Preoperative muscle weakness as defined by handgrip strength and postoperative outcomes: a systematic review
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Abstract

Background: Reduced muscle strength - commonly characterized by decreased handgrip strength compared to population norms - is associated with numerous untoward outcomes. Preoperative handgrip strength is a potentially attractive real-time, non-invasive, cheap and easy-to-perform “bedside” assessment tool. Using systematic review procedure, we investigated whether preoperative handgrip strength was associated with postoperative outcomes in adults undergoing surgery.

Methods: PRISMA and MOOSE consensus guidelines for reporting systematic reviews were followed. MEDLINE, EMBASE, and the Cochrane Central Register of Controlled Clinical Trials (1980-2010) were systematically searched by two independent reviewers. The selection criteria were limited to include studies of preoperative handgrip strength in human adults undergoing non-emergency, cardiac and non-cardiac surgery. Study procedural quality was analysed using the Newcastle-Ottawa Quality Assessment score. The outcomes assessed were postoperative morbidity, mortality and hospital stay.

Results: Nineteen clinical studies (17 prospective; 4 in urgent surgery) comprising 2194 patients were identified between 1980-2010. Impaired handgrip strength and postoperative morbidity were defined inconsistently between studies. Only 2 studies explicitly ensured investigators collecting postoperative outcomes data were blinded to preoperative handgrip strength test results. The heterogeneity of study design used and the diversity of surgical procedures precluded formal meta-analysis. Despite the moderate quality of these observational studies, lower handgrip strength was associated with increased morbidity (n = 10 studies), mortality (n = 2/5 studies) and length of hospital stay (n = 3/7 studies).

Conclusions: Impaired preoperative handgrip strength may be associated with poorer postoperative outcomes, but further work exploring its predictive power is warranted using prospectively acquired, objectively defined measures of postoperative morbidity.

Background

A substantial minority of patients sustain an excess of postoperative complications [1] and accelerated, post-hospital discharge mortality [2]. In surgical procedures known to have a mortality of greater than 5% in the UK, elderly patients (mean age 75 years) and emergency procedures account for over 80% of deaths but less than 15% of total procedures [3]. Physician- and patient-friendly, practical and inexpensive tools are required to guide and risk-stratify perioperative management objectively for this cohort of patients. Measurements of exercise capacity and muscle strength are associated with increased all-cause and cardiovascular mortality in the general population [4-7]. However, the comprehensive assessment of cardiovascular reserve - most objectively using cardiopulmonary exercise testing [8] - is challenging for immobile patients, time-consuming, and costly to extend as a general screening tool to the wider, at-risk surgical population. By contrast handgrip strength is an inexpensive, objective bedside test which has established population norms [9-13] and has been extensively tested in a range of chronic general medical conditions [14]. It may...
reflect, in part, the association of impaired muscle strength with malnutrition [15] and cardiopulmonary or metabolic diseases [4-7]. Hand grip strength can be assessed by instructing the patient to keep their shoulders adducted and neutrally rotated, the arm in a vertical position, the wrist in a neutral position and to squeeze the grip with maximal strength. The highest result in a seated or semi-seated position may be used [16,17]. Whether a robust relationship between preoperative handgrip strength and postoperative outcomes exists is unclear, since variable, and frequently retrospective, definitions of postoperative morbidity have been employed as outcome measures [18]. Therefore, we performed a systematic review of the literature to ascertain if preoperative assessment of handgrip strength is associated with (i) postoperative morbidity, (ii) length of hospital stay.

Methods
The systematic review was undertaken in accordance with the PRISMA [19] (Preferred Reporting Items for Systematic reviews and Meta-Analyses) and MOOSE (Meta-analysis of Observational Studies in Epidemiology) [20] guidelines. Figure 1 summarizes the flow of information through the different phases of this systematic review. A checklist demonstrating adherence to the PRISMA guidelines is available online (Additional File 1).

Two of the authors (P.S. and M.A.H.) searched the electronic databases MEDLINE, EMBASE, and the Cochrane Central Register of Controlled Clinical Trials independently using the following population search terms: ‘postoperative complications’ OR ‘perioperative complications’ OR ‘surgical complications’ OR ‘surgical outcome’. These search results were combined with ‘handgrip dynamometry’ OR ‘hand grip dynamometry’ OR ‘hand grip strength’ OR ‘handgrip strength’ OR ‘maximal voluntary contraction’ in the title or abstract text using the Boolean search operator ‘AND’. (Maximal voluntary contraction is the term used most commonly in the literature to describe maximal force produced by a muscle as it contracts while contracting against the hand dynamometer). The references of retrieved articles were

![Flow diagram showing systematic review synthesis, in accordance with PRISMA guidelines](http://www.biomedcentral.com/1471-2253/12/1)
hand searched for any relevant articles not identified in
the original search. The study selection criteria were lim-
ited to include only studies reported in the English lan-
guage and those involving human adults undergoing
surgery (including cardiac and transplant surgery). Each
abstract was screened to identify studies that had
assessed handgrip strength prior to surgery. Studies were
excluded if postoperative outcomes focussed on upper
limb neuromuscular functional outcomes alone.

The data were extracted on to a standardized data entry
form by each reviewer. Differences between the reviewers
were resolved by re-examination of the original manu-
script until consensus was obtained. Data extracted for
comparison included year of publication, primary author,
total number of subjects, mean patient age, proportion of
male subjects and co-morbidity (where reported). The
method of quantifying or qualifying handgrip strength was
recorded.

The specific outcomes sought in each article were: (i)
mortality, (ii) postoperative morbidity, categorized accord-
ing to the Post Operative Morbidity Survey, (iii) length of
hospital stay [21]. Primary and/or secondary outcomes
were recorded according to the a priori intention of each
original article. Each outcome was evaluated qualitatively
according to either qualitative and/or quantitative assess-
ment of handgrip strength. Because there were a limited
number of studies with homogenous design for each out-
come, a meta-analysis could not be performed.

The procedural quality of each trial was assessed using
several criteria, although no studies were excluded on the
basis of these assessments. The quality of studies was
scored according to the Newcastle-Ottawa Quality Assess-
ment Scale [22] (Additional File 2), on a scale from 1
(poor) to 8 (excellent), which includes patient follow-up
rates as a marker of study quality. Disagreements about
the eligibility of a study or differences between the two
sets of information extracted were resolved through dis-
cussion between all authors. After abstraction of informa-
tion, a level of evidence was assigned to the outcomes of
each study. Two authors (P.S. and M.A.H.) independently
reviewed and scored each study using this method.

Results

Nineteen studies were identified that compared post-
operative outcomes in relation to handgrip strength
(Table 1), comprising 2194 patients [9-13,16,17,23-34].
A wide range of surgical sub-specialties was explored.
Four studies were conducted in patients undergoing
urgent surgery for hip fractures. One study explored the
effect of pre-operative nutritional supplementation on
grip strength [25]. Although supplementation improved
post-operative grip strength compared to the control
group, it was not related to patient outcome. Only two
studies ensured that investigators who evaluated
postoperative morbidity also remained blinded to the
pre-operative grip strength values [10,17]. A wide range
of exclusion criteria were reported between studies.
One-third of studies reported the patient drop-out rate.

The majority of studies measured handgrip strength pre-
operatively (Table 2). Eleven studies did not comment on
how long before surgery the handgrip strength was mea-
sured [9,10,17,24,25,28,30-33]. Guo et al did not comment
on whether handgrip strength was measured pre or post-
surgery [11]. Very few studies achieved a quality assess-
ment score less than 6, consistent with moderate quality
(Table 3, Additional File 1).

Definition of impaired handgrip strength

Variable definitions for impaired handgrip strength have
been used across studies (Table 4). Studies compared
values of grip strength obtained from healthy controls,
reference populations or patients who did not sustain
postoperative morbidity with surgical patients. For exam-
ple, 9 studies defined impaired handgrip strength as < 85%
of a general, age-matched population - but these reference
populations were not common between studies. Table 1
demonstrates that six studies measured handgrip strength
exclusively from the non-dominant hand, compared to 3
studies that measured handgrip strength in the dominant
hand. Seven studies did not report which hand was tested.
11/19 studies did not report the timespan over which
handgrip strength measurements preceded surgery. Vari-
able time points were used between studies to assess post-
operative handgrip strength. Detailed protocols for the
performance of handgrip strength were absent in the
majority of studies.

Postoperative morbidity

Table 5 summarizes the 15 studies that detailed the
relationship between handgrip strength and various
aspects of postoperative morbidity. Ten out of these 15
studies described a significant relationship between
lower handgrip strength and postoperative morbidity
[9,10,12,13,25,28,30-33]. No studies defined postopera-
tive morbidity using validated morbidity tools. A range
of morbidities were recorded prospectively: very few stud-
ies defined in detail how these morbidities were deter-
mined. Five studies used length of hospital stay as a
surrogate for postoperative complications, but did not
describe the associated morbidities.

Length of Hospital Stay

Tables 5 and 6 show the 12 studies which utilised length
of stay as an outcome measure for postoperative morbidity.
Five of these studies incorporated length of hospital
stay into their definition of “complications” [9,28,30,32,33]
and 7 studies separately explored the relationship between
handgrip strength and length of hospital stay [10,11,13,17,
Table 1 Basic demographics, defined primary/secondary outcomes and handgrip site used for patient studies.

| Author          | Year | Study type | Surgery (urgency/type)                      | Number of patients (n) | Age (mean ± SD or mean range) | Gender (% male) | Primary Outcome | Secondary Outcome | Handgrip: dominant vs. non-dominant? |
|-----------------|------|------------|--------------------------------------------|------------------------|------------------------------|-----------------|-----------------|-------------------|------------------------------------|
| Beloosesky      | 2010 | Cohort*    | Urgent fractured neck of femur             | 105                    | 81 ± 7                       | 31              | Functional outcome | Not stated         | Dominant                            |
| Wehren [23]     | 2005 | Cohort     | Urgent Hip fracture                       | 205                    | 81 ± 8                       | 0               | Functional outcome | Complications       | Right arm                          |
| Mahalakshmi     | 2004 | Case control | Elective general                         | 100                    | 42 [13-70]                   | 62              |                | Complications       | Not stated Non dominant           |
| Cook [17]       | 2001 | Case control | Elective CABG                         | 200                    | Not stated                   | 73              |                | Complications       | Both hands                        |
| Figueiredo      | 2000 | Cohort     | Elective Liver transplant                | 53                     | 50 ± 12                      | 59              |                | Complications       | Not stated Both hands            |
| Le Cornu [25]   | 2000 | Case control | Elective liver transplant              | 82                     | 24-68                        | 73              |                | Complications       | Not stated Not stated              |
| Visser [26]     | 2000 | Cohort     | Urgent Hip fracture                      | 90                     | 79 ± 8                       | 0               |                | Mobility            | Not stated Not stated             |
| Guo [11]        | 1996 | Case control | Elective oral and maxillofacial cancers | 127                    | 54 ± 15                      | 69              |                | Complications       | Not stated Non dominant           |
| Watters [27]    | 1993 | Cohort     | Elective general                        | 40                     | < 50 y group (36 ± 9)        | 65              |                | Relate Muscle strength to body composition and nitrogen balance | Not stated Non dominant          |
| Schroeder       | 1993 | Cohort     | Elective general                        | 84                     | 54 ± 18                      | 44              |                | Post-op fatigue     | Not stated Dominant              |
| Griffith [28]   | 1989 | Cohort     | Elective general and vascular            | 61                     | 66 [41-82]                   | 75              |                | Complications       | Not stated Dominant              |
| Kalfarentzos    | 1989 | Case control | Elective general                  | 95                     | 70 [42-88]                   | 56              |                | Complication        | Not stated Not stated            |
| Brenner [29]    | 1989 | Cohort     | Elective general and vascular            | 249                    | Not stated                   | 66              |                | Complications       | Not stated Not stated            |
| Webb [30]       | 1989 | Case control | Elective general                  | 90                     | 58 [20-88]                   | 60              |                | Complications       | Not stated Not stated            |
| Shukla [31]     | 1987 | Case control | Elective Major general            | 110                    | 20-70                        | 49              |                | Complications       | Not stated Non dominant           |
| Hunt [13]       | 1985 | Case control | General, Orthopedic, Urology, Gynaecology, Cardiovascular, Endocrine and Miscellaneous | 205 | 45 ± 17 | 46 | Complications | Not stated Not stated |
| Davies [32]     | 1984 | Cohort     | Urgent Fracture neck of femur           | 76                     | Not stated                   | Female          |                | Complications       | Not stated Not stated            |
| Klidjian [33]   | 1982 | Case control | Elective general                  | 120                    | 60 [24-86]                   | 55              |                | Complications       | Not stated Non dominant           |
| Klidjian [9]    | 1980 | Case control | Elective general                 | 102                    | 57 [16-81]                   | 46              |                | Complications       | Factors impairing handgrip strength Non dominant |

*Retrospective study; # median value.
Three of these 7 studies reported an association between lower handgrip strength and prolonged length of stay [10,13,25]. Mean or median values were compared rather than log-rank analysis.

### Mortality

Table 7 summarizes the 5 studies that explored the relationship between handgrip strength and postoperative mortality. Variable time points for postoperative

### Table 2 Timing of handgrip measurements in patient studies.

| Author          | Year | Timing of measurement                  |
|-----------------|------|----------------------------------------|
| Beloosesky [16] | 2010 | 7-10 days and 1, 3, 6 months post-op   |
| Wehern [23]     | 2005 | During hospitalisation and 2, 6, 12 months post-op |
| Mahalakshmi [10]| 2004 | Pre-op- timing not specified           |
| Cook [17]       | 2001 | Pre-op- timing not specified           |
| Figueiredo [24] | 2000 | Pre-op- timing not specified           |
| Le Cornu [25]   | 2000 | Pre-op- timing not specified           |
| Visser [26]     | 2000 | 2-10 days and 12 months following admission |
| Guo [11]        | 1996 | Not specified whether pre or post-surgery |
| Watters [27]    | 1993 | Pre-op on day of surgery and post-op days 2, 4 and 6 |
| Schroeder [34]  | 1993 | Pre-op on day of surgery               |
| Griffith [28]   | 1989 | Pre-op- timing not specified           |
| Kalfarentzos [12]| 1989 | 2-3 days pre-op                        |
| Brenner [29]    | 1989 | 2 days pre-op                          |
| Webb [30]       | 1989 | Pre-op- timing not specified           |
| Shukla [31]     | 1987 | Pre-op- timing not specified           |
| Hunt [13]       | 1985 | 12-72 hours pre-op                    |
| Davies [32]     | 1984 | Pre-op- timing not specified           |
| Klidjian [33]   | 1982 | Pre-op- timing not specified           |
| Klidjian [9]    | 1980 | Pre-op- timing not specified           |

### Table 3 Newcastle -Ottawa Quality Assessment Scores (NOS score).

| Study            | Year | Study type | NOS score | Selection | Comparability | Outcome |
|------------------|------|------------|-----------|-----------|---------------|---------|
| Beloosesky [16]  | 2010 | Cohort     | 6 D       | 1 a*      | a*            | a*      |
| Wehern [23]      | 2005 | Cohort     | 6 a*      | a* b*      | a*            | a*      |
| Figueiredo [24]  | 2000 | Cohort     | 6 D a*    | a* a*      | a*            | a*      |
| Visser [26]      | 2000 | Cohort     | 6 D a* a* | a* a*      | a*            | a*      |
| Watters [27]     | 1993 | Cohort     | 7 a*      | a* b*      | a*            | a*      |
| Schroeder [34]   | 1993 | Cohort     | 6 D a*    | b* a*      | a*            | a*      |
| Griffith [28]    | 1989 | Cohort     | 7 a*      | a* b*      | a*            | a*      |
| Brenner [29]     | 1989 | Cohort     | 6 D a*    | a* b*      | a*            | a*      |
| Davies [32]      | 1984 | Cohort     | 7 a*      | a* b*      | a*            | a*      |
| Mahalakshmi [10] | 2004 | Case-control | 7 a*    | a* b*      | a*            | a*      |
| Cook [17]        | 2001 | Case-control | 7 a*    | a* b*      | a*            | a*      |
| Le Cornu [25]    | 2000 | Case-control | 7 a*    | a* b*      | a*            | a*      |
| Guo [11]         | 1996 | Case-control | 6 a*    | a* b*      | a*            | a*      |
| Kalfarentzos [12]| 1989 | Case-control | 6 a*    | a* b*      | a*            | a*      |
| Webb [30]        | 1989 | Case-control | 4 C    | b b*      | a*            | a*      |
| Shukla [31]      | 1987 | Case-control | 6 a*    | a* b*      | a*            | a*      |
| Hunt [13]        | 1985 | Case-control | 4 C    | b b*      | a*            | a*      |
| Klidjian [33]    | 1982 | Case-control | 4 C    | b b*      | a*            | a*      |
| Klidjian [9]     | 1980 | Case-control | 4 C    | b b*      | a*            | a*      |

Letters represent answer for corresponding numbered question in each section. A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability. See Additional File 1 for full details of assessment criteria.
associated death were defined across studies, ranging from 30 days to 6 month mortality following surgery. One study did not define the time period of follow-up for patients to determine mortality. Two studies reported an association between lower handgrip strength and increased mortality [12,17].

Discussion
Contrary to large population studies, our systematic review of the relationship between preoperative handgrip strength and postoperative outcome did not find compelling data to support the hypothesis that the results of studies in the general population translate to

Table 4 Definitions used for impaired handgrip Strength.

| Author          | A priori definition of Impaired handgrip strength? | Definition of impaired handgrip strength | Post-hoc Definition/comparison                      |
|-----------------|--------------------------------------------------|----------------------------------------|---------------------------------------------------|
| Belooosesky     | NO                                               | Functional Independence Measure 6 months postoperatively |
| Wehren [23]     | NO                                               | Activities of Daily Living             |
| Mahalakshmi     | YES                                              | < 85% control values                   |
| Cook [17]       | NO                                               | According to low or high risk status    |
| Figueiredo [24] | NO                                               | Critical Care length of stay           |
| Le Cornu [25]   | NO                                               | < 85% and > 85%                        |
| Visser [26]     | NO                                               | Loss in grip strength post-operatively |
| Guo [11]        | YES                                              | < 85% control values                   |
| Watters [27]    | NO                                               | Loss in grip strength post-operatively |
| Schroeder [34]  | NO                                               | Post-operative fatigue                 |
| Griffith [28]   | NO                                               | Loss in grip strength post-operatively |
| Kalfarentzos    | YES                                              | < 85% control values                   |
| Brenner [29]    | NO                                               |                                         |
| Webb [30]       | YES                                              | < 85% population norm                  |
| Shukla [31]     | NO                                               | < 85% and > 85%                        |
| Hunt [13]       | YES                                              | < 85% healthy controls                 |
| Davies [32]     | NO                                               | < 15 kg                                |
| Kalfarentzos    | YES                                              | < 85% controls [1980 study]            |
| Kalfarentzos    | YES                                              | < and > 85%                            |

Table 5 Type of Postoperative morbidity included in follow-up of patients.

| Author          | Pulmonary | Infectious | Renal | Gastrointestinal | Cardiovascular | Neurological | Wound | Haematological | Pain | LOS |
|-----------------|-----------|------------|-------|------------------|----------------|--------------|-------|----------------|------|-----|
| Mahalakshmi     | Y         | Y          | Y     | Y                | Y              | Y            |       |                 |      | Sep |
| Cook [17]       | Y         | Y          | Y     | Y                |                 |              |       |                 |      | Sep |
| Figueiredo [24] | Y         |            |       |                  |                 |              |       |                 |      |     |
| Le Cornu [25]   | Y         |            | Y     |                  |                 |              |       |                 |      |     |
| Guo [11]        | Y         |            |       |                  |                 |              |       |                 |      |     |
| Watters [27]    |            |            | Y     |                  |                 |              |       |                 |      | Sep |
| Schroeder [34]  |            |            |       |                  |                 |              |       |                 |      |     |
| Griffith [28]   | Y         |            |       |                  |                 |              |       |                 |      |     |
| Brenner [29]    | Y         |            |       |                  |                 |              |       |                 |      |     |
| Webb [30]       |            |            |       |                  |                 |              |       |                 |      |     |
| Shukla [31]     | Y         |            |       |                  |                 |              |       |                 |      |     |
| Hunt [13]       | Y         | Y          |       |                  |                 |              | Y     |                 |      | Sep |
| Davies [32]     | Y         |            |       |                  |                 |              |       |                 |      |     |
| Kalfarentzos    | Y         |            |       |                  |                 |              |       |                 |      |     |
| Kalfarentzos    |            |            |       |                  |                 |              |       |                 |      |     |

Y- Included in definition of complications. LOS (length of stay)-definition of morbidity includes length of stay greater than pre-defined level. Sep: LOS is analysed separately i.e. not included in definition of morbidity. Y* defined as complication if > 14 day LOS postop. Y† Complication resulting in ≥16 day LOS post op. Y‡ Defined as serious complication if > 14 day LOS.
| AUTHOR            | GS of LOS “Controls” (kg or %) | Control LOS (mean days ± SD) | GS of LOS “comparators” (kg or %) | Comparator LOS (mean days ± SD) | Log-rank test? | LOS and Handgrip strength associated? |
|-------------------|--------------------------------|------------------------------|-----------------------------------|--------------------------------|----------------|--------------------------------------|
| Mahalakshmi       | < 85%                          | 12.8 ± 6.6                   | > 85%                             | 9.3 ± 3.4                      | NO             | YES                                  |
| Cook              | Male < 32 kg Female < 20.5 kg  | 8.1 ± 10                     | Male > 32 kg Female > 20.5 kg     | 6.8 ± 7.5                      | NO             | NO                                   |
| Figueiredo        | ICU stay only*                 | Not presented                | Not presented                     | Not presented                  | NO             | NO                                   |
| Le Cornu          | Not presented                  | Not presented                | Not presented                     | Not presented                  | YES†           | Positive correlation                 |
| Guo               | < 85%                          | 42 ± 20                      | > 85%                             | 32 ± 10                        | NO             | NO                                   |
| Watters           | Not presented                  | Not presented                | Not presented                     | Not presented                  | NO             | NO                                   |
| Hunt              | < 85%                          | 11.4 ± 12                    | > 85%                             | 6.8 ± 3.8                      | NO             | YES                                  |
| Griffith          | Mean: Male 25.4 ± 9.1 kg Female 14.4 ± 4.3 kg | 7/61 had “Complications” (definition included LOS > 14 days) | Mean: Male 30.2 ± 8.4 kg Female 14.9 ± 5.7 kg | 48/61 had LOS < 14 days | NO | Not reported |
| Webb              | < 85%                          | 20/51 had “complications” (definition included LOS > 14 days) | > 85%                             | 7/39 had LOS < 14 days | NO | Not reported |
| Davies            | < 15 kg                        | 27/37 had “Complications” (definition included LOS > 14 days) | > 15 kg                          | 3/14 had LOS < 16 days | NO | Not reported |
| Klidjian          | < 85%                          | 43/72 had “complications” (definition included LOS > 14 days) | > 85%                             | 5/48 had LOS < 14 days | NO | Not reported |
| Klidjian          | < 85%                          | 20/44 had “complications” (definition included LOS > 14 days) | > 85%                             | 3/58 had LOS < 14 days | NO | Not reported |

*Increased ITU stay was associated with lower handgrip strength (right (27 ± 6 and 36 ± 12 kg p < 0.01) and left (27 ± 7 and 35 ± 12 kg p = 0.01))
†There was a correlation between grip strength and day of discharge post-transplant (r = -0.41, P = 0.01). There was no association between grip strength and length of time spent on ventilatory support post-transplant (r = -0.250) or length of time spent on the intensive care unit post-transplant (r = -0.112)
* Survival plot from time of listing to transplant or death (not for grip strength).
Table 7 Studies describing relationship between handgrip strength and postoperative mortality.

| AUTHOR          | YEAR | Duration of mortality follow-up | Mortality “Control” handgrip strength | Control Mortality | Mortality “comparator” Handgrip strength | Comparator Mortality | Log-rank? |
|-----------------|------|----------------------------------|---------------------------------------|-------------------|----------------------------------------|----------------------|-----------|
| Cook [17]       | 2001 | 3 months                         | Male < 32 kg                          | 11.3%             | Male > 32 kg                           | 29%                  | NO        |
| Figueiredo [24] | 2000 | 1 year                           | GS data not presented                 | Not reported      | GS > 85%                               | Not reported         | YES*      |
| Le Cornu [25]   | 2000 | 30 days, 6 months                | GS < 85%                              | 8.7%              | GS > 85%                               | Figures not presented| NO        |
| Griffith [28]   | 1989 | 7 days                           | Male 27 ± 6 kg                        | 17.2%             | GS > 85%                               | 0%                   | NO        |
| Kalfarentzos [12]| Not stated |                                | GS < 85%                              | 13.3%             | GS > 85%                               |                      |           |

GS = handgrip strength
A. None of the nutritional parameters assessed including handgrip strength were associated with increased risk of mortality
B. Survival plot from time of listing to transplant or death (not for grip strength)
*GS < 85% was significantly related to post transplant occurrence of major complications (definition includes death), minor sepsis and no sepsis (p = 0.05)

perioperative medicine. The majority of studies were considered to be of reasonable quality. Despite these quality scores, many studies contained important potential confounding factors which varied markedly between studies. A range of different instruments have been employed to measure grip strength, with other corroborative assessments of strength being frequently absent. Due to the substantial variation in the way in which each specified outcome had been defined between studies, plus the lack of analyses testing any one particular association, it was not possible to perform meta-analyses of results or formally test the heterogeneity (consistency) between studies. This marked heterogeneity between studies limits any definitive conclusions for the perioperative environment and renders this preoperative assessment largely unexplored. Nevertheless, several of these studies - albeit with the limitations as discussed above - suggest the role for preoperative handgrip strength assessment should be explored further.

Large epidemiological studies have shown that perioperative morbidity is associated with dramatic differences in post-discharge life expectancy across different operations and health systems [2]. The cost and expertise required by certain preoperative tests, such as cardiopulmonary exercise testing, plus other limiting factors (e.g. dysmobility, acuity of surgery) necessitates an alternative approach to be developed for the objective assessment of perioperative risk in the substantial minority of patients who may sustain morbidity that impacts on their long-term survival. The development of an inexpensive, mass screening preoperative assessment tool with high sensitivity and specificity to detect postoperative morbidity is clearly attractive. Handgrip strength is an easy, non-invasive, cheap, real-time and established independent “bedside” predictor of long-term all-cause mortality in more than 44,000 patients studied in the general population [14].

There are also compelling basic biological reasons for establishing the role of handgrip strength in preoperative assessment. Cardiopulmonary reserve is a long-established predictor of cardiovascular and all-cause mortality, in both asymptomatic individuals and patients with cardiovascular disease [35]. Cardiac insufficiency has emerged as the commonest preoperative morbidity associated with increased morbidity and mortality [36,37]. An important component of cardiac failure is dysfunctional skeletal muscle metabolism [38] and impaired strength - as reflected by handgrip strength [39]. Skeletal muscle exerts important effects on the patterns of substrate use during periods of increased cardiopulmonary performance [40,41]. Major alterations in skeletal muscle histology and biochemistry occur in patients with long-term heart failure [42,43]. These skeletal muscle adaptations may underlie the early onset of anaerobic metabolism, increased lactate production and fatigue in heart failure. Handgrip strength improves following specific interventions that increase cardiopulmonary reserve [44,45]. Muscle (handgrip) strength is also impaired in metabolic disease [46], which may in part explain its association with both poorer perioperative outcomes and all-cause mortality.

One limitation of this systematic review is that no original study data were retrieved, although given the heterogeneity of both study design and the surgical populations in question this would have been unlikely to alter the main conclusions. Because only published reports were examined (obtained from searches performed only on MEDLINE, EMBASE and Cochrane databases), a formal assessment of publication bias was not undertaken. It remains possible that not all relevant studies may have
been identified since unpublished studies were not sought. There is very little perioperative demographic data provided in these studies, including cardiovascular risk and the identification of higher risk patients. Standards of postoperative care were not reported or apparently standardized. Since no interventions were conducted based on preoperative handgrip strength assessment, the studies only provide associative conclusions.

This systematic review has generated two significant clinical implications. Firstly, given the compelling general population data that predicts longevity, there is clearly a need for the further prospective assessment of whether preoperative handgrip strength can help stratify risk of adverse postoperative outcomes. Second, these studies demonstrate that handgrip strength is a feasible, pragmatic, real-time bedside tool that may enhance preoperative risk stratification.

Conclusions
Impaired preoperative handgrip strength may be associated with increased postoperative morbidity, mortality and prolonged hospital stay following surgery. Given the robust predictive power of this inexpensive, objective bedside test beyond the perioperative population, further studies of its' role in predicting postoperative outcomes appear to be warranted provided prospective, objectively defined measures of morbidity are employed.

Additional material

- **Additional file 1: Checklist of items demonstrating adherence to PRISMA systematic review guidelines**
- **Additional file 2: Newcastle Ottowa Scale**

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**Authors’ contributions**
All authors contributed to Study design, Conduct of study, Data analysis and Manuscript preparation.

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