Biological Sex and the Association Between Grip Strength and Cardiovascular Disease: a Scoping Review

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ABSTRACT

Background

This scoping review examines how biological sex has been considered in studies investigating the association between grip strength and cardiovascular outcomes and risk factors.

Methods

We used the Askey and O'Malley framework, reported as per the PRISMA extension for scoping reviews. A search was conducted in four electronic bibliographic databases to identify relevant peer-reviewed studies published after 2001.

Results

Of the 39 included studies, 82.0% (n = 32) used biological sex as a confounder variable in the association of interest. Two studies used interaction terms between biological sex and grip strength and found no statistically significant interactions. Five studies used sex-stratified analyses alone. Three of these studies found that the cardiovascular risk due to low grip strength is higher in males than in females. Two other studies used both interaction terms between biological sex and grip strength and sex-stratification analyses and found no statistically significant differences. Sociocultural gender was not considered in any of the identified studies.

Conclusion

We found that biological sex was often considered as a confounder variable in the association between grip strength and cardiovascular outcomes, as well as cardiovascular risk factors. On the other hand, two studies reported the presence of effect modification by sex rather than confounding, that these associations were stronger in males versus females. Five other studies did not identify evidence of interaction nor effect modification. Future research is needed to clarify the nature of these associations and understand any potential biological mechanisms.

Key words: frailty, elderly, aging, heart disease, stroke

INTRODUCTION

Frailty, as it pertains to the gradual decline of muscle mass, is a crucial component of better understanding cardiovascular health in older adults. Frailty is a multi-dimensional condition that often manifests as the loss of muscle strength which significantly increases the risk of poor health outcomes, including cardiovascular disease (CVD).[(1)] Muscle strength is frequently assessed through grip strength due to its simplicity, cost-effectiveness, and high reliability as an indicator of overall muscle function.[(2,3)]

Grip strength has been shown to be inversely associated with cardiovascular risk.[(4)] In particular, low grip strength has been consistently linked to an increased risk of stroke, coronary heart disease, and peripheral vascular disease. Evidence suggests that even modest decreases in grip strength significantly increase the risk of these cardiovascular events.[(5-7)] This relationship between grip strength and cardiovascular disease, however, is not uniform across all populations and may be influenced by biological sex.[(8)]

In the context of frailty-informed care, understanding the importance of grip strength and the influence of biological sex is pivotal. For example, females, who tend to have smaller statures and lower muscle mass compared to males, may experience different health outcomes related to muscle strength.[(9,10)] These differences in physical characteristics could contribute to distinct grip strength profiles in males and females. Additionally, conditions such as arthritis, carpal tunnel syndrome, or neuropathy can disproportionately affect females, leading to further differences in grip strength profiles.[(11)]

The present scoping review aims to systematically evaluate how biological sex has been considered in studies on grip strength and cardiovascular disease. By clarifying whether sex acts as a confounder or an effect modifier, this review will help guide future research and inform clinical practices for frailty-informed care, emphasizing the need to tailor cardiovascular risk assessments based on sex-specific factors.

METHODS

We used the methodological framework proposed by Arksey and O'Malley[12] for the development of our study protocol. This framework consists of: i) identifying relevant studies; ii) selecting studies to include in the scoping review; iii) extracting and charting the data of relevant studies retained; and iv) summarizing and reporting the results. Our report was drafted according to the guidelines laid out by the PRISMA extension for scoping reviews (Appendix Table A1).[13] Our PRISMA flow diagram is consistent with the most recent recommendations.[14]

Issues Related to Sex & Gender

Our primary interest in this study was biological sex assigned at birth (i.e., related to whether a person is born with XX versus XY chromosomes). Sociocultural gender (i.e., the set of socially constructed behaviours, expressions, and identities that influences how people see themselves and others) is an important determinant of health outcomes. The American Psychological Association style guide specifies that the terms "woman" and "man" refer to sociocultural gender and not biological sex (https://apastyle.apa.org/style-grammar-guidelines/bias-free-language/gender). As a result, we have chosen to avoid the terms "woman" and "man" throughout this manuscript, even when used by the authors of the primary studies.

Identification of Relevant Studies

We considered observational studies published after 2001, the year in which the work of Fried *et al*.[1] introduced the modern concept of physical frailty (of which grip strength is a component). Given that grip strength decreases with increasing age, we considered the concept of aging in our search strategy to identify those studies relating to older adults. We did not limit inclusion based on the language of the article. We excluded methodological articles, narrative reviews, conference abstracts, and book chapters. According to the most updated search on heart disease conducted by the Public Health Agency of Canada and Canadian Heart and Stroke Foundation, CVD is a term that refers to diseases of the circulatory system including the heart and blood vessels (https://www.canada.ca/en/public-health/services/chronic-diseases/cardiovascular-disease/six-types-cardiovascular-disease.html). These include ischemic heart disease, cerebrovascular disease, peripheral vascular disease, heart failure, rheumatic heart disease, and congenital heart disease. We also included studies reporting cardiovascular mortality and risk factors.

We developed the search strategy with the assistance of a health sciences librarian with expertise in knowledge synthesis (NC). Four electronic databases were used in this scoping review: Ovid MEDLINE, Ovid Embase, Web of Science, and CINAHL. The search strategy for electronic databases was based on a combination of MeSH (Medical Subject Headings) or EMTREE search terms, where appropriate, and keywords. The search used the AND and OR Boolean operators with exhaustive combinations of search terms for frailty, grip strength, and CVD terms. Our final search strategy is summarized in Appendix Table A2. We consulted the reference lists of included studies, as well as citation searching to identify additional studies. Our search strategy for electronic databases was last performed on 15th November 2022.

Study Selection

Two independent reviewers (CWM and AVO) conducted the first screen which was based on study titles and abstracts. We submitted any article judged potentially relevant by either reviewer to the second screen. In the second screen, we obtained all full texts which were independently reviewed by the two reviewers to decide on which articles to include in the final review. At the beginning of this second screen, we began by randomly selecting a sample of 100 studies to pilot the article selection process. The goal of this pilot was to ensure that the two reviewers had a high interrater reliability. Any disagreements between reviewers for the second screen were settled by consensus, with the involvement of a third reviewer (MRK) when necessary, to resolve any persistent disagreements. Interrater reliability between the two reviewers during the pilot phase of the second screen of full texts was measured using Cohen's kappa (95% CI). We used Covidence (https://app.covidence.org, Melbourne, Australia) to manage the citations during the screening process.

Data Extraction Process

Data extraction was independently completed by two reviewers (CWM and AVO) according to the "PCC" mnemonic device, namely Population-Concept-Context. A third reviewer (MRK) resolved any conflicts where consensus was not achieved by the first two reviewers.

The data extraction tool included aim of the study design, year of publication, study location, study characteristics, and authors conclusion related to biological sex. At the end of data extraction, CWM and AC compiled key information from the included studies and quantified their characteristics.

Charting the Data & Data Synthesis

Using Microsoft Excel, we charted the data according to the data extraction framework presented in Table 1. Data charting was done by CWM and MRK, using the main themes retained in the framework. Data synthesis was based on descriptive statistics.

During the charting process, we paid particular attention to whether sex was treated as a confounding variable or a source of effect modification. Confounding occurs when a third variable distorts (i.e., biases) the association between an exposure (in this case, grip strength) and an outcome (such as CVD). In contrast, effect modification is not a bias but occurs when the association between exposure and outcome varies depending on the level of this third variable (e.g., sex).[15,16] When studies suggest that grip strength may only be associated with cardiovascular disease in males, this finding raises questions about the potential role of sex as an effect modifier rather than a confounder.

Ethics Approval & Protocol Registration

This study is based upon a secondary data analysis. For this reason, approval by our research ethics board was not required. The protocol for this scoping review was registered on the open science framework (https://osf.io/dashboard), and a DOI was assigned (DOI: 10.17605/OSF.IO/D93Z8).

RESULTS

The searches from the four electronic databases included a total of 2,535 studies. Five additional publications were identified through searching reference lists and citation searching. After removal of duplicates, the titles and abstracts of 1,354 studies were assessed, with 1,238 studies identified as not relevant. One hundred and sixteen full text articles were assessed for eligibility and 82 were excluded. The reliability between the two reviewers during the pilot second screen of full texts was substantial, with a Cohen's kappa = 0.78 (95% CI: 0.72, 0.84). The two primary reviewers could not reach consensus on two full texts. The third reviewer examined these and decided that both should be included. The process for selecting studies included in this scoping review is outlined in our PRISMA flowchart (Figure 1).

Characteristics of Included Studies

The literature on the association between grip strength and CVD is recent. Of the 39 included studies, the great majority (93.7%) were published between 2015 and 2022. The geographical scope revealed that studies were mostly conducted among populations from three world regions. Fifty-six per cent were conducted in the USA, 30.8% in Asia, and 12.8% in Europe.

Longitudinal studies accounted for 61.5% (n = 24) of the included studies, while 28.3% (n = 11) were cross-sectional and only 10.2% (n = 4) were based on another research design (e.g., systematic review). While grip strength was the primary exposure for all included studies, about 87.2% (n = 34) focused on cardiovascular mortality as the primary outcome, against 10.3% for CVD, and only 2.5% for a cardiovascular risk factor.

The mean and age range of the participants varied between 60 to 65 years and 45 to 90 years, respectively, across the studies. Females represented more than 50% of participants among all included studies. Regarding the instrument and the method for measuring and reporting grip strength, the Jamar Hydraulic Hand Dynamometer was the instrument most often used. The mean of three consecutive average measurements of the dominant hand was the most frequently used method (92.3% [n = 36] of studies used average measurement versus only 7.7% [n = 3] for maximum measurement).

Grip Strength as Predictor of Cardiovascular Outcomes & Risk Factors

Of the 39 included studies, 41.0% (n = 16) found a statistically significant positive association between low grip strength and increased risk of CVD.[17-30] A little over 50% (n = 20) reported a statistically significant positive association between low grip strength and cardiovascular mortality,[4,22,31-45] while 5.1% (n = 2) suggested that low grip strength is positively associated with an increased risk of vascular atherosclerosis (the main underlying cause of CVD).[46,47] These associations were generally moderate, with relative effect measures (e.g., odds ratio or hazards ratio) that were between 0.5 and 2.0. One study found no association between low grip strength and CVD.[48]

TABLE 1.
Data extraction framework

Key Domains	*Description*
Focus of research	Aim of the study
Year Published	Year of study publication
Study location	The world region where the study was conducted, and the respective country
Study characteristics	Study design Definition of the cardiovascular outcome Method for measuring and reporting grip strength Research participants characteristics Number of participants included in the study Proportion of female versus male sex Mean/median and range participant age
Thematic analysis	Biological sex was considered in the study design and analyses? If so, how (e.g., as confounder variable, stratification by sex, in interaction term)? What were the findings of sex-based analyses? Did the authors offer any biological mechanisms to explain their findings sex-based analyses? How were the findings related to sex interpreted by the authors (e.g., evidence of confounding or effect modification measure)? Did the authors consider the difference between biological sex and sociocultural gender? Did the authors discuss what impact biological sex could have on public health interventions?

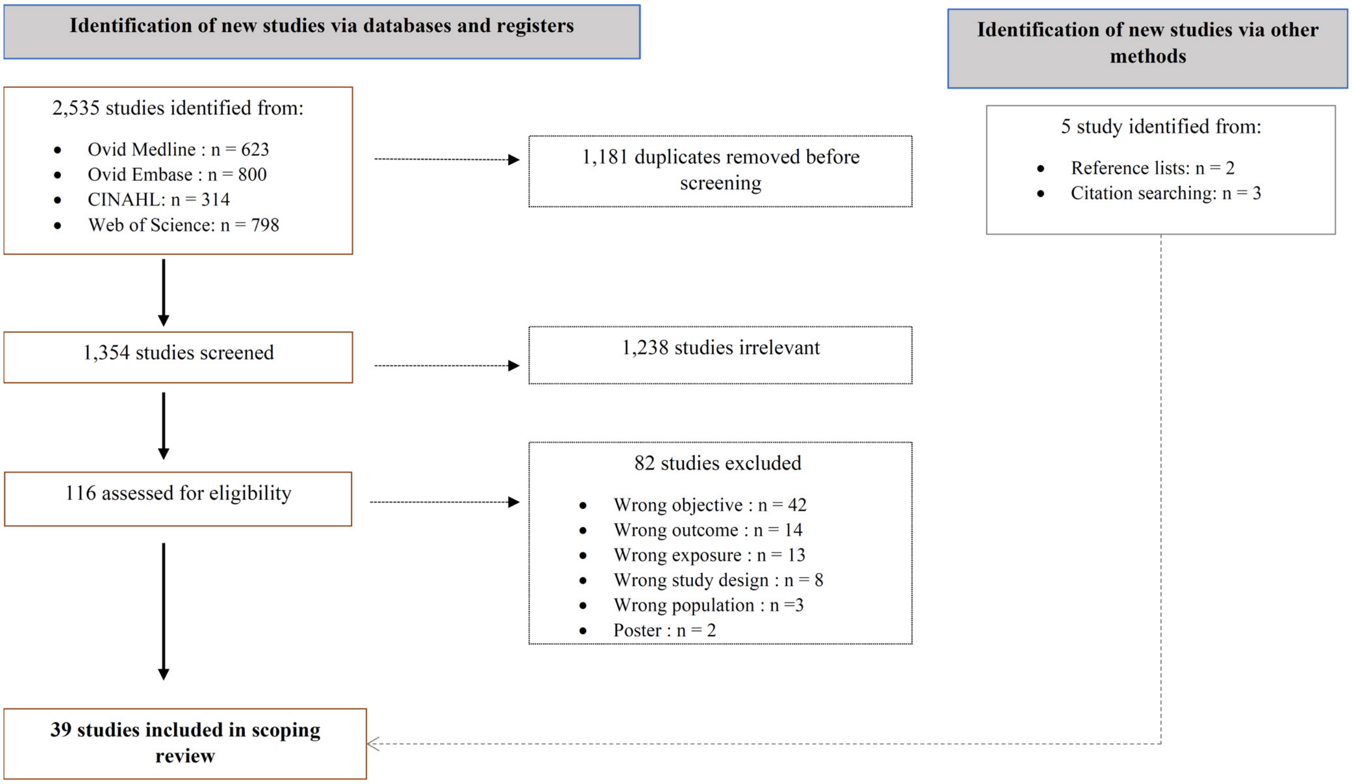

FIGURE 1. Flow chart of the studies identification and selection process

Sex Differences in the Association Between Grip Strength Cardiovascular Disease

Eighty-two per cent (n = 32) of studies used biological sex as a confounder variable in the association of interest. Table 2 presents the odds ratios and hazard ratios of these studies that included sex in their analyses.

Three studies considered an interaction term between grip strength and biological sex (Table 2). Two of these studies found no significant interaction (*p* values = .117 and .214) in the association between grip strength and cardiovascular outcomes,[49] as well as cardiovascular risk factors such as systolic blood pressure, HDL cholesterol, triglycerides, plasma insulin, and glucose.[5] The third study found a significant interaction (*p* value = .002) in the association between grip strength and cardiovascular outcomes.[35] Five studies used stratified analyses by sex to investigate whether the association between grip strength and cardiovascular outcomes, as well as cardiovascular risk factors, differs between biological sex (Table 2). Three of these studies found that the positive association between low grip strength, and the risk of cardiovascular outcomes and risk factors was greater in males as compared to females, but to a very modest degree (OR [95% CI] range from 1.23 [1.17; 1.31] to 1.45 [1.30; 1.60] in males, and 1.02 [1.01, 1.09] to 1.39 [1.27; 1.43]) in females, respectively).[24,36,50] The two other studies did not demonstrate a difference between males and females.[32,51] Two studies used both interactions terms between grip strength and biological sex, and stratified analyses by sex (Table 2). These studies did not identify a statistically significant interaction between grip strength and sex (*p* values = .217 and .709).[20,52]

Only two studies described the underlying biological mechanisms that could explain biological sex-differences in the association between grip strength and CVD. The first study reported that the insulin-like growth factor 2 (IGF-2)—a protein hormone that is structurally similar to insulin, and plays a pivotal role in skeletal muscle growth and differentiation—is associated with grip strength in males but not in females.[53] The second study highlighted that low levels of oestradiol and testosterone are associated with low grip strength in males but not in females.[54]

Of the 39 studies included in this scoping review, none distinguished between biological sex and sociocultural gender. There were three studies (Table 2) that included adults as young as 45 years. Their results were broadly similar to those who limited inclusion to people aged at least 65 years.

DISCUSSION

This scoping review was conducted to examine how biological sex has been considered in studies investigating the association between grip strength and cardiovascular outcomes (i.e., CVD and cardiovascular mortality), as well as cardiovascular risk factors in older adults. We used the methodological framework of Arksey and O'Malley to identify, select, and synthesize the results of 39 studies published between 2001 and 2022.

TABLE 2.
Summary of the results of studies that considered biological sex

Study	*Outcomes*	*Type of Analyses (Stratification by sex or interaction)*[a]	*Association in Males*[b]	*Association in Females*[b]
Studies that Considered Adults Aged 45 Years and Older				
Cheung et al.[49]	Chronic diseases and morbidity	Interaction test (GS*Sex) p value = .117	n/a	n/a
Lawman et al.[50]	CVD risk factors[c]	Stratification	OR (95% CI) = 1.23 (1.17; 1.31)	OR (95% CI) = 1.02 (1.01; 1.09)
Arvandi et al.[52]	CVD mortality	Interaction test (GS*Sex) p value = .217 and Stratification	HR (95% CI) = 1.42 (0.61; 3.28)	HR (95% CI) = 3.33 (1.53; 7.22)
Celis-Morales et al.[5]	CVD and all-cause mortality	Interaction test (GS*Sex) p value = .214	n/a	n/a
Yates et al.[20]	CVD and all-cause mortality	Interaction test (GS*Sex) p value = .709 and Stratification	HR (95% CI) = 1.30 (1.02; 1.66) to 1.41 (1.03; 1.94)	HR (95% CI) = 0.86 (0.54; 1.38) to 1.46 (0.92; 2.31)
Shim et al.[24]	CVD	Stratification	OR (95% CI) = 1.51 (1.48; 1.55)	OR (95% CI) = 1.39 (1.27; 1.43)
Cheng et al.[51]	CVD	Stratification	OR (95% CI) = 2.52 (1.03; 6.14)	OR (95% CI) = 2.31 (1.09; 7.27)
Studies that Considered Adults as Young as 45 Years				
Kim et al.[36]	CVD	Stratification	OR (95% CI) = 1.45 (1.30; 1.60)	OR (95% CI) = 1.10 (0.90; 1.30)
Garcia-Hermoso et al.[32]	CVD and all-cause mortality	Stratification	HR (95% CI) = 0.69 (0.62, 0.77)	HR (95% CI) = 0.60 (0.51; 0.69)
Han et al.[35]	CVD mortality	Interaction test (GS*Sex) p value <.05	n/a	n/a

GS = grip strength; n/a = not applicable; OR = odds ratio; HR = hazard ratio; CI = confidence interval.
[a]We report the *p* value of the interaction test for the studies that used interaction analysis (interaction term corresponds to the product between grip strength and sex in the regression model).
[b]The odds ratio and the hazard ratio, respectively, represent the relative odds or instantaneous risk for a person with low grip strength to have cardiovascular disease, or to die from a cardiovascular cause, compared to those with high grip strength.
[c]Risk factors included high blood pressure, high low-density lipoprotein (LDL) cholesterol, diabetes, smoking and second-hand smoke exposure, obesity, unhealthy diet, and sedentary.

We documented the literature by analyzing the geographical scope, study design, and study characteristics. Of the 39 studies included in this scoping review, 32 studies included biological sex as a confounder variable in their association of interest. Seven studies included interaction terms between sex and grip strength and/or carried out sex-stratified analyses. Two of these studies found that the association between low grip strength and cardiovascular risk is stronger in males than in females. The remaining five studies did not identify evidence of interaction or effect modification.

A deeper exploration of how biological sex impacts the association between GS and cardiovascular outcomes or risk factors is essential for advancing our understanding of both frailty and cardiovascular disease.[55] The potential biological mechanisms linking grip strength to CVD are complex, and understanding these mechanisms through a sex-specific lens could have a profound impact on patient care and well-being.[4] For example, differences in muscle metabolism, hormonal influences (e.g., estrogen and testosterone), and vascular health between males and females may drive distinct cardiovascular risks associated with low grip strength.[56,57] Hormonal differences, such as the protective effects of estrogen in premenopausal females, could alter the cardiovascular risk profiles for males and females with similar levels of grip strength.[58,59] Additionally, sex-specific differences in body composition, fat distribution, and muscle mass may modify how muscle strength relates to heart health.[60]

A better understanding of these mechanisms is crucial for future research. They may inform the development of targeted interventions for both males and females. For example, if sex-specific mechanisms are identified, health-care providers should tailor exercise or rehabilitation programs that specifically address the unique needs of male and female patients.[61] This could lead to more effective prevention and treatment strategies, particularly for older adults at risk of frailty and cardiovascular disease.[1]

Although the literature has explored the association between grip strength and cardiovascular disease, only a limited number of studies have specifically examined how biological sex modifies this relationship. While some studies suggest that sex differences could act as potential confounders—introducing bias in the association between grip strength and cardiovascular disease—others argue that sex acts as an effect modifier, influencing the strength of the association between muscle mass and CVD.[20,62] The distinction between confounding and effect modification is crucial for understanding the role of biological sex in cardiovascular risk assessment.

Scoping reviews are very useful in determining the scope or literary coverage on a given topic, while giving a clear indication of the volume of literature and studies available, as well as a broad, but detailed, overview of existing evidence.[63] We identified several additional knowledge gaps. One of our main observations with this scoping review was the small number of studies investigating biological sex differences in the association between grip strength and cardiovascular outcomes and risk factors (i.e., only seven of 39 studies either included interaction terms or stratified analyses). Few studies discussed the biological mechanisms that may explain biological sex-differences in the association between grip strength and CVD. Although in practice it is not always easy to separate the influence of biological sex and sociocultural gender within an association, the fact remains that primary study investigators did not distinguish between these fundamentally distinct constructs.

The strengths of this scoping review include a comprehensive search strategy covering publications from 2001 to 2022 without any restrictions on language of publication, in four electronic databases. Our charting of the data considered multiple ways that sex could be considered in the analyses, including confounder, the use of interaction terms, and stratification. Our article is reported according to the PRISMA guidelines extension for scoping reviews.[13]

As a main limitation, we did not carry out a search for studies in the grey literature, and we introduced terms relevant to frailty into our search strategy. This was done to ensure that the search strategy produced a number of titles and abstracts that was reasonable for us to review given our available resources. We cannot rule out the possibility that these steps may have overlooked relevant studies. We focused on aggregate outcomes such as cardiovascular events, mortality, and risk factors. It is possible that the impact of biological sex on the effect of grip strength differs between cardiovascular conditions.

CONCLUSIONS

Although the literature on the association between grip strength and cardiovascular outcomes and risk factors is relatively recent, this scoping review found that biological sex was predominantly considered as a confounding variable. We also identified some studies (5 out of 39) that explored sex as an interaction variable, although without consistent or strong conclusions. These point to a need for more targeted research to better understand the sex-specific mechanisms at play.

Future research should delve into the biological and sociocultural factors that might underlie these sex differences, as well as investigate how these differences can inform personalized health-care strategies. By understanding how grip strength correlates with cardiovascular risk in a sex-specific manner, clinicians will be better equipped to offer tailored interventions, which could improve both patient outcomes and the management of frailty and cardiovascular health in older adults.

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Not applicable.

CONFLICT OF INTEREST DISCLOSURES

We have read and understood the *Canadian Geriatrics Journal*'s policy on conflicts of interest disclosure and declare the following interests: MRK reports unrestricted educational grants from UCB, Jazz Pharmaceuticals, and Eisai, and research grants for investigator-initiated studies from UCB and Eisai. CM, NC, AC, AVO and MPS declare no conflict of interest.

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APPENDIX TABLE A1 (part 1 of 2).
Preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) checklist

SECTION	*ITEM*	*PRISMA-ScR CHECKLIST ITEM*	*REPORTED ON PAGE #*
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	3
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	3-4
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	8
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	4-5
Information sources[a]	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	4-5
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	5 & 16-17
Selection of sources of evidence[b]	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	5
Data charting process[c]	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	6
Critical appraisal of individual sources of evidence[d]	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	-
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	7
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	8
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	8-11
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	8-11
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	8-11
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	8-11

APPENDIX TABLE A1 (part 2 of 2).
Preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) checklist

SECTION	*ITEM*	*PRISMA-ScR CHECKLIST ITEM*	*REPORTED ON PAGE #*
		DISCUSSION	
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	11
Limitations	20	Discuss the limitations of the scoping review process.	11-13
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	13
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	15

From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. *Ann Intern Med*. 2018; 169:467–473. doi: 10.7326/M180850.
JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.
[a]Where "sources of evidence" (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.
[b]A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with "information sources" (see first footnote).
[c]The frameworks by Arksey and O'Malley[(12)] refer to the process of data extraction in a scoping review as data charting.
[d]The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

APPENDIX TABLE A2 (part 1 of 2). Search strategies for scoping review

Database: Ovid-Medline
1. exp muscle strength/
2. (grip strength*OR handgrip *OR hand strength*). ab, kf, ti
3. 1 or 2
4. exp frail/ OR frailty/ OR frail elderly/
5. (unintentional weight loss* OR weakness* OR slow gait* OR low physical activity* OR low grip strength* OR exhaustion*). ab, kf, ti
6. 4 or 5
7. exp cardiac disease/OR heart failure/OR heart disease/OR peripheral heart disease/
8. (cardiac* OR cardiac disease* OR heart failure*OR heart disease*OR peripheral heart disease). ab, kf, ti
9. (myocardial infarction*OR elevation myocardial infarction* OR acute coronary syndrome*OR coronary artery disease* OR stroke*). ab,kf,ti
10. 7 or 8 or 9
11. exp Aged/ or exp geriatrics/
12. (Geriatric* OR Elder* OR old-age* OR pensioner* OR frail*). ab, kf, ti
13. ((Ag? ing OR aged OR senior OR old*) adj2 (wom#n OR m#n OR lady OR ladies OR citizen OR residents OR adult* OR population*OR people OR person*)). ab, kf, ti
14. 11 or 12 or 13
15. 3 and 6 and 10 and 14

APPENDIX TABLE A2 (part 2 of 2). Search strategies for scoping review

Database: Ovid-EMBASE

1. exp muscle strength/
2. (grip strength*OR handgrip *OR hand strength*). ab,kw,ti
3. 1 or 2
4. exp frail/ OR frailty/ OR frail elderly/
5. (unintentional weight loss* OR weakness* OR slow gait* OR low physical activity* OR low grip strength* OR exhaustion*). ab, kw, ti
6. 4 or 5
7. exp cardiac disease/OR heart failure/OR heart disease/OR peripheral heart disease/
8. (cardiac* OR cardiac disease* OR heart failure*OR heart disease*OR peripheral heart disease). ab, kw, ti
9. (myocardial infarction*OR elevation myocardial infarction* OR acute coronary syndrome*OR coronary artery disease* OR stroke*). ab,kw, ti
10. 7 or 8 or 9
11. exp Aged/ or exp geriatrics/
12. (Geriatric* OR Elder* OR old-age* OR pensioner* OR frail*). ab, kw, ti
13. ((Ag? ing OR aged OR senior OR old*) adj2 (wom#n OR m#n OR lady OR ladies OR citizen OR residents OR adult* OR population*OR people OR person*)).ab,kw,ti
14. 12 or 13
15. 11 or 14
16. 3 and 6 and 10 and 15
17. **limit 16 to Embase**

Database CINAHL

S1 (MH" muscle strength")
S2 TI ((grip strength*OR handgrip *OR hand strength*))
S3 S1 or S2
S4 (MH" frail") OR (MH"frailty") OR (MH"frail elderly")
S5 TI ((unintentional weight loss* OR weakness* OR slow gait* OR low physical activity* OR low grip strength* OR exhaustion*))
S6 S4 or S5
S7 (MH" cardiac disease") OR (MH"heart failure") OR (MH"heart disease") OR (MH"peripheral heart disease")
S8 TI ((cardiac* OR cardiac disease* OR heart failure*OR heart disease*OR peripheral heart disease))
S9 (MH"myocardial infarction") OR (MH"elevation myocardial infarction") (MH"OR acute coronary syndrome") OR (MH"coronary artery disease")OR (MH"stroke")
S10 S7 or S8 or S9
S11 (MH" Aged") OR(MH" geriatrics")
S12 TI(Geriatric* OR Elder* OR old-age* OR pensioner* OR frail*))
S13 TI((Ag?ing OR aged OR senior OR old*) adj2 (wom#n OR m#n OR lady OR ladies OR citizen OR residents OR adult* OR population*OR people OR person*)))
S14 S12 or S13
S15 S11 or S14
S16 S3 and S6 and S10 and S15

Database Web of Science

1 "muscle strength"
2 TS= (grip strength*OR handgrip *OR hand strength)
3 #1 or # 2
4 TS= (frail*OR frailty* OR frail elderly)
5 TS= (unintentional weight loss* OR weakness* OR slow gait* OR low physical activity* OR low grip strength* OR exhaustion)
6 #4 or #5
7 TS= (cardiac disease*OR heart failure*OR heart disease*OR peripheral heart disease)
8 TS= (cardiac* OR cardiac disease* OR heart failure*OR heart disease*OR peripheral heart disease)
9 TS= (myocardial infarction*OR elevation myocardial infarction* OR acute coronary syndrome*OR coronary artery disease* OR stroke)
10 #7 or #8 or #9
11 TS= (Aged* or geriatrics)
12 TS= (Geriatric* OR Elder* OR old-age* OR pensioner* OR frail)
13 TS= ((Ag?ing OR aged OR senior OR old*) adj2 (wom#n OR m#n OR lady OR ladies OR citizen OR residents OR adult* OR population*OR people OR person))
14 #11 or #12 or #13
15 #3 and #6 and #10 and #14