, 6, 9), see table 4.

Five studies used bioelectrical impedance analysis (BIA) (2, 3, 4, 6, 7) and four studies used dual-energy X-ray absorptiometry (DXA) (1, 5, 8, 10) to measure body composition. One study did not measure body composition (9). The intervention period ranged from eight weeks to 18 months, with a median of 12 weeks. The frequency of exercise was either two or three times per week in all included studies. The control group consisted mostly of participants who either received health education or were told to maintain their normal daily lifestyles. One trial (7) had postural training as a second intervention group, exploring the effects of both resistance training and postural training.

The resistance training was performed with kettlebell (4), elastic bands (1, 6, 8, 9), dumbbells or ankle/wrist weights (2), or weight machines (3, 7, 10). Only one study focused solely on lower limb exercises, while the other nine studies included exercises for both upper and lower limbs. Six studies defined intensity based on 1 repetition maximum (1 RM), where

the intensity ranged from 40 to 85 percent of 1 RM (2, 3, 4, 5, 9, 10). Two studies used the OMNI resistance exercise scale for measuring intensity (1, 8), one study classified intensity as low/moderate (7), and one study did not specify the exercise intensity (6). Resistance training was mainly performed with 1-3 sets of 8-12 repetitions (table 6).

One included study had a nutritional component (10), which included protein, vitamin D and calcium supplements. The intervention group was supplied with up to 1.5-1.6 g protein per kg body-mass per day, while the control group received 1.2-1.3 g/kg body-mass per day. This was based on a calculated need. Vitamin D intake was based on national guidelines and individual baseline levels.

3.3 Quality assessment

The methodological quality of the included studies is presented in Table 3. Overall, the methodological quality assessment revealed that seven of the included studies have "some concerns" of bias, and three studies have "low risk of bias".

All ten RCTs had random allocation, but two lacked information about the process (3, 4), and all groups were similar at baseline. Because of the nature of the intervention, blinding of the participants and therapists was difficult. However, assessor blinding was performed by five of the included studies (1, 2, 3, 9). All the included trials showed low risk of bias in the missing outcome and measurement of the outcome domains. The low risk of bias in measurement of outcome is due to the use of standardized assessment tools, which coincides with the EWGSOP2 consensus.[1]

Table 3: Methodological quality assessment (RoB2)

Art.ID:	1: Banitalebi et al. 2020	2: Cebria il Iranzo et al. 2018	3: Chen et al. 2017	4: Chen et al. 2018	5: Jung et al., 2019	6. Kim et al. 2016	7: Piastra et al. 2018	8: Seo et al. 2021	9: Vasconcelos et al. 2016	10: FrOST-study (all pub.)
Risk of bias assessment										
Domain 1: Risk of bias arising from the randomization process	+	+	?	?	?	?	?	?	+	+
Domain 2: Risk of bias due to deviations from the intended interventions	?	−	−	−	?	?	?	?	?	+
Domain 3: Missing outcome data	+	+	+	+	+	+	+	+	+	+
Domain 4: Risk of bias in measurement of the outcome	+	+	+	+	+	+	+	+	+	+
Domain 5: Risk of bias in selection of the reported result	+	?	?	?	?	?	?	?	?	?
Overall risk of bias										
Risk-of-bias judgement	+	?	?	?	?	?	?	?	+	+

Notes: + , low risk of bias; ? , some risk of bias; − , high risk of bias. For more information see appendix 4.

Table 4: Study characteristics

ID	Author (year)	Country Living Status	Study design	Diagnosis of sarcopenia Sarcopenia criteria	Sample size	Age Sex	Assessment tool for body-composition	Outcomes (assessment tool)
1	Banitalebi et al. (2020)[39]	Iran Community dwelling	Two armed RCT	Osteosarcopenia Sarcopenia scale: SMI < 25 % or < 7.76 kg/m2 Gait speed < 1 m/s[2]	63 RT = 32 C = 31	64 F	DXA	Hand grip strength (max) (kg) (dynamometer) Gait speed (6MWT) Maximal gait speed (10 MWT(s)) Physical performance (TUG) Lower body strength (30s chair stand test) OSO-syndrome markers (blood sample)
2	Cebrià I Iranzo et al. (2018)[40]	Spain Nursing home	Three armed RCT	Sarcopenia EWGSOP, Tyrovolas 2015: SMI = ASM < 0.93/0.57 (men/women) Gait speed < 0.95/0.8 m/s (men/women)	(81) 37 RT = (27) 11 C = (27) 17 RMTG: (27) 9	81.9 F+M	BIA	ASMM (BIA) Hand grip strength (max) (kg) (dynamometer) Maximal isometric muscle strength(kg) knee extension (dynamometer) Maximal isometric elbow flexion strength(N) (dynamometer) Maximal gait speed (m/s) (10 MWT) MIP and MEP (respiratory pressure meter) MVV (spirometer)
3	Chen et al. (2017)[41]	China/Taiwan Community center	Four armed RCT	Sarcopenic obesity Sarcopenia scale: ASM (kg)/Weight (kg)*100 % Men: < 32.5 %. Woman: < 25.7 %	(93) 60 RT = (22) 15 C = (22) 15 AT = (24) 15 CT = (25) 15	68.8 F+M	BIA	Skeletal muscle mass (kg) (BIA) Hand grip strength (max) (kg) (dynamometer) Maximal isometric muscle strength (kg) knee extension (dynamometer) Maximum Back Extensor Strength (dynamometer) Sarcopenia index IGF-1 Concentration (blood sample)
4	Chen et al. (2018)[42]	China/Taiwan Community dwelling	Two armed RCT	Sarcopenia AWGS	33 RT = 17 C = 16	67.5 F	BIA	ASMM (BIA) Hand grip strength (max) (kg) (dynamometer) Isometric back strength (dynamometer) Maximum PEF and FVC (CHEST pulmonary function test analyzer) Cytokine concentration (blood sample)
5	Jung et al. (2019)[43]	Korea Community dwelling	Two armed RCT	Sarcopenia AWGS	26 RT = 13 C = 13	75 F	DXA	ASMM (BIA) Knee extension 90°/s Peak power (Nm) (Isokinetic dynamometer) Maximal gait speed (10 MWT(s)) Balance (moving platform) Pulmonary function (FVC, FEV[1].0, FEF 25-75 %) and MVV)
6	Kim et al. (2016)[44]	Japan Community dwelling	Four armed RCT	Sarcopenic obesity Low ASM (w/BIA) < 5.67 kg/m[2] Low grip strength < 17.0 kg Low walking speed < 1.0 m/s High body fat mass > 32 %	(139) 137 RT = (35) 34 C = 34 Ex + N = 36 N = (34) 33	81.3 F	BIA	ASMM (BIA) Hand grip strength (max) (kg) (dynamometer) Maximal isometric knee extension strength (N) (dynamometer) Habitual gait velocity (m/s) (5 MTW) Blood indicators (blood sample)

7	Piastra et al. (2018) [45]	Italy Community dwelling	Two armed RCT	Sarcopenia EWGSOP	72 RT = (35) 33 C = (37) 33	70 F	BIA	Skeletal muscle mass (SM) equation (SM/height2) (BIA) Hand grip strength (max) (kg) Balance (moving platform)
8	Seo et al. (2021)[46]	Korea Senior center	Two armed RCT	Sarcopenia IWGS and EWGSOP	(27) 22 RT = (14) 12 C = (13) 10	71.6 F	DXA	ASMM (DXA) Hand grip strength (max) (kg) (dynamometer) Maximal isometric knee extension strength (N) (dynamometer) Muscle quality: Thigh composition (DXA) Gait speed (4MWT) Functional fitness (SFT) Biochemical markers (blood sample)
9	Vasconcelos et al. (2016)[47]	Brazil Community dwelling	Two armed RCT	Sarcopenic obesity Grip strength < 21 kg	(31) 28 RT = (16) 14 C = (15) 14	72 F	-	Isokinetic knee extensor strength (J) (isokinetic dynamometer) Gait velocity (10 MTS (m/s) Functional fitness (SPPB)
10	FrOST-study a) Ghasemikaram et al. (2021)[48] b) Kemmler et al. (2020).[49] c) Kemmler et al. (2020)[50] d) Kemmler et al. (2020)[51] e) Lichtenberg et al. (2019)[52]	Germany Community dwelling	Two armed RCT	Osteosarcopenia EWGSOP	43 HIT-RT = (21) 19 C = (22) 21	78.5 M	DXA	Skeletal muscle mass index (SMI) (kg/m^2) (DXA) Hand grip strength (max) (kg) (dynamometer) Maximum isokinetic hip leg-extensor strength (N) (dynamometer) Habitual gait velocity (m/s) (10 MWT) Muscle quality: Tight composition (DXA)

Notes: SMI, Skeletal muscle mass index; ASM, Appendicular skeletal muscle; BIA, Bioelectrical Impedance analysis; RT, Resistance training; C, Control; CT, Control group; RMTG, respiratory muscle training group; HIT-RT, High intensity resistance training; DXA, dual-energy X-ray absorptiometry; 6MWT, six meters walking test; 10MWT, 10 meters walking test; TUG, Timed up and go; ASMM, Appendicular skeletal muscle mass; SFT, Senior Fitness Test; SPPB, Short Physical Performance Battery

3.4 Data synthesis and analysis of sarcopenia parameters

Body composition: Muscle mass and muscle quality

Eight studies included muscle mass as a primary outcome, but only seven of these were included in the analysis due to lack of information in the remaining article (FrOST). Five studies used ASM (kg/m^2) (2, 4, 5, 6, 8) to assess muscle mass, one study used SMM (kg) (3), one study used SMI (kg/m^2) (10), and one used SM/h^2 (7). The meta-analysis showed the difference in muscle mass between the intervention group and the control group as being insignificant (p = 0.08), although all studies reported an increased or unchanged muscle mass in the intervention group (SMD 0.21, 95% CI -0.03 to 0.46, I^2 = 0%) (figure 2). It should be noted that five (2, 4, 6, 7, 8) of the eight studies exploring muscle mass reported a decrease in muscle mass in the no-intervention control groups.

Only two studies measured muscle quality, including the FrOST study, which did not have the data necessary to be included in a meta-analysis. The results from the two studies are therefore presented in a narrative. Both trials presented an improvement in thigh muscle quality. The FrOST study showed a significant increase in thigh lean body mass (TLB) (kg/g) (p < 0.001). In the study done by Seo et al.,[46], the intervention group showed similar effects in thigh muscle volume, with a significant between-group change (p = 0.039), although not a significant withing-group-change. Both studies showed a decline in muscle quality for the control groups.

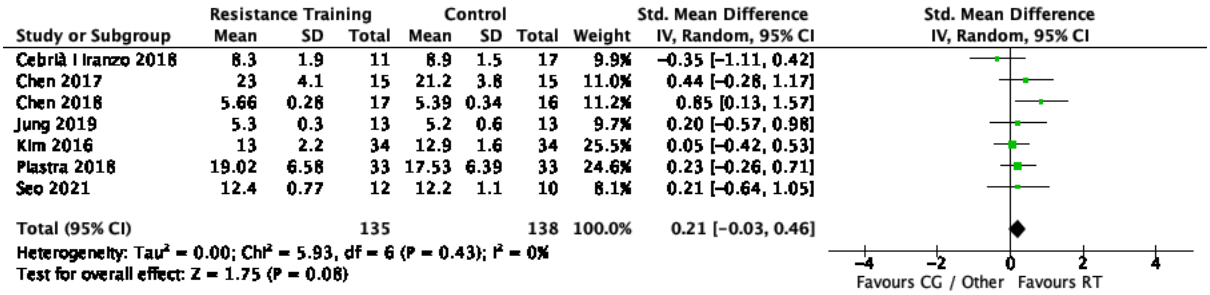

Figure 2: Forest plot, Muscle quantity (mass), between-group effect

Muscle strength

All the included studies assessed muscle strength, although different measurements were utilized. Eight studies (1, 2, 3, 4, 6, 7, 8, 10) used a handheld dynamometer for measuring hand grip strength, and six studies analyzed the effect of resistance training on quadriceps femoris strength using either isokinetic (5, 9) or isometric dynamometer (2, 3, 6, 8). Resistance training significantly increased quadriceps femoris strength in favor of the intervention group (SMD = 0.69, 95% CI 0.39 to 0.98, p < 0.00001, I^2 = 79%) (figure 3). The meta-analysis results also show an increase in hand grip strength (SMD = 0.51, 95% CI -0.04 to 1.06, I^2 = 75%), but the result is not statistically significant (p = 0.07) (figure 4).

Two articles that measured both hand grip strength and lower limb strength were excluded from the meta-analysis due to lack of data. Banitalebi et al.,[39] showed a significant increase in the intervention group in both grip strength (F = 6.411, p = 0.013, ES = 0.065) and 30s chair stand test (F= 4.599, p = 0.036, ES = 0.063) compared to the control group. FrOST concluded that hand grip strength was maintained in the intervention group and decreased in the control group. The differences in hand grip strength between the groups were

significant ($p < 0.001$). There was also a significant between-group difference in leg press performance, ($p < 0.001$), in favor of the HIT-RT group.

Of the six studies included in the meta-analysis for hand grip strength, five reported a decrease in the control group. Regarding quadriceps strength, five of the six included studies showed a decline in the control group, in addition to the FrOST-study.

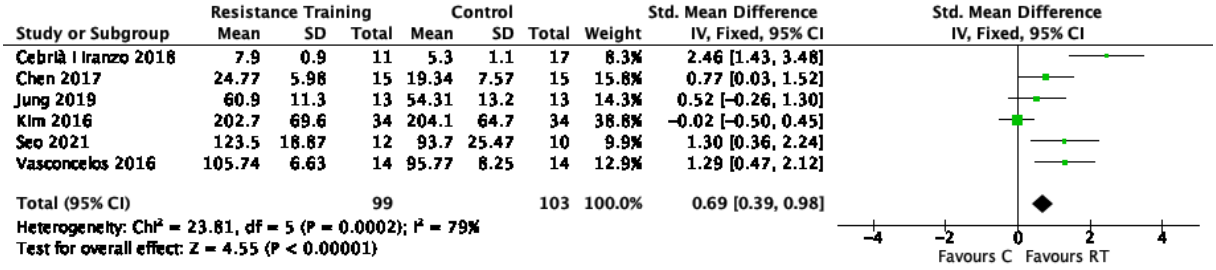

Figure 3: Forest plot, Muscle strength, quadriceps femoris strength (knee extension), between-group effect

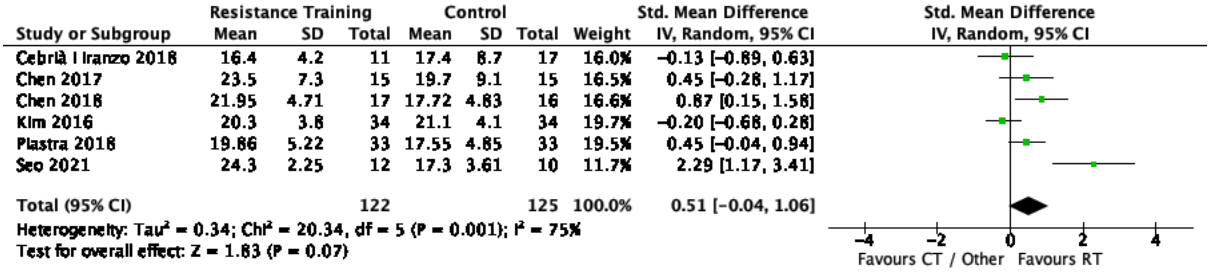

Figure 4: Forest plot, Muscle strength, hand grip, between-group effect

Physical function

Seven studies measured physical function using gait speed. Three studies included maximal gait speed (1, 2, 5), while five studies included habitual gait velocity (1, 6, 8, 9, 10). One study looked at balance (7), and two studies used a test battery (8, 9) to assess physical function. Because of the wide range of outcome measures, the heterogeneity between the studies assessing physical function was high. On such basis we concluded that most value would be gained from presenting the results in a narrative. We decided to focus on gait function in accordance with the EWGSOP2 consensus.

Five of the included studies showed no significant between-group differences regarding gait speed/physical function (1, 2, 6, 9, 10). On the other hand, both Seo et al.,[46] and Jung et al.,[43] presented a significant change in gait speed in favor of the intervention group. Seo et al.,[46] also concluded that all variables concerning physical function were significantly improved in the intervention group ($p < 0.001$). Results from the same study also showed a decline in chair-sit-and-reach, 4-min up and go, and 2-min step test for the control group, ($p = 0.05$), which means that there was a statistically significant degeneration in the control group regarding overall physical function.

3.5 Results: CERT

None of the included studies covered all 16 CERT items. The mean number of items included in the studies was 8.2, and the median score/number was 8. The scores ranged from 2 to 18 (out of a maximum score of 19 points for the 16 CERT items).

Well-reported items included description of exercise intervention (nine studies) and description of number of exercises, repetitions, sets and sessions (nine studies). Seven studies described how exercises progressed, while six studies reported the progression decision rules. Four studies reported the exercise instructor qualifications. Similarly, four studies included information about any potential non-exercise components.

The most poorly reported items were description of motivation strategies (one study), description of home program component (one study), description of how exercises are tailored to the individual (one study), decision rules for determining starting level (two studies), to which extent the intervention was delivered as planned (two studies), how adherence to exercise was measured and reported (three studies), and how adherence to exercise was assessed (three studies). See table 5 for the overall scoring, and appendix 5 for complete scoring.

Table 5: Critical evaluation of intervention reporting (CERT)

		1. Banitalebi et al., 2020	2. Cebrià I Iranzo et al. 2018	3. Chen et al., 2017	4. Chen et al., 2018	5. Jung et al. 2019	6. Kim et al., 2016	7. Piastra et al., 2018	8. Seo et al., 2021	9. Vasconcelos et al. 2016	10. FrOST (all pub.)	Section total:
Section	**#**											
WHAT: materials	**1.**	1	1	0	1	0	1	0	1	0	1	6
WHO: provider	**2.**	1	1	0	0	0	0	0	1	1	0	4
HOW: delivery	**3.**	1	1	0	0	0	1	1	0	1	1	6
	4.	1	1	0	0	0	1	0	0	1	1	5
	5.	0	1	0	0	0	0	0	0	1	1	3
	6.	0	0	0	0	0	0	0	0	0	1	1
	7a	1	1	0	1	0	0	0	1	1	1	6
	7b	1	0	1	1	0	1	0	1	1	1	6
	8	1	1	1	1	1	1	0	1	1	1	9
	9	0	0	0	0	0	0	0	0	0	1	1
	10	1	0	0	0	0	1	0	1	0	1	4
	11	1	1	0	0	0	1	0	0	1	1	5
WHERE: location	**12**	0	0	0	1	0	1	1	0	0	1	4
WHEN, HOW MUCH: dosage	**13**	1	1	1	1	1	1	0	1	1	1	9
TAILORING: what, how	**14a**	1	1	0	0	0	0	0	0	1	1	4
	14b	0	0	0	0	0	0	0	0	0	1	1
	15	1	0	0	0	0	0	0	0	0	1	2
HOW WELL: planned, actual	**16a**	0	1	0	0	0	0	0	0	1	1	3
	16b	0	0	0	0	0	0	0	0	1	1	2
Total:		12	11	3	6	2	9	2	7	12	18	

Table 6: Intervention characteristics and critical evaluation score

ID	Intervention	Duration	FITT-VP *Frequency*	*Intensity*	*Time*	*Type*	*Volume (r x s)*	**Pattern** *Rest bw. Session (bw. sets)*	**Progression**	**Control:**	**RoB2 grade**	**CERT - score**
1	Elastic band RT	12 wk	3*wk	7 OMNI-IR	60 min	AMMG	12 x 1-2	-	Individual Color of elastic band	Waitlist	⊕	12
2	RT	12 wk	3*wk	Borg CR10 40-60 % 1RM	30-40 min	AMMG	12 x 1	48 h -	Individual Monthly measurement	1 Waitlist 2 RMTG	?	11
3	RT	8 wk	2*wk	Borg CR10 60-70 % 1 RM	60 min	AMMG	8-12 x 3	48 h (2-3 min)	Every 2 weeks	1. Waitlist / No Intervention 2. Aerobic training 3. Combination training	?	3
4	KB-RT	8 wk	2*wk	60-70 % 1 RM	60 min	AMMG	8-12 x 3	48 h (2-3 min)	Every 2 weeks >10 reps → increased load	Waitlist	?	6
5	Circuit-RT and walking	12 wk	3*wk	60-80 % HRR	25-75 min	AMMG	1 min each exercise 2-4 sets	-	-	Usual care + education	?	2
6	RT	12 wk (3 mth)	2*wk	-	60 min	AMMG	10 x 1-3	-	-	1. Health education 2. Ex + N 3. N	?	9
7	RT	36 wk	2*wk	-	60 min	AMMG	-	-	-	Postural training	?	2
8	RT	16 wk	3*wk	4-8 OMNI-RES	60 min	AMMG	6-15 x 3-5	- (60 s)	Progressive overload	Waitlist / No intervention	?	7
9	RT	10 wk	2*wk	40-60 % 1RM	60 min	Lower limb	8-12 x 2-3	-	Every two weeks	Waitlist / No intervention	⊕	12
10	HIT-RT + nutrition	12 wk	2*wk	P1: no P2: 1-2RR P3: RM-1	50 min	AMMG	P1: 8-15 x 1-2 P2: 15-18→7-10 x 1 P3: 12-15→6-8 x 1	(P1: 90-120s) (P2: 90s)	Linear periodization P2+3 (wk 12→): recovery week each forth week	Nutrition	⊕	18

Notes: RT, resistance training; wk, week; mth, month; bw, between; AMMG, all major muscle groups; HRR, heart rate reserve; ⊕, low risk of bias; ?, some risk of bias; ⊖, high risk of bias.

4. DISCUSSION

4.1 Discussion of results

In this systematic review and meta-analysis, consisting of ten RCTs with 414 older adults with sarcopenia, we investigated to which extent the resistance training interventions were reported, as well as the effect of resistance training on the sarcopenia parameters. We found that resistance training significantly increases muscle strength, and has a positive effect on muscle mass and physical function in elderly with sarcopenia compared to a non-exercise control group. We also found that the overall reporting of exercise interventions in studies assessing the effect of resistance training on older adults with sarcopenia are poor.

Muscle strength

The results from our meta-analysis demonstrated that resistance training significantly improves muscle strength compared to no intervention. More specifically, resistance training improved both quadriceps femoris strength (six studies) ($p < 0.00001$) and hand grip strength (six studies) ($p = 0.07$), however the findings on hand grip strength were not statistically significant. This is consistent with previous findings[24 53], where resistance training is seen as superior when it comes to improving muscle strength.

In an umbrella review from 2019[24], it is argued that resistance training with higher intensity and volume, specifically 70-80 percent 1 RM, with 4 sets of 8-15 repetitions 2-3 times per week, is beneficial for this population. This is overall a higher training volume than in the trials included in this review (table 6), but it is, due to the sparse information about intensity and overall volume reported, generally difficult to evaluate whether the dosages in the trials are optimal.

The lack of a statistically significant change in hand grip strength could be explained by limited specific training. None of the studies included exercises for hand grip or lower arm muscles specifically, although muscles were activated through holding external loads, e.g., kettlebell and/or elastic band. Such activation could arguably be a sufficient load to achieve the desired adaptation, but most of the exercises prescribed in the studies are either without external load or involves exercise machines. This may not be a sufficient load for the underarm muscles, and is not consistent with the exercise principle of specificity. Also, five of the six studies reported a decline in hand grip strength in the control group (p. 17). This could explain the between-group change of SMD = 0,51 ($p = 0.07$).

Muscle mass

The results from the meta-analysis showed a favorable effect regarding muscle mass for the intervention group. However, the between-group effect is mainly seen because of a decline in muscle mass in the control group and maintenance of muscle mass in the intervention group, and not because of an increase in muscle mass in the intervention group.

The fact that muscle strength was significantly improved, but not muscle mass, could be explained by the muscle strength increase being a result of muscle fiber tissue improvement rather than muscle mass hypertrophy.[54] Neural adaptations also play an essential role in the improvements of muscle strength in elderly after resistance training.[55] Another possible

explanation for the difference could be the relative short intervention time, as the median intervention time was only 12 weeks, which can be long enough to see measurable changes in muscle function, but not hypertrophy.[56]

Physical function
Only two studies presented a significant change in gait speed in favor of the intervention group, while four studies showed no significant between-group difference in gait speed. Still, the meta-analysis showed a significant between-group change in quadriceps femoris strength, which may indicate that the applicability from muscle strength to physical ability is sparse. This coincides with the results from Liu and Latham's systematic review[57], where progressive resistance training had a large positive effect on muscle strength (SMD = 0.84, 95% CI, 0.67-1.00), but only small improvements were shown in physical function (SMD = 0.14, 95% CI, 0.05-0.22).

On the other hand, a recent systematic review[58], presented improvements in both physical performance and muscle strength, arguing that increased lower limb strength led to enhanced gait speed and physical performance. It is worth noting that this systematic review included studies that assessed aerobic training and mixed interventions in addition to strength training. It is therefore uncertain whether the results regarding physical function were due to resistance training alone.

Considering that the participants in the included studies in our systematic review performed mainly resistance training interventions, with a majority of seated or machine-based exercises, the transferability to gait function may be restricted. Utilizing the principle of specificity, e.g inclusion of exercises imitating movement patterns of gait, would probably lead to greater improvements in gait function.[59]

4.2 CERT

4.2.1 General considerations

We used CERT to evaluate and assess the resistance training interventions described in the included studies. Even though the template was initially developed to guide authors in fully describing exercise interventions[36], it has also been used as a tool to critically evaluate the completeness of the reporting of exercise interventions, with high inter-rater reliability.[60]

4.2.2 Individual progression

We found poor reporting of several items, including the item *exercise tailored to the individual* (#14b CERT). According to Hurst et al.,[61], an appropriate and individualized exercise dose is key to an effective approach for treatment of sarcopenia. With the lack of detailed description of individual adaptations, it is difficult to replicate the exercises to clinical practice. We believe it is imperative to include information about individualization in the training intervention descriptions. We acknowledge that fully individualized programs cannot be completely described and that clinicians will need to personalize programs based on their specific knowledge in each individual case. Still, we urge authors to describe any modifications of the exercise program they have done due to individualization or other factors.

In contrast, important items for replication in clinical practice, including descriptions of exercises and dosage, were well reported in the included studies (#8, #13 CERT). The majority of the studies either named their exercises or described the execution, as well as including descriptions of volume (repetitions*set*frequency), making it easier to incorporate the exercise prescription in targeting sarcopenia.

4.2.3 Supervision and motivational strategies

Motivational strategies, such as verbal encouragement and physiological feedback, can enhance self-efficacy in exercise. Getting appropriate instructions, as well as experiencing proper feeling of mastery can be assuring for participants during exercise execution.[62] The supervision and motivational strategy items were poorly reported in the included publications (#4, #6 CERT). Because of the potential impact participant motivation has on exercise intensity and performance, information regarding motivational strategies are of great value.[63]

Social support is a powerful motivation for exercise. Training in group can enhance the overall adherence to exercise, and such training in groups can provide a crucial social support system for persons starting an exercise program.[62] Five of the included studies had group training interventions (#3 CERT), potentially having a positive impact on adherence to and effects of these interventions.

4.2.4 Fidelity, adherence, and adverse events

Descriptions of fidelity, adherence to intervention and adverse events, were generally limited for the studies (#11, #16a, b CERT). Intervention fidelity has important implications for the internal validity of a study, whereas reporting of adherence and adverse events is crucial to enable assessment of an intervention's tolerability and feasibility. It is necessary for the clinicians to ensure that their prescribed training interventions are safe and tolerable for their patients. If adverse events are not sufficiently reported, it may lead to training prescriptions being incorrectly recommended.[64]

Training intervention effectiveness is reliant on adherence and fidelity. ACSM recommends a training frequency of three times per week in older adults, as long-term compliance is approximately 60-70 percent of the prescribed volume. Thus, an average of two sessions per week will be performed in practice, which should be both achievable and tolerable.[20] If fidelity and adherence to the prescribed intervention is not properly documented in the studies, it is difficult to know whether any effect, or lack thereof, is due to the prescribed intervention, or because of insufficient compliance.

4.2.5 Implications for research and future directions

Hurst et al.,[61] highlights the need for further studies involving older adults with sarcopenia in order to improve the evidence base in this area, including higher quality intervention studies and trials of longer duration. We see the need for embedding the principles of resistance training prescription when designing future trials, and authors should in future reports address these in accordance with CERT.

Hansford, et al. [65] discuss that due to confining word limits of many journals, full adherence to reporting guidelines may be difficult. As a solution, they propose authors to provide manuscripts as detailed as possible, with the additional information required by relevant reporting guidelines as supplementary material. We believe such approach would increase the clinical uptake of trials assessing exercise interventions.

There have already been some improvements in reporting of trials and systematic reviews[66], partly due to journals requesting the use of reporting guidelines such as Consolidated Standard of Reporting Trials[67] and PRISMA.[68] The same measures could be taken by exercise medicine journals, encouraging, or even requiring, submission of a complete CERT checklist[65]. By doing so, exercise intervention reporting may be improved, and clinicians would easier be able to correctly implement the potentially beneficial exercise interventions in clinical practice.

4.3 Discussion of method

4.3.1 Limitations of our study

There are some limitations in this review. Firstly, we did not set any exclusion criteria for the diagnostic criteria for sarcopenia, which resulted in significant heterogeneity across the participants in the included studies. The results from our meta-analysis should therefore be viewed in light of such heterogeneity. Future systematic reviews should be based on well-defined criteria for diagnosing participants, e.g. EWGSOP2[1] or AWGS[13], for increased homogeneity.

We restricted the search to studies after 2010, due to the publication of the first EWGSOP consensus. This may have resulted in relevant studies being overlooked in the search process.

Due to our exclusion of studies with nutritional interventions, potential studies where nutrition is a minor part of an otherwise exercise intervention study could have been overlooked. However, due to our primary goal of assessing the extent of reporting resistance training interventions, to our knowledge, all relevant studies have been identified and included. The participants in the included FrOST study received a nutritional component. Since both the intervention group and the control group received similar nutritional interventions, only distinguished by dosage based on a calculated need, we considered the nutritional component not to be influential on the result, and the study was therefore included.

Due to lack of information in some of the published articles, several studies were excluded from the meta-analysis. As a consequence, we see a relatively small sample size for the meta-analysis, and this may reduce the strength of our findings.

4.3.2 Discussion of included studies

RoB2 is a comprehensive tool for assessing the methodological quality of RCTs. According to Minozzi et al.,[69], RoB2 is quite complex to apply, even for experienced researchers. As the authors are not experienced in the use of RoB2, this may have impacted our scoring. We have tried to make the scoring as correct as possible by thoroughly going through the

different domains in advance and using guidance documents before and during the application of the tool.

Our findings during the quality assessment revealed some concerns with the overall methodological quality of the included studies. One of the domains with highest risk of bias was blinding. Blinding is difficult to achieve when researching the effect of resistance training, as the participants cannot be unaware of what intervention they are receiving. Also, the person who supervises or instructs the participants in the exercise program cannot be blinded or unaware of which exercise/intervention they are prescribing. On the other hand, assessor blinding is both possible to accomplish and should be seen as a requirement in such randomized control studies. This was done in half of the included studies. The other five studies did not describe whether the assessor was aware of the intervention; we view this as a potential bias that may reduce the studies' credibility and integrity.

Only one study showed low risk of bias in the *selection of the reported results* domain. We conducted comprehensive searches in order to obtain study protocols or pre-specified analysis plans for the included studies. Only one of the obtained study protocols included a pre-specified analysis plan, making assessment of selection bias difficult. We urge authors to include pre-specified analysis plans in the published study protocol, as well as clearly referring to the study protocol in the published articles.

On a positive note, all studies used standardized measuring tools for the sarcopenia parameters, limiting the risk of measurement bias. The assessment tools were in accordance with EWGSOP2 and are proposed as a reliable and valid method to measure the different sarcopenia parameters, both in research and in clinical practice.

The study done by Banitalebi et al.,[39] specified in the inclusion criteria that eligible participants were between 65 and 80 years old, which was in accordance with our inclusion criteria. However, it was stated in the characteristics of the participants that some of the participants were younger than 65 y/o, with an average age of 64.11 +/- 3.81 and 64.05 +/- 3.35 y/o in the intervention group and the control group, respectively. After discussing the concern with a third party, we included the study in this review based on the inclusion criteria stated. The divergence from the stated inclusion criteria is seen as a major weakness in the included study.

We did not assess publication bias, however all included studies have been published in peer-reviewed journals, which supports their reliability.

5. CONCLUSION

This systematic review found that resistance training interventions had positive effects on the sarcopenia parameters, which is in accordance with previous findings. However, as with other therapeutic strategies, appropriate prescriptions of the resistance training are essential to maximize benefits and effects in clinical use. Our critical evaluation using CERT revealed that the reporting of resistance training interventions are overall lacking information regarding fundamental principles of resistance training. The limited availability of detailed interventions means that it is currently not possible to provide a fully evidence-based prescription for resistance training for sarcopenia, and there remains a need for relevant intervention studies and trials involving older adults diagnosed with sarcopenia to provide this information.

We propose that future studies plan and report their intervention in accordance with CERT, for easier replication in clinical practice. Following such standardization approach will most probably also benefit researchers in this area.

REFERENCES

1. Cruz-Jentoft AJ, Bahat G, Bauer J, et al. Sarcopenia: revised European consensus on definition and diagnosis. *Age and ageing* 2019;48(1):16-31. doi: 10.1093/ageing/afy169
2. Escriche-Escuder A, Fuentes-Abolafio IJ, Roldán-Jiménez C, et al. Effects of exercise on muscle mass, strength, and physical performance in older adults with sarcopenia: A systematic review and meta-analysis according to the EWGSOP criteria. *Experimental gerontology* 2021;151:111420-20. doi: 10.1016/j.exger.2021.111420
3. Cruz-Jentoft AJ, Landi F, Schneider SM, et al. Prevalence of and interventions for sarcopenia in ageing adults: a systematic review. Report of the International Sarcopenia Initiative (EWGSOP and IWGS). *Age Ageing* 2014;43(6):748-59. doi: 10.1093/ageing/afu115
4. Beaudart C, Zaaria M, Pasleau F, et al. Health Outcomes of Sarcopenia: A Systematic Review and Meta-Analysis. *PLoS One* 2017;12(1):e0169548-e48. doi: 10.1371/journal.pone.0169548
5. Cruz-Jentoft AJ, Baeyens JP, Bauer JrM, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age Ageing* 2010;39(4):412-23. doi: 10.1093/ageing/afq034
6. Sloniger MA. Cardioresperatory and Health-related Physical Fitness Assessment. In: Swain DP, ed. ACSM's resource manual for guidelines for exercise testing for prescription. 7 ed. Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins 2014:335-54.
7. Beaudart C, Locquet M, Reginster J-Y, et al. Quality of life in sarcopenia measured with the SarQoL®: impact of the use of different diagnosis definitions. *Aging Clin Exp Res* 2017;30(4):307-13. doi: 10.1007/s40520-017-0866-9
8. Landi F, Cruz-Jentoft AJ, Liperoti R, et al. Sarcopenia and mortality risk in frail older persons aged 80 years and older: results from ilSIRENTE study. *Age Ageing* 2013;42(2):203-09. doi: 10.1093/ageing/afs194
9. Sousa AS, Guerra RS, Fonseca I, et al. Financial impact of sarcopenia on hospitalization costs. *Eur J Clin Nutr* 2016;70(9):1046-51. doi: 10.1038/ejcn.2016.73
10. Janssen I, Shepard DS, Katzmarzyk PT, et al. The Healthcare Costs of Sarcopenia in the United States. *J Am Geriatr Soc* 2004;52(1):80-85. doi: 10.1111/j.1532-5415.2004.52014.x
11. Kirk B, Miller S, Zanker J, et al. A clinical guide to the pathophysiology, diagnosis and treatment of osteosarcopenia. *Maturitas* 2020;140:27-33. doi: 10.1016/j.maturitas.2020.05.012
12. Duque G. Osteosarcopenia: A Geriatric Giant of the XXI Century. *The Journal of nutrition, health & aging* 2021;25(6):716-19. doi: 10.1007/s12603-021-1640-4
13. Chen L-K, Woo J, Assantachai P, et al. Asian Working Group for Sarcopenia: 2019 Consensus Update on Sarcopenia Diagnosis and Treatment. *J Am Med Dir Assoc* 2020;21(3):300-07.e2. doi: 10.1016/j.jamda.2019.12.012
14. Paintin J, Cooper C, Dennison E. Osteosarcopenia. *British journal of hospital medicine* 2018;79(5):253-58. doi: 10.12968/hmed.2018.79.5.253
15. Paddon-Jones D, Rasmussen BB. Dietary protein recommendations and the prevention of sarcopenia. *Curr Opin Clin Nutr Metab Care* 2009;12(1):86-90. doi: 10.1097/MCO.0b013e32831cef8b

16. Kirk B, Al Saedi A, Duque G. Osteosarcopenia: A case of geroscience. *Aging Med (Milton)* 2019;2(3):147-56. doi: 10.1002/agm2.12080
17. Gianoudis J, Bailey CA, Daly RM. Associations between sedentary behaviour and body composition, muscle function and sarcopenia in community-dwelling older adults. *Osteoporos Int* 2014;26(2):571-79. doi: 10.1007/s00198-014-2895-y
18. Bao W, Sun Y, Zhang T, et al. Exercise programs for muscle mass, muscle strength and physical performance in older adults with sarcopenia: a systematic review and meta-analysis. *Aging & Disease 2020 Jul;11(4):863-873* 2020
19. Moore SA, Hrisos N, Errington L, et al. Exercise as a treatment for sarcopenia: an umbrella review of systematic review evidence. *Physiotherapy* 2020;107:189-201. doi: https://doi.org/10.1016/j.physio.2019.08.005
20. Singh MAF. Exercise Prescription in Special Populations: Women, Pregnancy, Children, and Older Adults. In: Swain DP, ed. ACSM's resource manual for guidelines for exercise testing for prescription. 7 ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins 2014:565-95.
21. Kraemer WJ. Adaptation to Resistance Training. In: Swain DP, ed. ACSM's resource manual for guidelines for exercise testing for prescription. 7 ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins 2014:511-32.
22. Kraemer WJ. Musculoskeletal Exercise Prescription. In: Swain DP, ed. ACSM's resource manual for guidelines for exercise testing for prescription. 7 ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins 2014:482-510.
23. Deschenes MR. General Principles of Exercise Prescription. In: Riebe D, Ehrman JK, Liguori G, et al., eds. ACSM´s Guidelines for Exercise Testing and Prescription. 10 ed. Philadelphia: Wolters Kluwer 2018:143-79.
24. Beckwée D, Delaere A, Aelbrecht S, et al. Exercise Interventions for the Prevention and Treatment of Sarcopenia. A Systematic Umbrella Review. *J Nutr Health Aging* 2019;23(6):494-502. doi: 10.1007/s12603-019-1196-8 [published Online First: 2019/06/25]
25. Tsuzuku S, Kajioka T, Sakakibara H, et al. Slow movement resistance training using body weight improves muscle mass in the elderly: A randomized controlled trial. *Scand J Med Sci Sports* 2018;28(4):1339-44. doi: 10.1111/sms.13039 [published Online First: 2017/12/17]
26. Peterson MD, Rhea MR, Sen A, et al. Resistance exercise for muscular strength in older adults: A meta-analysis. *Ageing Res Rev* 2010;9(3):226-37. doi: 10.1016/j.arr.2010.03.004
27. Jadczak AD, Makwana N, Luscombe-Marsh N, et al. Effectiveness of exercise interventions on physical function in community-dwelling frail older people: an umbrella review of systematic reviews. *JBI Database System Rev Implement Rep* 2018;16(3):752-75. doi: 10.11124/JBISRIR-2017-003551
28. Glasziou P, Meats E, Heneghan C, et al. What is missing from descriptions of treatment in trials and reviews? *BMJ* 2008;336(7659):1472-74. doi: 10.1136/bmj.39590.732037.47
29. Page MJ, Moher D, Bossuyt PM, et al. PRISMA 2020 explanation and elaboration : updated guidance and exemplars for reporting systematic reviews. 2021 doi: 10.1136/bmj.n160
30. Killam L. Research terminology simplified: Paradigms, axiology, ontology, epistemology and methodology: Laura Killam 2013.

31. Polit DF, Beck CT. Nursing research : generating and assessing evidence for nursing practice. 11 ed. Philadelphia: Lippincott Williams & Wilkins 2020.
32. SIGN. Search filters: Healthcare Improvement Scotland,; 2021 [Available from: https://www.sign.ac.uk/what-we-do/methodology/search-filters/.
33. EndNote [program]. EndNote 20 version. Philadelphia, PA: Clarivate, 2013.
34. Ouzzani M, Hammady H, Fedorowicz Z, et al. Rayyan-a web and mobile app for systematic reviews. *Syst Rev* 2016;5(1):210-10. doi: 10.1186/s13643-016-0384-4
35. Sterne JAC, Savovic J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. 2019 doi: 10.1136/bmj.l4898
36. Slade SC, Dionne CE, Underwood M, et al. Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *Br J Sports Med* 2016;50(23):1428-37. doi: 10.1136/bjsports-2016-096651
37. Review Manager (RevMan), [program]. 5.4 version: The Cochrane Collaboration, 2020.
38. Sola Serrabou M, Lopez del Amo JL, Valero O. The effect of 24 weeks of moderate-to-high intensity strength training on the elderly. *Revista espanola de geriatria y gerontologia* 2014;49(3):115-20. doi: 10.1016/j.regg.2013.12.002
39. Banitalebi E, Faramarzi M, Ghahfarokhi MM, et al. Osteosarcopenic obesity markers following elastic band resistance training: A randomized controlled trial. *Experimental Gerontology* 2020;135:110884. doi: https://doi.org/10.1016/j.exger.2020.110884
40. Cebrià I Iranzo MÀ, Balasch-Bernat M, Tortosa-Chuliá MÁ, et al. Effects of Resistance Training of Peripheral Muscles Versus Respiratory Muscles in Older Adults With Sarcopenia Who are Institutionalized: A Randomized Controlled Trial. *J Aging Phys Act* 2018;26(4):637-46. doi: 10.1123/japa.2017-0268
41. Chen HT, Chung YC, Chen YJ, et al. Effects of Different Types of Exercise on Body Composition, Muscle Strength, and IGF-1 in the Elderly with Sarcopenic Obesity. *J Am Geriatr Soc* 2017;65(4):827-32. doi: 10.1111/jgs.14722 [published Online First: 2017/02/17]
42. Chen HT, Wu HJ, Chen YJ, et al. Effects of 8-week kettlebell training on body composition, muscle strength, pulmonary function, and chronic low-grade inflammation in elderly women with sarcopenia. *Exp Gerontol* 2018;112:112-18. doi: 10.1016/j.exger.2018.09.015 [published Online First: 2018/09/24]
43. Jung W-S, Kim Y-Y, Park H-Y. Circuit Training Improvements in Korean Women with Sarcopenia. *Percept Mot Skills* 2019;126(5):828-42. doi: 10.1177/0031512519860637
44. Kim HP, Kim MP, Kojima NMS, et al. Exercise and Nutritional Supplementation on Community-Dwelling Elderly Japanese Women With Sarcopenic Obesity: A Randomized Controlled Trial. *J Am Med Dir Assoc* 2016;17(11):1011-19. doi: 10.1016/j.jamda.2016.06.016
45. Piastra G, Perasso L, Lucarini S, et al. Effects of two types of 9-month adapted physical activity program on muscle mass, muscle strength, and balance in moderate sarcopenic older women. *BioMed Research International 2018;(5095673):Epub* 2018
46. Seo M-W, Jung S-W, Kim S-W, et al. Effects of 16 Weeks of Resistance Training on Muscle Quality and Muscle Growth Factors in Older Adult Women with Sarcopenia: A Randomized Controlled Trial. *International journal of environmental research and public health* 2021;18(13):6762. doi: 10.3390/ijerph18136762
47. Vasconcelos KSS, Dias JMD, Araújo MC, et al. Effects of a progressive resistance exercise program with high-speed component on the physical function of older women with

sarcopenic obesity: a randomized controlled trial. *Braz J Phys Ther* 2016;20(5):432-40. doi: 10.1590/bjpt-rbf.2014.0174
48. Ghasemikaram M, Chaudry O, Nagel AM, et al. Effects of 16 months of high intensity resistance training on thigh muscle fat infiltration in elderly men with osteosarcopenia. *Geroscience* 2021;43(2):607-17. doi: 10.1007/s11357-020-00316-8
49. Kemmler W, Kohl M, Fröhlich M, et al. Effects of High-Intensity Resistance Training on Fitness and Fatness in Older Men With Osteosarcopenia. *Frontiers in physiology* 2020;11:1014-14. doi: 10.3389/fphys.2020.01014
50. Kemmler W, Kohl M, Fröhlich M, et al. Effects of High-Intensity Resistance Training on Osteopenia and Sarcopenia Parameters in Older Men with Osteosarcopenia—One-Year Results of the Randomized Controlled Franconian Osteopenia and Sarcopenia Trial (FrOST). *J Bone Miner Res* 2020;35(9):1634-44. doi: 10.1002/jbmr.4027
51. Kemmler W, Weineck M, Kohl M, et al. High Intensity Resistance Exercise Training to Improve Body Composition and Strength in Older Men With Osteosarcopenia. Results of the Randomized Controlled Franconian Osteopenia and Sarcopenia Trial (FrOST). *Frontiers in sports and active living* 2020;2:4-4. doi: 10.3389/fspor.2020.00004
52. Lichtenberg T, von Stengel S, Sieber C, et al. The Favorable Effects of a High-Intensity Resistance Training on Sarcopenia in Older Community-Dwelling Men with Osteosarcopenia: The Randomized Controlled FrOST Study. *Clin Interv Aging* 2019;14:2173-86. doi: 10.2147/cia.S225618 [published Online First: 2020/01/08]
53. Mende E, Moeinnia N, Schaller N, et al. Progressive machine-based resistance training for prevention and treatment of sarcopenia in the oldest old: A systematic review and meta-analysis. *Exp Gerontol* 2022;163:111767-67. doi: 10.1016/j.exger.2022.111767
54. Wu P-Y, Huang K-S, Chen K-M, et al. Exercise, Nutrition, and Combined Exercise and Nutrition in Older Adults with Sarcopenia: A Systematic Review and Network Meta-analysis. *Maturitas* 2021;145:38-48. doi: 10.1016/j.maturitas.2020.12.009
55. McArdle WD, Katch VL, Katch FI. Exercise physiology : nutrition, energy, and human performance. 8 ed. Philadelphia,Baltimore: Lippincott Williams & Wilkins Wolters Kluwer Health 2015.
56. Vlietstra L, Hendrickx W, Waters DL. Exercise interventions in healthy older adults with sarcopenia: A systematic review and meta-analysis. *Australas J Ageing* 2018;37(3):169-83. doi: 10.1111/ajag.12521 [published Online First: 2018/04/12]
57. Liu Cj, Latham NK, Liu Cj. Progressive resistance strength training for improving physical function in older adults. *Cochrane Database Syst Rev* 2009;2010(1):CD002759-CD59. doi: 10.1002/14651858.CD002759.pub2
58. Zhang Y, Zou L, Chen S-T, et al. Effects and Moderators of Exercise on Sarcopenic Components in Sarcopenic Elderly: A Systematic Review and Meta-Analysis. *Frontiers in medicine* 2021;8:649748-48. doi: 10.3389/fmed.2021.649748
59. Keating CJ, Cabrera-Linares JC, Párraga-Montilla JA, et al. Influence of Resistance Training on Gait & Balance Parameters in Older Adults: A Systematic Review. *Int J Environ Res Public Health* 2021;18(4):1759. doi: 10.3390/ijerph18041759
60. Slade SC, Finnegan S, Dionne CE, et al. The Consensus on Exercise Reporting Template (CERT) applied to exercise interventions in musculoskeletal trials demonstrated good rater agreement and incomplete reporting. *J Clin Epidemiol* 2018;103:120-30. doi: 10.1016/j.jclinepi.2018.07.009

61. Hurst C, Robinson SM, Witham MD, et al. Resistance exercise as a treatment for sarcopenia: prescription and delivery. *Age Ageing* 2022;51(2) doi: 10.1093/ageing/afac003
62. Baruth M. Behavioral Theories and Strategies for Promoting Exercise. In: Riebe D, Ehrman JK, Liguori G, et al., eds. ACSM's Guidelines for Exercise Testing and Prescription. 10 ed. Philadelphia: Wolters Kluwer 2018:377-404.
63. Greenleaf CA. Principles of Behavior Change: Skill Building to Promote Physical Activity. In: Swain DP, ed. ACSM's resource manual for guidelines for exercise testing for prescription. 7 ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins 2014:774-85.
64. Golder S, Loke YK, Wright K, et al. Reporting of Adverse Events in Published and Unpublished Studies of Health Care Interventions: A Systematic Review. *PLoS Med* 2016;13(9):e1002127-e27. doi: 10.1371/journal.pmed.1002127
65. Hansford HJ, Wewege MA, Cashin AG, et al. If exercise is medicine, why don't we know the dose? An overview of systematic reviews assessing reporting quality of exercise interventions in health and disease. *Br J Sports Med* 2022 doi: 10.1136/bjsports-2021-104977
66. Agha RA, Fowler AJ, Limb C, et al. Impact of the Mandatory Implementation of Reporting Guidelines on Reporting Quality in a Surgical Journal: A Before and After Study. *Int J Surg* 2016;30:169-72. doi: 10.1016/j.ijsu.2016.04.032
67. Plint AC, Moher D, Morrison A, et al. Does the CONSORT checklist improve the quality of reports of randomised controlled trials? A systematic review. *Med J Aust* 2006;185(5):263-67. doi: 10.5694/j.1326-5377.2006.tb00557.x
68. Panic N, Leoncini E, de Belvis G, et al. Evaluation of the Endorsement of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Statement on the Quality of Published Systematic Review and Meta-Analyses. *PloS one* 2013;8(12):e83138-e38. doi: 10.1371/journal.pone.0083138
69. Minozzi S, Dwan K, Borrelli F, et al. Reliability of the revised Cochrane risk-of-bias tool for randomised trials (RoB2) improved with the use of implementation instruction. *J Clin Epidemiol* 2022;141:99-105. doi: 10.1016/j.jclinepi.2021.09.021

Appendix 1: Search Strategy, 21.10.21

Embase Ovid <1974 to 2021 Week 42>

#	Search	Result
1	sarcopenia/	14261
2	(sarcopenia or presarcopenia or pre-sarcopenia or sarcopenic or pre-sarcopenic or presarcopenic).tw.	16540
3	1 or 2	18910
4	exercise/	300311
5	Exercise Therapy/	30666
6	Resistance Training/	21818
7	((strength$ or resist$ or weight$) adj3 (training or exercise$)).tw.	43487
8	4 or 5 or 6 or 7	354683
9	Clinical Trial/	1016814
10	Randomized Controlled Trial/	680253
11	controlled clinical trial/	464226
12	multicenter study/	303194
13	Phase 3 clinical trial/	56780
14	Phase 4 clinical trial/	4504
15	exp RANDOMIZATION/	92273
16	Single Blind Procedure/	44083
17	Double Blind Procedure/	188829
18	Crossover Procedure/	68442
19	PLACEBO/	372452
20	randomi?ed controlled trial$.tw.	268864
21	rct.tw.	43899
22	(random$ adj2 allocat$).tw.	47931
23	single blind$.tw.	27704
24	double blind$.tw.	224221
25	((treble or triple) adj blind$).tw.	1438
26	placebo$.tw.	333000
27	Prospective Study/	719803
28	or/9-27	2580684
29	Case Study/	81631
30	case report.tw.	464607
31	abstract report/ or letter/	1213665
32	Conference proceeding.pt.	0
33	Conference abstract.pt.	4224946
34	Editorial.pt.	705757
35	Letter.pt.	1194713
36	Note.pt.	869449
37	or/29-36	7487220
38	28 not 37	1887113
39	3 and 8 and 38	425
40	limit 39 to embase	334
	Limited to 2010 - 2021	**301**

Ovid MEDLINE 1946 to October 21, 2021		
#	Search	Result
1	Sarcopenia/	6261
2	(sarcopenia or presarcopenia or pre-sarcopenia or sarcopenic or pre-sarcopenic or presarcopenic).tw.	10417
3	1 or 2	11382
4	Exercise/	124152
5	Exercise Therapy/	44587
6	Resistance Training/	10373
7	((strength$ or resist$ or weight$) adj3 (training or exercise$)).tw.	33430
8	4 or 5 or 6 or 7	184520
9	Randomized Controlled Trials as Topic/	149184
10	Randomized Controlled Trial/	546938
11	Random Allocation/	106047
12	Double-Blind Method/	167716
13	Single-Blind Method/	31026
14	Clinical Trial/	531606
15	clinical trial, phase i.pt.	22479
16	clinical trial, phase ii.pt.	36050
17	clinical trial, phase iii.pt.	19241
18	clinical trial, phase iv.pt.	2210
19	controlled clinical trial.pt.	94473
20	randomized controlled trial.pt.	546938
21	multicenter study.pt.	306101
22	clinical trial.pt.	531606
23	exp Clinical Trials as topic/	365054
24	or/9-23	1466215
25	(clinical adj trial$).tw.	414299
26	((singl$ or doubl$ or treb$ or tripl$) adj (blind$3 or mask$3)).tw.	183604
27	Placebos/	35719
28	placebo$.tw.	229534
29	randomly allocated.tw.	32065
30	(allocated adj2 random$).tw.	35560
31	or/25-30	699082
32	24 or 31	1765610
33	case report.tw.	346016
34	Letter/	1155675
35	Historical Article/	366010
36	or/33-35	1850475
37	32 not 36	1725554
38	3 and 8 and 37	353
	Limited to 2010 - 2021	**332**

CINAHL October 21. 2021		
S1	(MH " Sarcopenia")	
S2	TI (sarcopenia or presarcopenia or pre-sarcopenia or sarcopenic or pre-sarcopenic or presarcopenic)	
S3	S1 or S2	
S4	(MH "Exercise")	
S5	(MH "Therapeutic Exercise")	
S6	(MH "Resistance Training")	
S7	TI (((strength* or resist* or weight*) N2 (training or exercise*))) OR AB (((strength* or resist* or weight*) N2 (training or exercise*)))	
S8	S4 OR S5 OR S6 OR S7	
S9	(MH "Clinical Trials+")	326713
S10	PT Clinical trial	109468
S11	TX clinic* n1 trial*	309847
S12	(TX ((singl* n1 blind*) or (singl* n1 mask*))) OR (TX ((doubl* n1 mask*))) OR (TX ((tripl* n1 blind*) or (tripl* n1 mask*))) OR (TX ((trebl* n1 blind*) or (trebl* n1 mask*)))	1193558
S13	TX randomi* control* trial*	233045
S14	(MH "Random Assignment")	70870
S15	TX random* allocat*	14436
S16	TX placebo*	73672
S17	(MH "Placebos")	13048
S18	(MH "Quantitative Studies")	30550
S19	TX allocat" random"	14436
S20	S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19	1594813
S21	S3 AND S8 AND S20	251

Cochrane Library Search, October 21. 2021			
#	Search		Result
#1	MeSH descriptor: [Sarcopenia] this term only	MeSH	549
#2	(sarcopenia or presarcopenia or pre-sarcopenia or sarcopenic or pre-sarcopenic or presarcopenic): ti,ab	Limits	1425
#3	#1 or #2	Limits	1639
#4	MeSH descriptor: [Exercise] this term only	MeSH	17447
#5	MeSH descriptor: [Exercise Therapy] this term only	MeSH	11141
#6	MeSH descriptor: [Resistance Training] this term only	MeSH	3884
#7	((strength* or resist* or weight*) NEAR/3 (training or exercise*)):ti,ab	Limits	20165
#8	#4 or #5 or #6 or #7	Limits	43002
#9	#3 and #8	Limits	584

PEDro search was conducted on October 21, 2021. Due to the restricted "Advanced Search page", a full search strategy is not submitted. The following search words were used: Abstract & Title: *Sarcopenia,* Therapy: *Strength Training,* Method: *Clinical Trial,* Published since: *2010*. 61 records were identified.

Appendix 2: Pre-specified scoring guide, CERT

	Should be described	Must be described
1	○ Easy to identify used equipment ○ Descriptions may include type or brand of apparats, weights, grading of elastic bands ○ Specific instructions regarding equipment instructions	○ Mentioning any form of equipment. ○ For example: “weights” or “elastic band”
2	○ Previous experiences regarding training exercise. Details concerning training/education of the supervisors ○ Were the instructors’ qualifications assessed beforehand – did the instructors with lacking ability get excluded or were they given training ○ Were the interventions given as a part of regular work or were the instructors hired to attend the study ○ Were the instructors paid	○ Mention of the profession of the instructor, years of experience, number of instructors
3	○ Group sessions: describe number of participants ○ Was supervision performed face-to-face or telecommunicated (or similar). ○ Could other parts influence the supervision	○ Specific mentioning of whether the supervision was performed in group or individual.
4	○ Method of supervision should be described, may include information regarding if it was done face-to-face, by telephone, SMS or similar	○ Describe whether exercises were performed alone or with supervision. If performed with instructor – should describe what the instructor did (observation, correct, guide)
5	○ Describe how the measurements was reported and followed up by the researchers	○ How are compliance measured?
6	○ May include setting goals, achieving goals, cooperation on decisions, recognition of success, graphic/visual/verbal hints and feedback, motivating interviews, advises	○ Mentioning whether motivational strategies were done (setting goals and similar)
7a	○ Example: “When the perceived effort is reduced within the same number of sets/repetitions, it is seen as a stimulus to progress the exercise”.	○ Description of how it was decided when to make changes in the training program to create progression.
7b	○ If it was made changes in the training program to ensure progress. - Example: increasing volume, intensity, frequency, or time. May also be performed by reducing rest-time, changing stimulus, performing more challenging exercises	○ Describe which changes were performed to ensure progression

8	○ Information regarding which position the exercises were performed in, muscle groups, ROM, use of pictures of preparation and performed exercises	○ Describe the exercises to such extent it is possible to replicate them in the same way (name of exercise is enough)
9	○ Had the participants been notified to do any home-based training or similar activities? Were they told to do "nothing" at home?	○ Describe whether the exercises/training are seen as "home-program" or if they are supposed to not do any other activities
10	○ If the interventions included non-training components, this should be described (written instructions, information, where to find these)	○ Describe if the intervention consisted of any additional treatments, or if they used written instructions
11	○ Did any adverse events occur?	○ Report adverse events, either with both type and number, or "none"
12	○ Should describe if the settings could affect the delivery of the intervention (hospitals, gym, equipment availability)	○ Describe where the exercises were performed, e.g., at home, clinic, gym
13	○ Type of exercises performed, loading/resistance, type of muscle contraction (eccentric, concentric), time in contraction, rest-time, training-speed, session duration, number of sessions per day/week ○ If the intervention included several sessions the time schedule should be noted/described, and if they were preplanned or could be altered during the intervention-time.	○ Number of repetitions and set, intensity, number of sessions per week. Duration of the intervention
14a	○ Example: "exercises were changed following the participants ability"	○ Mention that the exercises are tailored to the individual
14b	○ Example: "loading was increased when a person could do x repetitions above set repetition range, e.g. 3x8-12 reps	○ Describe how the exercises were individually tailored to the individual
15	○ May include strength testing of 1RM, use of Borg scale, OMNI etc.	○ Describe if the participants´ starting level was assessed.
16a	○ Description of who delivered the interventions, and how they were delivered. ○ Any strategies made for ensuring equal treatment should be documented (similar training of the instructors)	○ Describe whether any tools were used to report adherence/fidelity.
16b	○ What was done? Were there any changes from the original plan?	○ Reporting of either the participants or the instructors´ compliance to the intervention

Appendix 3: Excluded studies and reason for exclusion

Author (year):	Title:	Journal	Exclusion reason:
Balachandran, A., Krawczyk, S. N., Potiaumpai, M., Signorile, J. F. (2014)	High-speed circuit training vs hypertrophy training to improve physical function in sarcopenic obese adults: a randomized controlled trial	*Experimental Gerontology*, *60*, 64–71. https://doi.org/10.1016/j.exger.2014.09.016	Wrong population
Bellomo, R. G., Lodice, P., Maffulli, N., Maghradze, T., Coco, V., Saggini, R. (2013)	Muscle strength and balance training in sarcopenic elderly: a pilot study with randomized controlled trial	*European Journal of Inflammation*, *11*(1), 193–201. https://doi.org/10.1177/1721727X1301100118	Wrong population
Carral, Rodríguez, A. L., Cardalda, I. M., & Bezerra, J. P. A. G. (2019).	Muscle strength training program in nonagenarians - a randomized controlled trial	*Revista Da Associacao Medica Brasileira (1992)*, *65*(6), 851–856. https://doi.org/10.1590/1806-9282.65.6.851	Wrong population
Carlsson, Littbrand, H., Gustafson, Y., Lundin-Olsson, L., Lindelöf, N., Rosendahl, E., Håglin, L. (2011)	Effects of high-intensity exercise and protein supplement on muscle mass in ADL dependent older people with and without malnutrition: a randomized controlled trial	*The Journal of Nutrition, Health & Aging*, *15*(7), 554–560. https://doi.org/10.1007/s12603-011-0017-5	Wrong population
Chan, D. C., Chang, C. B., Han, D. S., Hong, C. H., Hwang, J. S., Tsai, K. S., Yang, R. S. (2017)	Effects of exercise improves muscle strength and fat mass in patients with high fracture risk: a randomized control trial	*Journal of the Formosan Medical Association*, *117*(7), 572–582. https://doi.org/10.1016/j.jfma.2017.05.004	Wrong population
Chaudry, O., Ghasemikaram, M., Jakob, F., Wolfgang, K., Engelke, K. (2021)	Effect of resistance training on muscle texture of the thigh as measured by MRI	*Bone Reports*, *14*, 100953. https://doi.org/10.1016/j.bonr.2021.100953	Conference abstract, Gashemikram 2021, included
Conceicao, M., Cavaglieri, C., Libardi, C., Vechin, F., Chacon-Mikahil, M. P., Bacurau, A., Brum, P. C., Ugrinowitsch, C. (2017)	Concurrent training does not impair myonuclei addition in elderly	*Journal of cachexia, sarcopenia and muscle*	Conference abstract, Full text not detected
Cunha, P. M., Ribeiro, A. S., Tomeleri, C. M., Schoenfeld, B. J., Silva, A. M., Souza, M. F., Nascimento, M. A., Sardinha, L. B., Cyrino, E. S. (2018)	The effects of resistance training volume on osteosarcopenic obesity in older women	*Journal of Sports Sciences*, *36*(14), 1564–1571. https://doi.org/10.1080/02640414.2017.1403413	Wrong population
Dela, F., Lindskov, F. O., Knudsen, A. K., Regnersgaard, S., Pressel, E. (2018)	Eccentric versus concentric training for increases in muscle mass and strength?	*European geriatric medicine*	Conference abstract, Full text not detected
Dela, F., Mrantinkovic, M., Lindskov, F. O., Knudsen, A. K., Regnersgaard, S., Pressel, E. (2019)	Eccentric training is superior to concentric training to increase muscle mass and strength in 65 1 year healthy subjects	*European geriatric medicine*	Conference abstract, Full text not detected
de Sá Souza, H., Piovezan, R. D., Miranda, R., Tufik, S., Poyares, D. L. R., D'Almeida, V. (2019)	Effects of resistance training on n3 sleep and muscular function in older adults with sarcopenia: a randomized controlled trial		Conference abstract, Full text not detected
De Sa Souza, H., Piovezan, R. D., Chagas Miranda, R. E., Silva, B. M., Tufik, S., Poyares, D., D'Almeida, V. (2020)	Physical exercise improves sleep and muscle function in sarcopenic patients: a randomized controlled trial	*Sleep*, *43*(Supplement_1), A317-A317.	Conference abstract, Full text not detected

Gadelha, A. B., Paiva, F. M., Gauche, R., de Oliveira, R. J., Lima, R. M. (2016)	Effects of resistance training on sarcopenic obesity index in older women: a randomized controlled trial	*Archives of gerontology and geriatrics*, *65*, 168-173.	Wrong population
Genest, F., Lindstrom, S., Luksche, N., Jakob, F., Seefried, L. (2017)	Combined efficacy of different exercise interventions in osteosarcopenic men	*Journal of bone and mineral research,* 32, S398-S398)	Conference abstract, Full text not detected
Hong, J., Kim, J., Kim, S. W., Kong, H. J. (2017)	Effects of home-based tele-exercise on sarcopenia among community-dwelling elderly adults: body composition and functional fitness	*Experimental gerontology*, *87*, 33-39.	Wrong population
Lee, Y. H., Lee, P. H., Lin, L. F., Liao, C. D., Liou, T. H., Huang, S. W. (2021)	Effects of progressive elastic band resistance exercise for aged osteosarcopenic adiposity women	*Experimental Gerontology*, *147*, 111272.	Wrong population
Liberman, K., Demesmaeker, L., Knoop, V., De Dobbeleer, L., Costenoble, A., Njemini, R., Beyer, I., Bautmans, I. (2018)	The effect of a six-month intensive strength training and strength-endurance training on muscle strength and body composition in older adults: a randomized controlled trial	*Journal of cachexia, sarcopenia and muscle*	Conference abstract, Full text not detected
Lu, Niti, M., Yap, K. B., Tan, C. T. Y., Zin Nyunt, M. S., Feng, L., Tan, B. Y., Chan, G., Khoo, S. A., Chan, S. M., Yap, P., Larbi, A., & Ng, T. P. (2019).	Assessment of Sarcopenia Among Community-Dwelling At-Risk Frail Adults Aged 65 Years and Older Who Received Multidomain Lifestyle Interventions: a Secondary Analysis of a Randomized Clinical Trial	*JAMA network open*, *2*(10), e1913346-e1913346.	Wrong intervention
Nunes, Barcelos, L. C., Oliveira, A. A., Furlanetto Júnior, R., Martins, F. M., Orsatti, C. L., Resende, E. A. M. R., & Orsatti, F. L. (2016)	Effect of resistance training on muscular strength and indicators of abdominal adiposity, metabolic risk, and inflammation in postmenopausal women: controlled and randomized clinical trial of efficacy of training volume	*Age*, *38*(2), 1-13.	Wrong population
Sousa, N., Mendes, R., Abrantes, C., Sampaio, J., Oliveira, J. (2013)	Is once-weekly resistance training enough to prevent sarcopenia?	*Journal of the American Geriatrics Society*, *61*(8), 1423-1424.	Conference abstract, Full text not detected
Strasser, E. M., Hofmann, M., Franzke, B., Schober-Halper, B., Oesen, S., Rasits, W., Graf, A., Praschak, M., Horvath-Mechtler, B., Krammer, C. (2018)	Strength training increases skeletal muscle quality but not muscle mass in old institutionalized adults: a randomized, multi-arm parallel and controlled intervention study	*European journal of physical and rehabilitation medicine*, *54*(6), 921-933.	Wrong population
Strasser, E. M., Praschak, M., Horvath-Mechtler, B., Krammer, C., Wessner, B., Bachl, N., Wagner, K. H., Quittan, M. (2014)	Effect of progressive muscle strength training with or without dietary supplementation on muscle mass in elderly	*Annals of Physical and Rehabilitation Medicine*, (57), e155.	Conference abstract, Strasser 2018, not included
Tsuzuku, S., Kajioka, T., Sakakibara, H., Shimaoka, K. (2018)	Slow movement resistance training using body weight improves muscle mass in the elderly: A randomized controlled trial	*Scandinavian journal of medicine & science in sports*, *28*(4), 1339-1344.	Wrong population
van den Helder, J., Mehra, S.., van Dronkelaar, C., Ter Riet, G., Tieland, M., Visser, B., Krose, B. J. A., Engelbert, R. H. H., Weijs, P. J. M. (2020)	Blended home-based exercise and dietary protein in community-dwelling older adults: a cluster randomized controlled trial	*Journal of cachexia, sarcopenia and muscle*, *11*(6), 1590-1602.	Wrong population
Yamada, M., Kimura, Y., Ishiyama, D., Nishio, N., Otobe, Y., Tanaka, T., Ohji, S., Koyama, S., Sato, A., Suzuki, M. (2019)	Synergistic effect of bodyweight resistance exercise and protein supplementation on skeletal muscle in sarcopenic or dynapenic older adults	*Geriatrics & gerontology international*, *19*(5), 429-437.	Wrong population

Yamamoto, Y., Nagai, Y., Kawanabe, S., Hishida, Y., Hiraki, K., Sone, M., Tanaka, Y. (2020)	Effects of resistance training using elastic bands on muscle strength with or without a leucine supplement for 48 weeks in elderly patients with type 2 diabetes	*Endocrine Journal*, EJ20-0550.	Wrong population
Zhu, L. Y., Chan, R., Kwok, T., Cheng, Kc-C., Ha, A., Woo, J. (2019)	Effects of exercise and nutrition supplementation in community-dwelling older Chinese people with sarcopenia: a randomized controlled trial	*Age and ageing*, *48*(2), 220-228.	Wrong intervention
Unknown (2012)	Land and aquatic strength exercises for obese old women with muscle weakness		Study protocol
Unknown (2017)	Resistance Training and Sarcopenic Obesity Elderly Women		Study protocol
do Nascimento, M. A., Gerage, A. M., Januario, R. S., Pina, F. L., Gobbo, L. A., Mayhew, J. L., & Cyrino, E. S. (2016).	Resistance training with dietary intake maintenance increases strength without altering body composition in older women	*The Journal of sports medicine and physical fitness*, *58*(4), 457-464.	Wrong population

Appendix 4: Revised Cochrane Risk of Bias tool (RoB2)

Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) TEMPLATE FOR COMPLETION											
Art.ID:	1: Banitalebi et al. 2020	2: Cebria et al. 2018	3: Chen et al. 2017	4: Chen et al. 2018	5: Jung et al., 2019	6: Kim et al. 2016	7: Piastra et al. 2018	8: Seo et al. 2021	9: Vasconcelos et al. 2016	10: FrOST-study (all pub.)	
Risk of bias assessment	Responses underlined in green are potential markers for low risk of bias, and responses in red are potential markers for a risk of bias. Where questions relate only to sign posts to other questions, no formatting is used.										
Domain 1: Risk of bias arising from the randomization process											**Respons options**
1.1 Was the allocation sequence random?	Y	Y	NI	NI	Y	Y	PY	Y	Y	Y	Y / PY / PN / N / NI
1.2 Was the allocation sequence concealed until participants were enrolled and assigned to interventions?	Y	Y	NI	NI	NI	NI	NI	NI	Y	Y	Y / PY / PN / N / NI
1.3 Did baseline differences between intervention groups suggest a problem with the randomization process?	N	N	PN	PN	N	N	N	N	N	N	Y / PY / PN / N / NI
Risk-of-bias judgement	**LOW**	**LOW**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	**LOW**	**LOW**	Low / High / Some concerns
Domain 2: Risk of bias due to deviations from the intended interventions (*effect of assignment to intervention*)											
2.1. Were participants aware of their assigned intervention during the trial?	Y	NI	NI	NI	NI	NI	NI	NI	NI	NI	Y / PY / PN / N / NI
2.2. Were carers and people delivering the interventions aware of participants' assigned intervention during the trial?	Y	NI	NI	NI	NI	NI	NI	NI	Y	N	Y / PY / PN / N / NI
2.3. If Y/PY/NI to 2.1 or 2.2: Were there deviations from the intended intervention that arose because of the trial context?	NI	NI	NI	NI	NI	NI	NI	NI	NI	NA	NA / Y / PY / PN / N / NI
2.4 If Y/PY to 2.3: Were these deviations likely to have affected the outcome?	NI	NA	NI	NI	NI	NI	NI	NI	NI	NA	NA / Y / PY / PN / N / NI

2.5. If Y/PY/NI to 2.4: Were these deviations from intended intervention balanced between groups?	NI	NA	NI	NI	NI	NI	N	NI	NI	NA	NA / Y / PY / PN / N / NI
2.6 Was an appropriate analysis used to estimate the effect of assignment to intervention?	Y	N	PN	PN	Y	Y	Y	Y	Y	Y	Y / PY / PN / N / NI
2.7 If N/PN/NI to 2.6: Was there potential for a substantial impact (on the result) of the failure to analyse participants in the group to which they were randomized?	-	PY	PY	PY	NA	NA	NA	NA	NA	NA	NA / Y / PY / PN / N / NI
Risk-of-bias judgement	**SOME**	**HIGH**	**HIGH**	**HIGH**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	**LOW**	Low / High / Some concerns
Domain 3: Missing outcome data											
3.1 Were data for this outcome available for all, or nearly all, participants randomized?	Y	N	PN	Y	Y	Y	Y	Y	Y	Y	Y / PY / PN / N / NI
3.2 If N/PN/NI to 3.1: Is there evidence that the result was not biased by missing outcome data?	NA	PY	PY	NA	NA	NA	NA	NA	NA	NA	NA / Y / PY / PN / N
3.3 If N/PN to 3.2: Could missingness in the outcome depend on its true value?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA / Y / PY / PN / N / NI
3.4 If Y/PY/NI to 3.3: Is it likely that missingness in the outcome depended on its true value?	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA / Y / PY / PN / N / NI
Risk-of-bias judgement	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	Low / High / Some concerns
Domain 4: Risk of bias in measurement of the outcome											
4.1 Was the method of measuring the outcome inappropriate?	N	N	N	N	N	N	N	N	N	N	Y / PY / PN / N / NI
4.2 Could measurement or ascertainment of the outcome have differed between intervention groups?	N	PN	PN	N	N	N	N	N	N	PN	Y / PY / PN / N / NI
4.3 If N/PN/NI to 4.1 and 4.2: Were outcome assessors aware of the intervention received by study participants?	N	N	N	NI	NI	NI	NI	NI	N	N	NA / Y / PY / PN / N / NI

4.4 If Y/PY/NI to 4.3: Could assessment of the outcome have been influenced by knowledge of intervention received?	**NA**	**NA**	**NA**	**PN**	**PN**	**PN**	**PN**	**PN**	**NA**	**NA**	NA / Y / PY / PN / N / NI
4.5 If Y/PY/NI to 4.4: Is it likely that assessment of the outcome was influenced by knowledge of intervention received?	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	NA / Y / PY / PN / N / NI
Risk-of-bias judgement	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	**LOW**	Low / High / Some concerns
Domain 5: Risk of bias in selection of the reported result											
5.1 Were the data that produced this result analysed in accordance with a pre-specified analysis plan that was finalized before unblinded outcome data were available for analysis?	**Y**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	Y / PY / PN / N / NI
Is the numerical result being assessed likely to have been selected, on the basis of the results, from...											
5.2. ... multiple eligible outcome measurements (e.g. scales, definitions, time points) within the outcome domain?	**N**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	Y / PY / PN / N / NI
5.3 ... multiple eligible analyses of the data?	**N**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	**NI**	Y / PY / PN / N / NI
Risk-of-bias judgement	**LOW**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	**SOME**	Low / High / Some concerns
Overall risk of bias											
Risk-of-bias judgement											Low / High / Some concerns

Appendix 5: CERT complete scoring

			1. Banitalebo et al., 2020	2. Cebria et al. 2018	3. Chen et al., 2017	4. Chen et al., 2018	5. Jung et al. 2019	6. Kim et al., 2016	7. Piastra et al., 2018	8. Seo et al., 2021	9. Vasconcelos et al. 2016	10. FrOST (all pub.)	Section total:
			Point	Point	Point	Point	Point	Point	Point	Point	Point	Point	
Section	#	Checklist item											
WHAT: materials	1.	Detailed description of the type of exercise equipment (e.g. Weights, exercise equipment susch as machines, treadmill, bicycle ergometer etc.)	1	1	0	1	0	1	0	1	0	1	6
WHO: provider	2.	Detailed description of the qualifications, teaching/supervising expertise, and/or training undertaken by the exercise instructor	1	1	0	0	0	0	0	1	1	0	4
HOW: delivery	3.	Describe whether exercises are performed individually or in a group	1	1	0	0	0	1	1	0	1	1	6
	4.	Describe whether exercises are supervised or unsupervised and how they are delivered	1	1	0	0	0	1	0	0	1	1	5
	5.	Detailed description of how adherence to exercise is measured and reported	0	1	0	0	0	0	0	0	1	1	3
	6.	Detailed description of motivation strategies	0	0	0	0	0	0	0	0	0	1	1
	7a	Detailed description of the decision rule(s) for determining exercise progression	1	1	0	1	0	0	0	1	1	1	6
	7b	Detailed description of how the exercise program was progressed	1	0	1	1	0	1	0	1	1	1	6
	8	Detailed description of each exercise to enable replication (e.g. photographs, illustrations , video etc)	1	1	1	1	1	1	0	1	1	1	9
	9	Detailed description of any home program component (e.g. other exercises, stretching etc)	0	0	0	0	0	0	0	0	0	1	1
	10	Describe whether there are any non-exercise components (e.g. education, cognitive behavioural therapy, massage etc)	1	0	0	0	0	1	0	1	0	1	4

Appendix 5: CERT complete scoring

	11	Describe the type and number of adverse events that occurred during exercise	1	1	0	0	0	1	0	0	1	1	5
WHERE: location	12	Describe the setting in which the exercises are performed	0	0	0	1	0	1	1	0	0	1	4
WHEN, HOW MUCH: dosage	13	Detailed description of the exercise intervention including, but not limited to, number of exercise repetitions/sets/sessions, session duration, intervention/program duration etc	1	1	1	1	1	1	0	1	1	1	9
TAILORING: what, how	14a	Describe whether the exercises are generic (one size fits all) or tailored whether tailored to the individual	1	1	0	0	0	0	0	0	1	1	4
	14b	Detailed description of how exercises are tailored to the individual	0	0	0	0	0	0	0	0	0	1	1
	15	Describe the decision rule for determining the starting level at which people commence an exercise program (such as beginner, intermediate, advanced etc)	1	0	0	0	0	0	0	0	0	1	2
HOW WELL: planned, actual	16a	Describe how adherence or fidelity to the exercise intervention is assessed/measured	0	1	0	0	0	0	0	0	1	1	3
	16b	Describe the extent to which the intervention was delivered as planned	0	0	0	0	0	0	0	0	1	1	2
Total:			**12**	**11**	**3**	**6**	**2**	**9**	**2**	**7**	**12**	**18**	

Appendix 6: PRISMA checklist for systematic reviews

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	p. 1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	p. 1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	p. 8
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	p. 9
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	p. 10
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.	p. 9
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	P. 9 and appendix: 1
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.	p. 9-10
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.	p. 9-10
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.	p. 10
	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.	p. 10
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.	p. 10-11
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.	p. 11-12
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)).	p. 11
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	p. 11-12
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	p. 11-12
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the	p. 11

Section and Topic	Item #	Checklist item	Location where item is reported
		model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	-
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	-
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	-
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	-
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.	p. 13
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	p. 14 and Appendix 3
Study characteristics	17	Cite each included study and present its characteristics.	p. 16-17, Table 4.
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	p. 15, Table 3 and Appendix 4
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.	p. 18-19
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	p. 15
	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.	p. 18-19
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	-
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	-
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	-
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	-
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	p. 22
	23b	Discuss any limitations of the evidence included in the review.	p. 25-26
	23c	Discuss any limitations of the review processes used.	p. 25
	23d	Discuss implications of the results for practice, policy, and future research.	p. 24-25
OTHER INFORMATION			
Registration and	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	p. 9

Section and Topic	Item #	Checklist item	Location where item is reported
protocol	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	p. 9
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	-
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	-
Competing interests	26	Declare any competing interests of review authors.	-
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.	-

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71
For more information, visit: http://www.prisma-statement.org/

Appendix 7: Authors guidelines, BMJ Open Sports and Exercise Medicine

Retrieved from: https://bmjopensem.bmj.com/pages/authors/#editorial_policy

Review

Review articles should not exceed 4500 words, excluding references and tables.

Reviews provide in-depth discussions in established and new areas in sports and exercise medicine. If you feel your review warrants additional length, consult the editorial office and/or mention the reason in your Cover letter.

For all reviews we ask you to provide in 3-4 bullet points subheadings "What is already known", and "What are the new findings", highlighting the clinical relevance of your work.

Systematic review

Systematic reviews provide Level One evidence; they form a critical part of the literature.

- We are looking for experts to synthesise the literature and to comment on the outcomes of the review in a meaningful and clinically relevant way
- The topic must be of relevance to clinicians with the key question 'will the findings change what practitioners do?''
- Succinct and focussed reviews, with questions that are topical, novel or controversial that will attract readers and researchers to the journal are more likely to be accepted
- The literature search should have been completed within 12 months of manuscript submission.
- All titles should include 'a Systematic Review'
- Systematic review registration: registry and number (if registered)

Word count: up to 4500 words
Abstract: up to 250 words and structured including the headings; Objectives, Design, Data sources, Eligibility criteria for selecting studies, Results and Summary/Conclusion
Tables/illustrations: up to 6 tables and/or figures
References: up to 100
Reporting guidelines: Prisma checklist/statement and flowchart

Formatting

Excerpt from: https://authors.bmj.com/writing-and-formatting/formatting-your-paper/

- **Title page:** The title page must contain the following information:
    - Title of the article
    - Full name, postal address and e-mail of the corresponding author
    - Full name, department, institution, city and country of all co-authors
    - Word count, excluding title page, abstract, references, figures and tables
- **Manuscript format:** The manuscript should be presented in the following order:
    1. Title page
    2. Abstract
    3. Main text, separated under appropriate heading and subheading using the following hierarchy: BOLD CAPS, bold lower case, Plain text, Italics.

- Tables should be in Word format and placed in the main text where the table is first cited. Tables should be cited in numerical order. Acknowledgments, Competing Interests, Funding and all other required statements
- Acknowledgments, Competing Interests, Funding and all other required statements
- References. All references should be cited in the main text in numerical order
- Figures and illustrations: Images must be uploaded as separate files. All images must be cited within the main text in numerical order and legends must be provided (ideally at the end of the manuscript). Figures should be submitted in TIFF, EPS, JPEG or PDF formats.

- **References:**
  - **Citing in the text:** BMJ (modified Vancouver). References must be numbered sequentially as they appear in the text. Reference numbers in the text should be inserted immediately after punctuation (with no word spacing)—for example,[6] not [6]. Where more than one reference is cited, these should be separated by a comma, for example,[1, 4, 39]. For sequences of consecutive numbers, give the first and last number of the sequence separated by a hyphen, for example,[22-25].
  - **Preparing the reference list**: References must be numbered consecutively in the order in which they are mentioned in the text.

For additional information about formatting in BMJ Open, please visit:
https://authors.bmj.com/writing-and-formatting/formatting-your-paper/