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SYSTEMATIC REVIEW

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Preoperative bioelectrical impedance, measured phase angle, and hand-grip strength as predictors of postoperative outcomes in patients undergoing cardiac surgery: a systematic review

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Abstract

Background Postoperative problems are a major danger for patients after heart surgery. Predicting postoperative outcomes for cardiac surgery is limited by current preoperative evaluations. Handgrip strength (HGS) testing and bioelectrical impedance analysis (BIA) may provide extra ways to identify individuals at risk of surgical problems, enhancing risk assessment and results.

Objective The purpose of this systematic review is to assess the utility of measured phase angle (PA), HGS, and bioelectrical impedance as perioperative risk markers in adult patients undergoing elective heart surgery.

Method The PRISMA principles were followed in this review. We searched all available electronic databases, including the Science Direct search engine and PubMed, MEDLINE, EMBASE, Cochrane Library, Web of Science, PsycINFO, CINAHL, Google Scholar, Scopus, and the Science Direct search engine, from their creation to the present, as well as the medRxiv pre-print site. We considered studies with adult subjects undergoing elective heart surgery who were monitored for problems after surgery and had perioperative BIA and HGS testing.

Results As a result, out of the 1544 pieces of research that were discovered, eight studies were deemed suitable for inclusion in the review and supplied data from 2781 people. The findings demonstrated a substantial correlation between poor preoperative PA and a higher risk of serious postoperative morbidity, as well as prolonged hospital stays. Furthermore, poor HGS and low PA were linked to greater death rates. Additionally, there was a strong correlation found between low PA and HGS and longer stays in the ICU, as well as an increased chance of dying from all causes in a year. In conclusion these results imply that preoperative HGS and PA may be significant indicators of postoperative results and may assist in identifying patients who are more vulnerable to problems and death.

Keywords Hand grip strength, Postoperative result, Bioimpedance measured phase angle, Cardiovascular surgery, Systematic review

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Introduction

Globally, cardiovascular disease (CVD) is a major contributor to morbidity and mortality [1]. It is common practice to treat patients with cardiovascular disease (CVD) or to perform cardiovascular surgery, such as valve replacement and coronary artery bypass grafting (CABG) [2, 3]. Even with the creation of numerous grading systems and prognostic algorithms for cardiac surgery, precisely projecting post-procedural morbidity and mortality is still a difficult task [4, 5]. One of the most crucial aspects of heart surgery is preoperative evaluation, which enables doctors to recognize possible hazards and best prepare patients for the operation [6–8]. Nevertheless, the accuracy and dependability of preoperative assessment instruments are frequently compromised [7, 9]. Better instruments to evaluate patients and forecast results have thus been sought after [8, 10].

Cardiac surgery patients, especially middle-aged and older patients who are more prone to frailty, have a higher risk of postoperative morbidity and mortality [11–13]. Nutritional deficiency is a common condition in these patients, with malnutrition posing a significant risk of infectious and non-infectious complications, mortality, prolonged ICU and hospital stay, and poor quality of life [14–17]. Conventional methods for evaluating nutritional status may not always be accurate in specific patient groups [14, 18–20], making accurate detection of preoperative malnutrition is crucial in predicting outcomes after cardiac surgery. Bioelectrical impedance Analysis (BIA) is a non-invasive method for determining body composition and is useful in identifying preoperative undernutrition, especially with the measurement of the phase angle (PA), which reflects cell membrane integrity and fluid redistribution between intra- and extracellular fluid compartments [21, 22]. Handgrip strength (HGS) is a simple and easy surrogate marker of overall muscle strength and an indicator of functional capacity, which can serve as a diagnostic tool for the assessment of nutritional status and overall nutritional risk in various clinical settings [23]. The preoperative identification and treatment of undernutrition can help mitigate postoperative complications and enhance patient outcomes following cardiac surgery, especially in patients with limited ability to recuperate [24].

Previous studies have suggested PA and HGS could be used as non-invasive markers to predict postoperative outcomes in patients undergoing cardiovascular surgery [23]. However, the results of these studies have shown that cardiac surgery patients, especially middle-aged and older patients who are more prone to frailty, have a higher risk of postoperative morbidity and mortality [11–13]. Nutritional deficiency is a common condition in these patients, with malnutrition posing a significant risk of infectious and non-infectious complications, mortality, prolonged ICU and hospital stay, and poor quality of life [14–17]. Conventional methods for evaluating nutritional status may not always be accurate in specific patient groups [14, 18–20], making accurate detection of preoperative malnutrition is crucial in predicting outcomes after cardiac surgery. Bioelectrical impedance Analysis (BIA) is a non-invasive method for determining body composition and is useful in identifying preoperative undernutrition, especially with the measurement of the phase angle (PA), which reflects cell membrane integrity and fluid redistribution between intra- and extracellular fluid compartments [21, 22].

Handgrip strength (HGS) is a simple and easy surrogate marker of overall muscle strength and an indicator of functional capacity, which can serve as a diagnostic tool for the assessment of nutritional status and overall nutritional risk in various clinical settings [23]. The preoperative identification and treatment of undernutrition can help mitigate postoperative complications and enhance patient outcomes following cardiac surgery, especially in patients with limited ability to recuperate [24].

Previous studies have suggested PA and HGS could be used as non-invasive markers to predict postoperative outcomes in patients undergoing cardiovascular surgery [23]. However, the results of these studies have been inconsistent. This systematic review is to evaluate the association between PA and HGS as predictors of cardiovascular surgery outcomes.

Method

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and MOOSE (Meta-analysis of Observational Studies in Epidemiology) criteria were adhered to when conducting this investigation. PROSPERO has the work registered (CRD42023409397).

Search strategy and study selection

PubMed, MEDLINE, EMBASE, Cochrane Library, Web of Science, PsycINFO, CINAHL, Google Scholar, Scopus, medRxiv pre-print, and the Science Direct search engine were among the databases that were searched. A manual search for research published from each database's creation to February 28, 2023, was conducted in March 2022 throughout publishers' and journals' websites. A librarian was consulted in the development of the search plan. "Bioelectrical impedance analysis," "phase angle," "handgrip strength," "sarcopenia," "cardiac surgery," and associated synonyms and Medical Subject Headings (MeSH) terms were among the search terms used. Particular search terms are listed in Supplementary Table S1. The search was limited to research that was published in English.

Study selection

Studies involving adult patients undergoing elective heart surgery (aged 18 years or older) met the inclusion criteria for this systematic review. Preoperative bioelectrical impedance assessed PA and/or HGS as predictors of postoperative outcomes, such as length of hospital stay, mortality, and morbidity, required to be reported by the research. There were only English-language studies included. Research on pediatric patients, studies focusing only on other predictors without taking into account bioelectrical impedance measured PA and/or HGS, studies on non-cardiac surgeries, case reports, conference abstracts, reviews, and studies not published in English were all excluded from the analysis. This systematic review did not include studies that reported on postoperative outcomes like functional status that were connected to hospital stay duration, death, or morbidity. Functional status, for example, was not included in this systematic study.

Study quality assessment

We employed the Newcastle–Ottawa Scale (NOS), which has a grading system ranging from 0 to 9, to assess the caliber of the research that was part of our systematic evaluation. A score of 0 to 3 was regarded as low quality, a score of 4 to 6 as medium quality, and a score of 7 to 9 as excellent quality. The studies were graded independently by AMA and BM, the two evaluators, and any disagreements were settled by consensus.

Data extraction and analysis

Using a consistent data entry form, each reviewer extracted data. Any disagreements between the two reviewers were settled by reexamining the original article until a consensus was formed. This procedure was known as consensus-building.

Statistical analysis

The papers that made up this systematic review all sought to look into different outcomes, such as mortality, length of hospital/ICU stay, and major postoperative morbidity events as outlined by the Society of Thoracic Surgeons (STS) risk appraisal model. The results were documented in accordance with each original article's predetermined objective and were assessed qualitatively. A meta-analysis was not feasible since there were not enough papers for each outcome with a comparable design (Fig. 1).

Study characteristics

Table 1 summarizes the characteristics of the included studies in this systematic review. The study identified a total of 1544 studies and found eight studies [21, 23, 25–30] eligible for inclusion in the review. The types of surgery included CABG, valve replacement, and other elective cardiac surgeries. Across all studies, total of 2781 patients were enrolled, with a mean age of 67.39 years and 71% being male. Two studies were conducted in Canada, one in Brazil, and one in China and the remaining studies were conducted in Europe. All studies were prospective in nature and were published after 2012. All of the studies included in this review measured preoperative PA and HGS as predictors of postoperative outcomes. The quality of the studies reviewed ranged from moderate to high, with each study achieving a score greater than 6 out of 9 on the NOS quality assessment tool (Table S2).

Definition of impaired of impaired PA and HGS

Variable definitions for impaired PA and HGS have varied across studies (Table 2). While some studies, such as da Silva et al. [23], and Tsaousi et al. [29], did not provide a definition for impaired PA and HGS, others compared various definitions to determine the most appropriate cutoffs. For instance, Fountotos et al. [25] conducted a study using multivariable logistic regression to analyze different cutoff values for HGS and found that the Foundation for the National Institutes of Health (FNIH) [31] cutoffs of 26 kg in men and 16 kg in women had the highest area under the curve (AUC) of 0.778 for predicting 1-year mortality. Therefore, the authors defined impaired HGS based on these values. Mullie et al. [21] defined impaired PA as $\leq 4.5°$, which was found to be associated with the optimal predictive value for mortality at 12 months. Panagidi et al. [26] defined impaired PA as $< 5.15°$ and impaired HGS as < 25.5 kg for predicting mortality and impaired PA as $< 5.15°$ and impaired HGS as < 30.75 kg for predicting length of ICU stay. The combination of PA ($< 5.15°$) and HGS (< 25.5 kg) had a significant yet fair predictive value for all-cause mortality, with an AUC of 0.657 (95% CI, 0.54–0.77; $p = 0.009$) for PA, 0.659 (95% CI, 0.5–0.78; $p = 0.008$) for HGS, and 0.671 (95% CI, 0.56–0.78; $p = 0.004$) for their combination. PA ($< 5.15°$), HGS (< 30.75 kg), and their combination also had a significant yet poor predictive value for prolonged stay in the ICU, with an AUC of 0.600 (95% CI, 0.52–0.68; $p = 0.016$) for PA, 0.586 (95% CI, 0.51–0.67; $p = 0.040$) for HGS, and 0.597 (95% CI, 0.52–0.68; $p = 0.019$) for their combination. Ringaitiene et al. [27] defined impaired PA based on the population reference values of the 15th percentile for men and women, according to Bosy-Westphal et al. [32]. Lastly, Ryz et al. [28] and Visser et al. [30] defined impaired PA as $\leq 5.58°$ and $\leq 5.38°$, respectively. Visser et al. [30] found that a PA of $\leq 5.38°$ was the cut-off that provided the highest accuracy for indicating adverse clinical outcomes, including infections (AUC: 0.54, 95% CI: 0.44–0.65), mortality (AUC: 0.70, 95% CI: 0.52–0.88), prolonged time of mechanical ventilation (AUC: 0.57, 95% CI: 0.50–0.63), prolonged ICU length of stay (AUC: 0.58, 95% CI: 0.51–0.65), and prolonged hospital LOS (AUC: 0.58, 95% CI: 0.51–0.65).

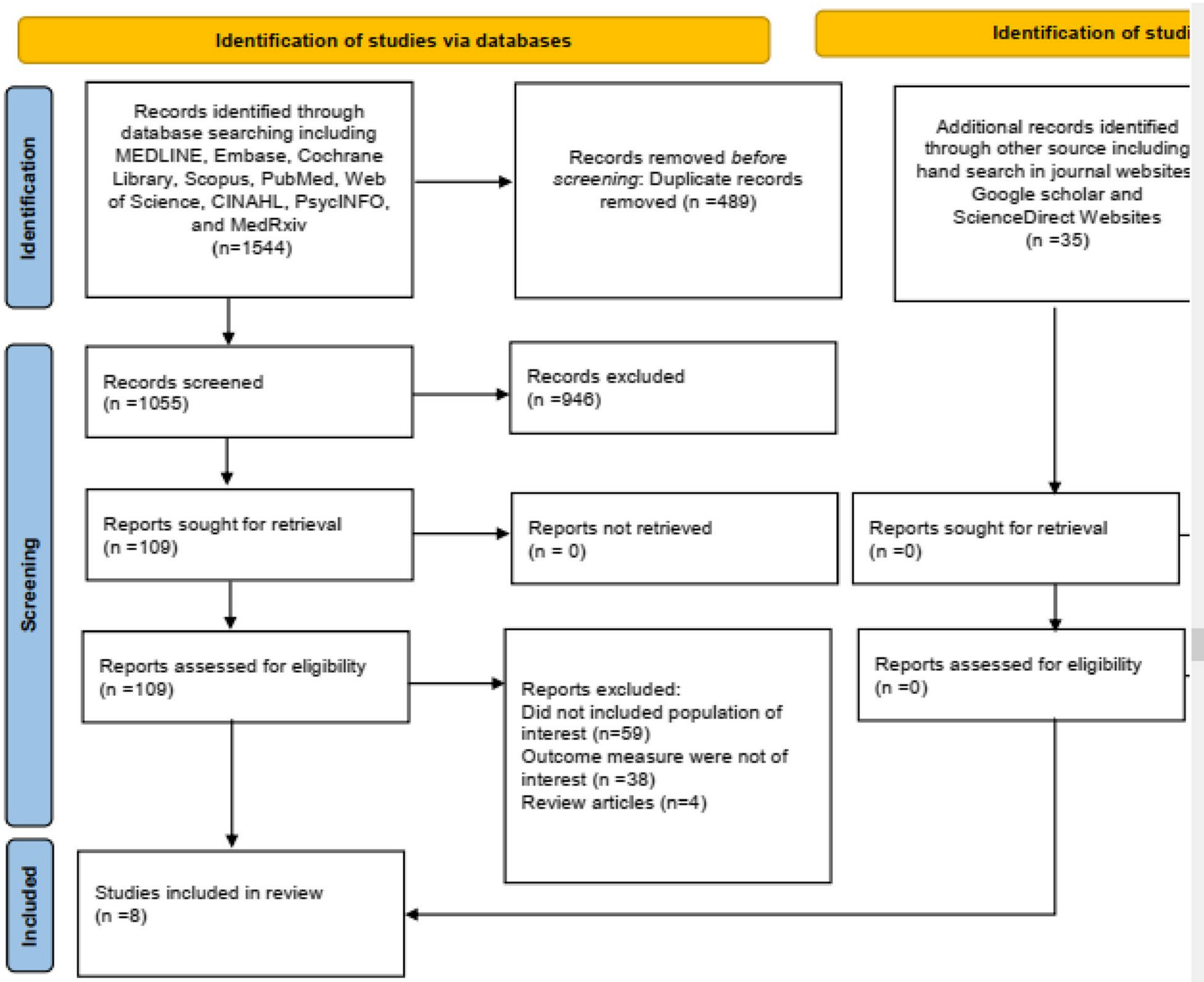

Fig. 1 Prisma 2020 Flowchart showing studies selection process

Major postoperative morbidities

Two studies [21, 27] were included in the report that investigated the association between evaluated parameters and composite major postoperative morbidity. Both studies focused on preoperative PA and found that low PA was significantly associated with an increased risk of experiencing composite major morbidity events, as defined by the STS risk evaluation model. Mullie et al. [21] reported an adj. OR of 1.74 (95% CI, 1.19–2.58) per 1° decrease in PA, while Ringaitiene et al. [27] found that low PA was significantly associated with postoperative STS morbidity (adj OR 2.50 (95% CI, 1.18–5.29) compared to normal PA.

Length of stay

Eight studies [21, 23, 25–30] investigated the association between evaluated parameters and postoperative LOS. Out of these eight studies, six [21, 23, 27–30] examined the association between preoperative PA and LOS, three [23, 25, 29] investigated HGS and LOS, and one [26] studied the combined PA, HGS, and LOS. Among the six studies that reported PA association with LOS, five studies found a significant association. Specifically, da Silva et al. [23] reported an inverse correlation between hospital LOS and PA preoperatively (rS = -0.314, $P = 0.026$). Mullie et al. [21] found that a low PA was associated with longer hospital LOS (adj b, 4.8 days per 1° decrease in PA; 95% CI, 1.3–8.2 days). Ringaitiene et al. [27] reported a significant difference in the total time spent in the hospital postoperatively (median [IQR]: 14 [11–15] vs. 12 [11–14], $p = 0.036$), but no difference in the length of stay in the ICU. Ryz et al. [28] found that patients with lower preoperative PhA stayed longer in the ICU (3.7 ± 4.5 vs. 2.6 ± 3.8 days, $p = 0.0182$). Visser et al. [30] reported that a preoperative low PA was associated with a prolonged ICU and hospital LOS (adj. hazard ratio (HR) 0.68 (95%

Table 1 General characteristics of the included studies

First author, pub. year	Study type	Country	No. of patients	Age, mean	Gender, male (%)	Surgery	Variable	Outcome measured
da Silva et al., 2018 [23]	Prospective	Brazil	50	62.8	64	Isolated valve replacement and/or CABG	PA and HGS	• ICU LOS • Hospital LOS
Fountotos et al., 2021 [25]	Prospective	Canada	1245	74	70	Isolated valve replacement and/or CABG	HGS	• 1-year mortality • 30-day mortality • Prolonged length of stay defined by STS (≥ 14 days)
Mullie et al., 2018 [21]	Prospective	Canada	277	71	75	Isolated valve replacement and/or CABG	PA	• All-cause mortality • 30-day mortality • Composite major morbidity defined by the STS • Hospital LOS
Panagidi et al., 2022 [26]	Prospective	Greece	195	67.18	76.9	Isolated valve replacement and/or CABG	Combined PA and HGS	• All-cause mortality • ICU LOS
Ringaitiene et al., 2016 [27]	Prospective	Lithuania	342	65	65.8	Isolated valve replacement and/or CABG	PA	• Composite major morbidity defined by the STS • ICU LOS • Hospital LOS
Ryz et al., 2022 [28]	Prospective	Austria	168	65.9	66.1	Elective cardiac surgery	PA	• ICU LOS
Tsaousi et al., 2021 [29]	Prospective	Greece	179	67	77.6	Isolated valve replacement and/or CABG	PA and HGS	• In hospital LOS
Visser et al., 2012 [30]	Prospective	Netherlands	325	66.2	72.3	Isolated valve replacement and/or CABG	PA	• ICU LOS • Hospital LOS • Mortality

PA Phase angle, *HGS* Handgrip strength, *ICU* Intensive care unit, *LOS* Length of stay, *CABG* Coronary artery bypass graft

30-day complications: Death, needing for reoperation, atrial fibrillation, deep sternal infection, pulmonary complications, stroke, sensory changes, renal failure requiring treatment, dehydration, multisystem organ failure, and readmission to the hospital within 30 days

Table 2 Definitions used for impaired phase angle and handgrip strength

First author, pub. year	A priori definition of Impaired PA or HGS?	Definition of impaired PA or HGS	
		PA	HGS
da Silva et al., 2018 [23]	No		
Fountotos et al.,2021 [25]	Yes		26 kg in men and 16 kg in women
Mullie et al., 2018 [21]	No	≤ 4.5°	
Panagidi et al., 2022 [26]	No	< 5.5°	< 25.5
Ringaitiene et al., 2016 [27]	Yes	Population reference values of the 15th percentile for men and women according to Bosy-Westphal et al. [32]	
Ryz et al., 2022 [28]	No	< 5.58°	
Tsaousi et al.,2021 [29]	No		
Visser et al., 2012 [30]	No	< 5.38°	

PA Phase angle, *HGS* Handgrip strength

CI, 0.49–0.94) and adj. HR 0.74 (95% CI: 0.55–0.99), respectively). However, Tsaousi et al. [29] could not find a significant association between PA and hospital LOS ($p = 0.150$). Regarding HGS's association with LOS, two out of three studies reported a significant association. Specifically, da Silva et al. [23] found a moderate inverse correlation between ICU LOS and HGS preoperatively (rS = -0.349, $p = 0.014$), and Fountotos et al. [25] reported that HGS was predictive of prolonged postoperative length of stay (adj. OR 1.88 (95% CI 1.26, 2.83). However, Tsaousi et al. [29] did not find a significant association between HGS and hospital LOS ($p = 0.059$). Finally, one study by Panagidiet et al. [26] investigated the combined association of PA and HGS with LOS and found that the PA-HGS combination was significantly associated with a prolonged stay in the ICU. Specifically, patients with PA < 5.15 and HGS < 30.7 were four times more likely to stay in the ICU for more than one day than those with PA > 5.15 and HGS > 30.7 (adj. OR 4.02 (95% CI 1.53–10.56).

Mortality

Four studies investigated the association between the evaluated parameters and postoperative mortality. Of the two [21, 30] studies that investigated PA and mortality, Mullie et al. [21] found that a 1° decrease in PA was associated with a 3.57-fold increase in mortality at 1 month (adj. OR (95% CI, 1.35–9.47) and a 3.03-fold increase in mortality at 12 months (adj. OR (95% CI, 1.30–7.09)). Similarly, a study by Visser et al. [30] found that patients with a low preoperative PA had a 5.43-fold higher risk of postoperative mortality compared to those with a high PA (7.6% vs. 1.5%; unadjusted OR, 95% CI, 1.32–22.26). Regarding HGS, Fountotos et al. [25] found that patients with weak HGS had a 2.44-fold higher risk of 1-year mortality (95% CI, 1.39–4.29) and a 2.83-fold higher risk of 30-day mortality (95% CI, 1.38–5.81) after adjustment, compared to those with normal HGS. In terms of continuous HGS, each 5-kg decrease in HGS was associated with a 20% increase in 1-year mortality (OR 1.038 per kg, 95% CI 1.003–1.075) [25]. Finally, one study by Panagidi et al. [26] investigated the combined association of PA and HGS with mortality and found that patients with a PA < 5.15 and HGS < 25.5 had a 9.28-fold higher risk of one-year all-cause mortality compared to those with a PA > 5.15 and HGS > 25.5 (adj. OR; 95% CI, 2.50–34.45).

Discussion

In this systematic review, we looked into the possibility of utilizing HGS and PA assessed by bioimpedance as predictors of the results of surgery after elective heart surgery. According to our research, a lower PA is substantially linked to a higher chance of composite major morbidity events and longer hospital admissions. Extended hospital stays were also associated with weak HGS. Furthermore, patients who had low PA and weak HGS had considerably greater postoperative death rates than those whose levels were normal. Moreover, a larger correlation was observed between longer ICU stays and higher fatality rates when poor PA and weak HGS were combined.

Examination of body composition with Because of its potential to evaluate postoperative morbidity in patients undergoing heart surgery [33]. The PA, a BIA-derived measurement, measures the health of the cell membrane equilibrium between intracellular and extracellular elements and has been linked to nutritional risk, morbidity, and death in patients with cancer, chronic kidney disease, and immune compromised individuals [34–36]. Our research shows how useful it is to use preoperative PA both by itself and in conjunction with HGS to stratify the risk of patients undergoing heart surgery. Reduced PA could be a sign of oxidative stress, inflammation, and cellular malfunction, which can lower the immune response, hinder tissue regeneration and repair, raise the risk of postoperative problems, and hinder the operation of the organs [33, 34, 36, 37]. Low PA could also be linked to malnourishment as well as sarcopenia, which may have a detrimental effect on surgical results and lengthen hospital stays, and further elevated death rates [33, 38–41]. The BIA has the potential to be an effective point-of-care instrument for perioperative physicians permitting follow-up evaluations at various points during a patient's surgical procedure in order to gather more data. Regarding the possibility of alterations in body composition or metabolic disturbances, however, medical professionals need to find out if BIA is being used to evaluate risk based on a derived measurement of body composition or to assess nutritional and metabolic health. Moreover, PA has been suggested as a dynamic metric that can respond to focused interventions meant to enhance physical activity, optimize fluid balance, and improve nutritional status [21]. To fully explore the potential benefits of utilizing BIA and PA in patients after cardiac surgery, more research is required.

Patients undergoing heart surgery frequently have underlying metabolic and cardiovascular comorbidities, which make them more susceptible to postoperative problems [21]. In our investigation, we discovered that in these patients, the HGS assessment was substantially linked to a higher risk of composite major morbidity events, longer hospital admissions, and postoperative mortality. Studies involving approximately 44,000 patients in the general population have demonstrated that HGS is a reliable independent "bedside" predictor of long-term all-cause death [42]. In addition, HGS evaluation is a cheap, non-invasive, and simple test that can give instantaneous information regarding a patient's general state of health [43]. The underlying biology of skeletal muscle metabolism and its effect on cardiopulmonary reserve may account for the correlation between preoperative HGS and postoperative outcomes in patients undergoing cardiac surgery [44]. A reliable indicator of both cardiovascular and all-cause mortality is cardiopulmonary reserve [45]. Significant cardiopulmonary reserve is necessary for patients undergoing cardiac surgery to withstand the physiological stress of the procedure, and muscular strength, as measured by HGS, can reveal information about the patient's general health state and risk of unfavorable outcomes [46]. One prevalent preoperative morbidity that is linked to higher morbidity and mortality rates is cardiac insufficiency [47]. Reduced strength and skeletal muscle metabolism, and HGS, which measures muscle strength, may be a factor in this cardiovascular dysfunction [48, 49]. Moreover, an early initiation of anaerobic metabolism, increased lactate generation, and tiredness in patients with heart failure may result from skeletal muscle adaptations in patients with chronic heart failure [50]. In order to improve surgical outcomes, preoperative HGS assessment may potentially offer useful information regarding a patient's skeletal muscle function. This information may be used to identify patients who may be more vulnerable to postoperative difficulties and to guide targeted therapies.

It is important to note that our study has certain important limitations that should be taken into consideration. Firstly, Firstly, our search was limited to English language studies, which means that relevant non-English publications may have been missed. Secondly, the BIA methodology was incompletely described in some studies, and the reporting of BIA results was restricted. In addition, the variability in reported PA risk thresholds or cut-offs across studies limits the strength of conclusions that can be drawn. Furthermore, the absence of raw data reporting, which is used to calculate PA, makes it difficult to draw strong conclusions from studies that use PA as a predictor of postoperative complications. PA is determined by taking the arc tangent of the ratio of resistance to reactance, and changes in these variables can influence PA [32]. However, since the studies included in our analysis did not report resistance and reactance measures, it is not possible to determine if changes in PA result from modifications in either one or both of these factors. Additionally, impedance changes with age and gender [51], which can affect the interpretation of PA and the validity of derived variables, are often not considered in study reporting. Thirdly, the demographic data during the perioperative period, including cardiovascular risk and the identification of higher-risk patients, was not provided in the included studies. Fourthly, standards of postoperative care were not reported in the studies. Fifthly, as no interventions were carried out based on preoperative PA and HGS, the findings of these studies only establish associations and not causal relationships. Lastly, the limited number of studies with a similar design for each outcome made it impossible to conduct a meta-analysis.

Conclusion

Impaired preoperative PA and HGS could be important predictors of postoperative outcomes and could help identify patients at higher risk of complications and mortality. These findings imply that assessing PA and HGS before surgery could help identify patients with a higher risk of complications and inform preoperative rehabilitation interventions to optimize patient outcomes. To confirm these results, more studies should investigate the potential of PA and HGS tests in predicting postoperative complications.

Supplementary Information

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Supplementary Material 1.

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Authors' contributions
-Amanuel Godana Arero: study conception and design, acquisition, and analysis of data. -Godana Arero Dassie: interpretation of data, drafting the article, revising, editing, and revising the manuscript. Both authors read and approved the final version of the study to be published.

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Availability of data and materials
No datasets were generated or analysed during the current study.

Declarations

Competing interests
The authors declare no competing interests.

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