BJA

British Journal of Anaesthesia, 128 (2): 244–257 (2022)

doi: 10.1016/j.bja.2021.11.014
Advance Access Publication Date: 16 December 2021
Review Article

CLINICAL PRACTICE

Prehabilitation in adult patients undergoing surgery: an umbrella review of systematic reviews

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Abstract

Background: The certainty that prehabilitation improves postoperative outcomes is not clear. The objective of this umbrella review (i.e. systematic review of systematic reviews) was to synthesise and evaluate evidence for prehabilitation in improving health, experience, or cost outcomes.

Methods: We performed an umbrella review of prehabilitation systematic reviews. MEDLINE, Embase, Cochrane, Cumulative Index to Nursing and Allied Health Literature, PsycINFO, Joanna Briggs Institute's database, and Web of Science were searched (inception to October 20, 2020). We included all systematic reviews of elective, adult patients undergoing surgery and exposed to a prehabilitation intervention, where health, experience, or cost outcomes were reported. Evidence certainty was assessed using Grading of Recommendations Assessment, Development and Evaluation. Primary syntheses of any prehabilitation were stratified by surgery type.

Results: From 1412 titles, 55 systematic reviews were included. For patients with cancer undergoing surgery who participate in any prehabilitation, moderate certainty evidence supports improvements in functional recovery. Low to very low certainty evidence supports reductions in complications (mixed, cardiovascular, and cancer surgery), non-home discharge (orthopaedic surgery), and length of stay (mixed, cardiovascular, and cancer surgery). There was low to very low certainty evidence that exercise prehabilitation reduces the risk of complications, non-home discharge, and length of stay. There was low to very low certainty evidence that nutritional prehabilitation reduces risk of complications, mortality, and length of stay.

Conclusions: Low certainty evidence suggests that prehabilitation may improve postoperative outcomes. Future low risk of bias, randomised trials, synthesised using recommended standards, are required to inform practice. Optimal patient selection, intervention design, and intervention duration must also be determined.

Keywords: exercise; nutrition; patient partnership; postoperative outcomes; prehabilitation; surgery; systematic review; umbrella review

Received: 12 October 2021; **Accepted:** 3 November 2021

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Editor's key points

- Prehabilitation is a high-priority intervention. Its effectiveness in improving outcomes across surgical specialities is unknown.
- In this umbrella review of 55 systematic reviews, there is evidence that prehabilitation may improve rates of complications and non-home-discharge, and improve length of stay and functional recovery. However, the certainty of these findings was low.
- For patients undergoing surgery to derive the greatest future benefit from prehabilitation, methodologically robust clinical trials and knowledge synthesis are required to identify optimal approaches to patient selection, intervention design, adherence strategies, and intervention duration.
- Prehabilitation is a promising intervention to improve postoperative outcomes. This review provides a map of key knowledge gaps that must be addressed with high-quality research to increase the certainty of effectiveness of prehabilitation.

More than 300 million people have surgery annually.[1,2] These surgeries put patients under physical, physiological, cognitive, and psychosocial stress.[3–5] Adverse events, such as complications (20%),[6,7] disability (10–20%),[8,9] impaired function (50%),[10] and cognitive dysfunction (25%),[11] are common and can be linked to poor tolerance of surgical stress.

Although no single definition of prehabilitation exists, this intervention typically involves actively preparing patients before surgery through exercise, nutritional support, psychocognitive training, or a combination thereof.[12] Patients identify prehabilitation as a high-priority intervention.[13,14] However, the evidence supporting its effects on improving outcomes and decreasing resource use remains mixed. Multiple systematic reviews exist and provide inconsistent findings.[15–27] Even with this inconsistency, however, national organisations are actively exploring promotion or implementation of prehabilitation programmes.[28–30]

System-wide implementation of prehabilitation should be guided by high-quality evidence. Scientists must understand what gaps remain to be addressed by future research. The current prehabilitation evidence base is broad and heterogeneous; therefore, a single systematic review or trial is unlikely to adequately advance the field.[31] Our objective was to conduct an umbrella review (i.e. a systematic review of systematic reviews[32]) to provide a broad yet detailed overview of the prehabilitation evidence base, informed by partnership with patients and knowledge users.[33] The specific objectives were to (i) appraise prehabilitation systematic reviews to understand populations, interventions, and outcomes studied; (ii) synthesise and map the evidence of the effect of prehabilitation on health, experience, and cost outcomes; and (iii) assess the certainty of the effect of prehabilitation on outcomes using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) framework.[34,35]

Methods

Design and research question

We conducted an umbrella review following recommended best practices.[36–38] A protocol was registered with the Open Science Framework (https://osf.io/8q7c2/)[112]. Reporting followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[39] Patient involvement (Supplementary Appendix 1) was reported using the Guidance for Reporting Involvement of Patients and the Public-2 checklist.[40]

Our research question was constructed using the following format: population (adult patients undergoing surgery), intervention (prehabilitation: exercise, nutrition, cognitive/psychological, or a combination), comparator (standard care or other prehabilitation), and outcomes (health, experience, or costs).

Search strategy

A search strategy was developed by an information specialist (Supplementary Appendix 2); underwent the Peer Review of Electronic Search Strategy process[41]; and was applied to MEDLINE, Embase, Cochrane Central and Database of Systematic Reviews, Cumulative Index to Nursing and Allied Health Literature, PsycINFO, Joanna Briggs Institute, and Web of Science without language restrictions. The search was initially run from inception of all databases on November 7, 2019, and was updated on October 20, 2020.

Study selection and data extraction

All stages were completed independently in duplicate using DistillerSR (Evidence Partners, Ottawa, ON, Canada). All phases of the review were piloted on a set of five citations by each reviewer and verified by the lead author (DIM). We included all published systematic reviews (with or without meta-analysis) addressing (i) a population aged ≥18 yr having elective surgery; (ii) exposure to a prehabilitation intervention; (iii) comparison to standard care or a different intervention; (iv) outcomes related to health, experience, or costs (per the Institute for Healthcare Improvement (IHI) Triple Aim framework).[42] Although no widely accepted definition of prehabilitation exists, we pre-specified our definition as a unimodal intervention consisting of exercise, nutrition, or cognitive/psychological training, or a multimodal intervention that combines exercise, nutrition, and cognitive/psychological training with or without other interventions (e.g. risk factor management), undertaken for 7 or more days before surgery.[12,16,24] We included reviews of all comparative study designs (randomised trials, cohort and quasi-experimental, or combinations thereof).

We excluded scoping reviews, narrative reviews,[37] and reviews of isolated medical risk factor management (e.g. smoking cessation, anaemia treatment, and medication management). We also excluded abstract-only citations, where the protocol of the review was not registered. Where eligible reviews reported mixed preoperative and postoperative interventions, reviews were excluded if <50% of included studies were preoperative or if preoperative subgroup data could not be extracted.

Titles and abstracts were reviewed; all moved to full-text review unless two reviewers indicated that they did not meet the inclusion criteria. Disagreements after full-text review were resolved by consensus discussion with the senior author (DIM). Included articles underwent duplicate data extraction (Supplementary Appendix 3: list of data points extracted).

Outcomes

We pre-specified that we would collect all outcomes relevant to the IHI Triple Aim framework (health, experience, and cost).[43]

Assessment of review quality

Methodological quality of included reviews was assessed in duplicate using the A MeaSurement Tool to Assess systematic Reviews (AMSTAR-2) tool.[44] The AMSTAR-2 ratings were used to directly inform GRADE certainty ratings and to describe and quantify the quality of reviews related to prehabilitation. We extracted the proportion of individual studies in each included review that were of low, moderate, high, or unclear risk of bias (as assessed and reported by the authors of each included review).

Data synthesis and analysis

Our approach to synthesis followed several steps. Elicitation of patient and knowledge user partner priorities identified that syntheses of findings according to the type of surgical procedure, the type of prehabilitation intervention, and the characteristics of the population under study were most important. Because the type of surgical procedure was most frequently and clearly reported across reviews, this characteristic was used to stratify our primary syntheses. As the umbrella review design uses the systematic review as the unit under study, we categorised the type of prehabilitation interventions synthesised at the review level based on their exclusive focus on exercise, nutrition, cognitive/psychological, multimodal (i.e. interventions in the included studies had to be multicomponent), or mixed (any type of prehabilitation intervention was included).

First, we created evidence tables to provide detailed overviews of available systematic reviews and their findings. Next, we assessed the certainty of evidence for prehabilitation using the GRADE framework. Our GRADE assessment was applied to included systematic reviews with meta-analyses of randomised trials only, in keeping with the GRADE approach for umbrella reviews described by Pollock and colleagues[45] (Supplementary Appendix 4). As recommended, included reviews were checked for overlap of included individual studies. Where >50% overlap in included studies occurred, our synthesis was informed by the most comprehensive, recent review without a critical AMSTAR-2 domain rating lower than moderate.[38] Evidence maps were created, stratified by type of surgery and type of intervention. Other partner-prioritised population characteristics were not adequately reported to allow creation of a patient-characteristic-based evidence map. Statements used to describe GRADE certainty followed best practice recommendations.[46]

Protocol deviations

There were no protocol deviations.

Results

We screened 1412 unique citations and included 55 systematic reviews (Fig. 1; reasons for exclusion, Supplementary Appendix 5). Twenty-seven reviews included only randomised trials: 21 of these presented results of a meta-analysis. The oldest review was from 2004 and the most recent from 2020. Included reviews contained data from 381 unique studies and at least 28 363 patients. No reviews reported any evidence of patient or knowledge user engagement or partnership. Cancer surgeries (22; 40%) were the most common focus of included reviews, followed by mixed procedures (17; 31%), orthopaedics (6; 11%), cardiac and vascular (4; 7%), other surgery types (4; 7%), and abdominal non-oncologic (2; 4%). Included reviews are described in Supplementary Appendix 6.

Patient characteristics

Mean patient age in included reviews was 61 yr; approximately 38% were female. Other than cancer status (26 studies; 47%), prioritised patient characteristics were rarely reported (malnutrition, five studies [9%]; multimorbidity, three studies [5%]; frailty, two studies [4%]; and baseline functional impairment, 0 studies [0%]). Only five (9%) reviews reported whether included studies were conducted concurrent with Enhanced Recovery After Surgery (ERAS) programmes; in each, a minority of studies used ERAS.[23,47–50]

Prehabilitation interventions

Only four reviews (7%) delineated how prehabilitation was defined to inform review inclusion eligibility. Most reviews focused on prehabilitation interventions that included exercise (31; 56%), followed by mixed (i.e. any form of prehabilitation was included in the review; 11; 20%), nutrition (11; 20%), other (a review of preoperative weight loss interventions; 1; 2%), or multimodal (i.e. included studies had to use multicomponent prehabilitation interventions; 1; 2%).

For reviews that included studies with exercise (i.e. exercise, mixed or multimodal; 43 reviews), five (12%) included only unimodal exercise interventions, 34 (79%) included different types of exercise, and four (9%) did not report the types of exercise. Figure 2a provides a breakdown of exercise types included across reviews. Aerobic and strength were most common (32; 78%).

For reviews that included studies with nutrition (i.e. nutrition, mixed or multimodal; 21 reviews), one (5%) included nutritional counselling only, nine (43%) included supplementation only, 10 (48%) included a mix of supplementation and counselling, and two (10%) did not report the type of nutritional prehabilitation. Figure 2b provides a breakdown of nutritional supplementation, as reported in each review.

Thirty-five (64%) reviews reported the duration of prehabilitation. Where reported, programmes were performed for ≥5 weeks (19; 54%), followed by 3–4 weeks (10; 29%) and 1–2 weeks (6; 17%); see Fig 2c. Most included reviews (38; 74%) reported prehabilitation location: home (n=1; 3%), hospital (n=5; 13%), combined (i.e. programmes had to be completed partly at home and partly in an institution; n=3; 8%), and mixed (i.e. any type of location was eligible for inclusion; n=29; 76%); see Fig 2d.

Only six (11%) reviews limited inclusion by supervisory approach (all unsupervised home-based programmes); other

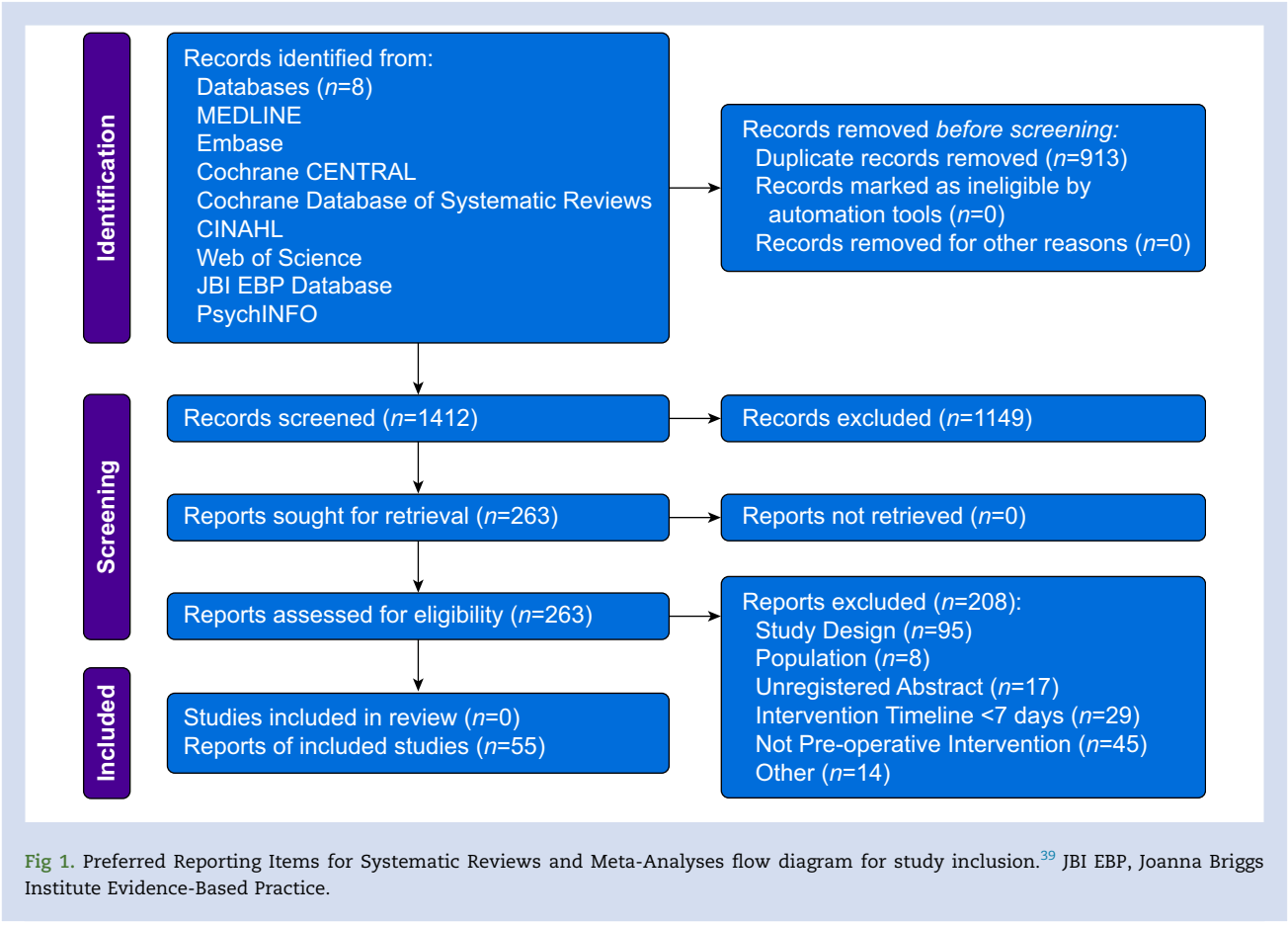


Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for study inclusion.[39] JBI EBP, Joanna Briggs Institute Evidence-Based Practice.

reviews either did not limit or report on supervisory approaches. Included reviews typically did not limit inclusion of individual studies by comparator (25; 45%); 14 were limited to standard care controls (25%) and one to sham interventions (2%). Fifteen (27%) reviews did not report specific comparator conditions. Twenty reviews reported prehabilitation adherence rates (36%), with a mean adherence rate of 70% (standard deviation 24%).

Outcomes

A full summary of all findings by outcome is provided in Supplementary Appendix 7. No reviews were excluded from synthesis because of >50% overlapping included studies. Complications were the most common health outcome (40; 73%), pain the most common experience outcome (9; 16%), and length of stay the most common cost outcome (38; 69%). Whilst data were inadequate to perform a GRADE assessment, two reviews, comprising 23 individual studies, found no differences in intervention-attributable cardiopulmonary adverse events between prehabilitation and control arms (Supplementary Appendix 7).[51,52]

Review quality assessment

The majority of included reviews had critical weaknesses and were rated as critically low (26; 47%)[21–23,47,53–73] or low (16; 29%)[25,49,50,74–86] quality. Only four reviews were rated as high quality (7%),[51,52,87,88] seven (13%) were rated as moderate quality,[48,89–94] and two (4%) as unclear.[95,96] A full description is provided in Supplementary Appendix 8.

GRADE certainty of evidence by surgical population

At least one systematic review and meta-analysis of randomised trial data was available to support GRADE certainty assessment for seven outcomes (health: complications, non-home discharge, mortality, and function; experience: pain; costs: length of stay and costs of care). Full results, stratified by surgery type, are provided in Table 1 (health outcomes) and Table 2 (experience and cost outcomes).

Complications

Nine systematic reviews with meta-analyses of randomised trial data reported on the effect of prehabilitation on medical and surgical complications.[23,52,71,73,74,79,80,83,89] All pooled effect estimates were consistent with benefit. Relative effect sizes ranged from 0.33 to 0.88 (Fig. 3a). Low- or very low-certainty evidence suggested that prehabilitation may reduce complications in mixed surgical populations (n=4054), abdominal non-oncologic surgeries (n=2122), and cardiovascular surgeries (n=889). Very low-certainty evidence suggested that prehabilitation may have no effect on complications in orthopaedic (n=198) and cancer (n=1763) surgeries.

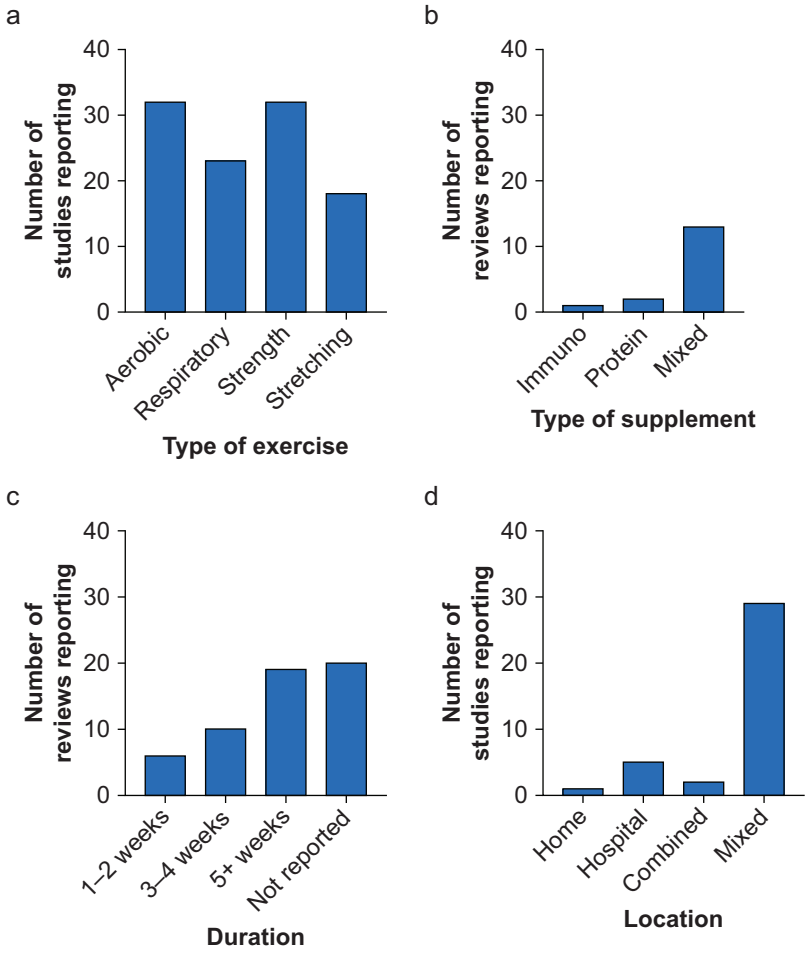


Fig 2. Count of included reviews reporting characteristics of prehabilitation programmes.

Non-home discharge

One systematic review with meta-analysis of randomised trial data for orthopaedic surgery with 187 total participants provided very low-certainty evidence that prehabilitation may reduce the risk of non-home discharge (pooled odds ratio 0.51; 95% confidence interval [CI]: 0.28–0.93; Fig. 3b).[22]

Mortality

Three systematic reviews with meta-analyses of randomised trial data for mixed surgical populations (n=4036) provided low-certainty evidence that prehabilitation may have no effect on mortality.[52,71,89] Pooled risk ratios ranged from 0.40 to 1.30, and all CIs were wide and included the null value (Fig. 3c).

Functional recovery

Three systematic reviews with meta-analyses of randomised trial data were available for functional recovery.[54,85,88] For patients with cancer undergoing surgery (n=929), there was moderate-certainty evidence that prehabilitation likely improved functional recovery (48 m increase in 6 min walk test; Fig. 3d).[85] For non-cancer abdominal surgery (specifically female urinary continence in urogynaecology (n=273)[54] and lower-limb function in orthopaedic surgery (n=290),[88] there was very low-certainty and low-certainty evidence, respectively, that prehabilitation may have no effect on functional outcomes.

Pain

Two systematic reviews with meta-analyses of randomised trial data were available for pain outcomes in orthopaedic surgery (n=1250) and provided low-certainty evidence that prehabilitation may have no effect on pain (see effect sizes; Fig. 3e).[87,88]

Length of stay

Ten systematic reviews with meta-analyses of randomised trial data reported on the effect of prehabilitation on length of stay.[23,25,52,71,74,79,80,83,88,89] All pooled mean differences were consistent with a reduced length of stay in the prehabilitation group (range −0.09 to −4.24 days; Fig. 3f). Prehabilitation may reduce length of stay in mixed surgical populations (n=4054;

Table 1 Certainty assessment for the comparison of prehabilitation to standard care for health outcomes. *Serious; †very serious. SRMA, systematic review and meta-analysis.

Design	Reviews	Participants	Overlapping studies	Reasons for vdowngrade	Direction of effect	Certainty
Complications						
Mixed surgical populations						
SRMA of RCTs	2	4054	0	Review risk of bias† Included study risk of bias*	Protective	⊕ Very low certainty
Abdominal surgeries						
SRMA of RCTs	4	2122	0	Review risk of bias* Included study risk of bias*	Protective	⊕⊕ Low certainty
Cardiovascular surgeries						
SRMA of RCTs	2	889	0	Included study risk of bias† Indirectness*	Protective	⊕ Very low certainty
Orthopaedic surgeries						
SRMA of RCTs	1	198	0	Review risk of bias* Included study risk of bias† Indirectness*	No effect	⊕ Very low certainty
Cancer surgeries						
SRMA of RCTs	2	1763	2	Review risk of bias* Included study risk of bias* Inconsistency*	No effect	⊕ Very low certainty
Non-home discharge						
Orthopaedic surgeries						
SRMA of RCTs	1	187	0	Review risk of bias† Imprecision* Included study risk of bias*	Protective	⊕ Very low certainty
Mortality						
Mixed surgical populations						
SRMA of RCTs	3	4036	0	Review risk of bias* Included study risk of bias*	No effect	⊕⊕ Low certainty
Function						
Cancer surgeries						
SRMA of RCTs	1	929	0	Review risk of bias*	Protective	⊕⊕⊕ Moderate certainty
Female urogenital surgeries						
SRMA of RCTs	1	273	0	Review risk of bias† Inconsistency*	No effect	⊕ Very low certainty
Orthopaedic surgeries						
SRMA of RCTs	1	290	0	Included study risk of bias*	No effect	⊕⊕ Low certainty

The presence of 1 circled cross indicates very low certainty, and 4 high certainty

very low-certainty evidence), cardiovascular surgery (*n*=889; low-certainty evidence), and cancer surgery (*n*=834; low-certainty evidence). No effect was identified for non-cancer abdominal surgeries (*n*=6190; very low-certainty evidence) or orthopaedic surgery (*n*=556; very low-certainty evidence).

Costs of care

One systematic review with meta-analysis of randomised trial data for mixed surgical populations (*n*=3055) provided very low-certainty evidence that prehabilitation may have no effect on costs of care (Fig. 3g).[71]

GRADE quality of evidence by prehabilitation intervention

Results of GRADE evaluation by the type of prehabilitation specified in included reviews were possible for exercise prehabilitation and nutritional prehabilitation (Supplementary Appendix 9). Exercise prehabilitation had very low-certainty evidence of possibly reducing complications, non-home discharge, and length of stay. Nutritional prehabilitation had evidence of possibly reducing complications (very low certainty), mortality (low certainty), and length of stay (very low certainty).

Table 2 Certainty assessment for the comparison of prehabilitation to standard care for experience and cost outcomes. *Serious; †very serious. SRMA, systematic review and meta-analysis.

Design	Reviews	Participants	Overlapping studies	Reasons for downgrade	Direction of effect	Certainty
Pain						
Orthopaedic surgeries						
SRMA of RCTs	2	1250	1	Included study risk of bias*	No effect	⊕⊕ Low certainty
Length of stay						
Mixed surgical populations						
SRMA of RCTs	2	4054	0	Review risk of bias† Included study risk of bias*	Protective	⊕ Very low certainty
Abdominal surgeries						
SRMA of RCTs	3	6190	5	Review risk of bias* Included study risk of bias†	No effect	⊕ Very low certainty
Cardiovascular surgeries						
SRMA of RCTs	2	889	0	Included study risk of bias*	Protective	⊕⊕ Low certainty
Orthopaedic surgeries						
SRMA of RCTs	2	556	1	Review risk of bias* Included study risk of bias†	No effect	⊕ Very low certainty
Cancer surgeries						
SRMA of RCTs	2	834	2	Review risk of bias* Included study risk of bias†	Protective	⊕⊕ Low certainty
Costs						
Mixed surgical populations						
SRMA of RCTs	1	3055	0	Review risk of bias† Inconsistency*	No effect	⊕ Very low certainty

The presence of 1 circled cross indicates very low certainty, and 4 high certainty

Evidence map

Figure 4 provides a map summarising the evidence from meta-analyses of randomised trials supporting prehabilitation across all outcomes and syntheses of mixed designs and narrative syntheses, stratified by surgery and intervention type.

Discussion

In this umbrella review of prehabilitation in adult patients undergoing surgery, we found evidence of beneficial effects of prehabilitation in decreasing complications, improving functional recovery, reducing risk of non-home discharge, and reducing length of stay. However, other than improving functional outcomes for patients with cancer undergoing surgery, all available evidence was rated as low or very low certainty using GRADE, and effects varied depending on the surgical population under study. Possibly beneficial effects were identified for both exercise and nutritional interventions, although the certainty of evidence for each intervention type was low or very low, and benefit was not evident across all outcomes. Improving the certainty of evidence for prehabilitation will require the conduct of methodologically robust and well-reported clinical trials focused on key knowledge gaps and synthesis of data of these trials using best practices for systematic reviews and meta-analysis.

Although no single definition or approach to prehabilitation exists, successful prehabilitation likely depends upon early identification of patients who may benefit from prehabilitation, enrolment in an effective programme, adequate adherence to the programme, and performing the programme for an adequate period to enhance health status before surgery. Heterogeneity across these steps, along with substantial methodological limitations of included reviews and their underlying primary studies, resulted in low- or very low-certainty ratings supporting the efficacy and effectiveness of prehabilitation. As summarised in Tables 1 and 2 and Fig. 4, a map of knowledge gaps now exists for clinicians, researchers, and patient partners to collaboratively target moving forward. Based on the GRADE framework, where low-certainty evidence exists, further research is likely to have an important impact on effect estimates and our confidence in these estimates.[34] Therefore, across surgical specialities, outcomes, and intervention types, robust prehabilitation research is likely to be high impact for all stakeholders in perioperative medicine.

To address this substantial uncertainty, we must strive to better understand the optimal approaches to patient selection, intervention design, and adherence-optimising strategies, and to understand the minimal and optimal time periods required for patients to benefit from prehabilitation using robust study designs. Current evidence related to patient selection, although sparse, suggests that individuals with decreased functional capacity at baseline may benefit most from prehabilitation[97]; however, these and related characteristics were rarely captured or reported in included reviews. For intervention design, we identified evidence of beneficial effects of both exercise and nutritional prehabilitation; however,

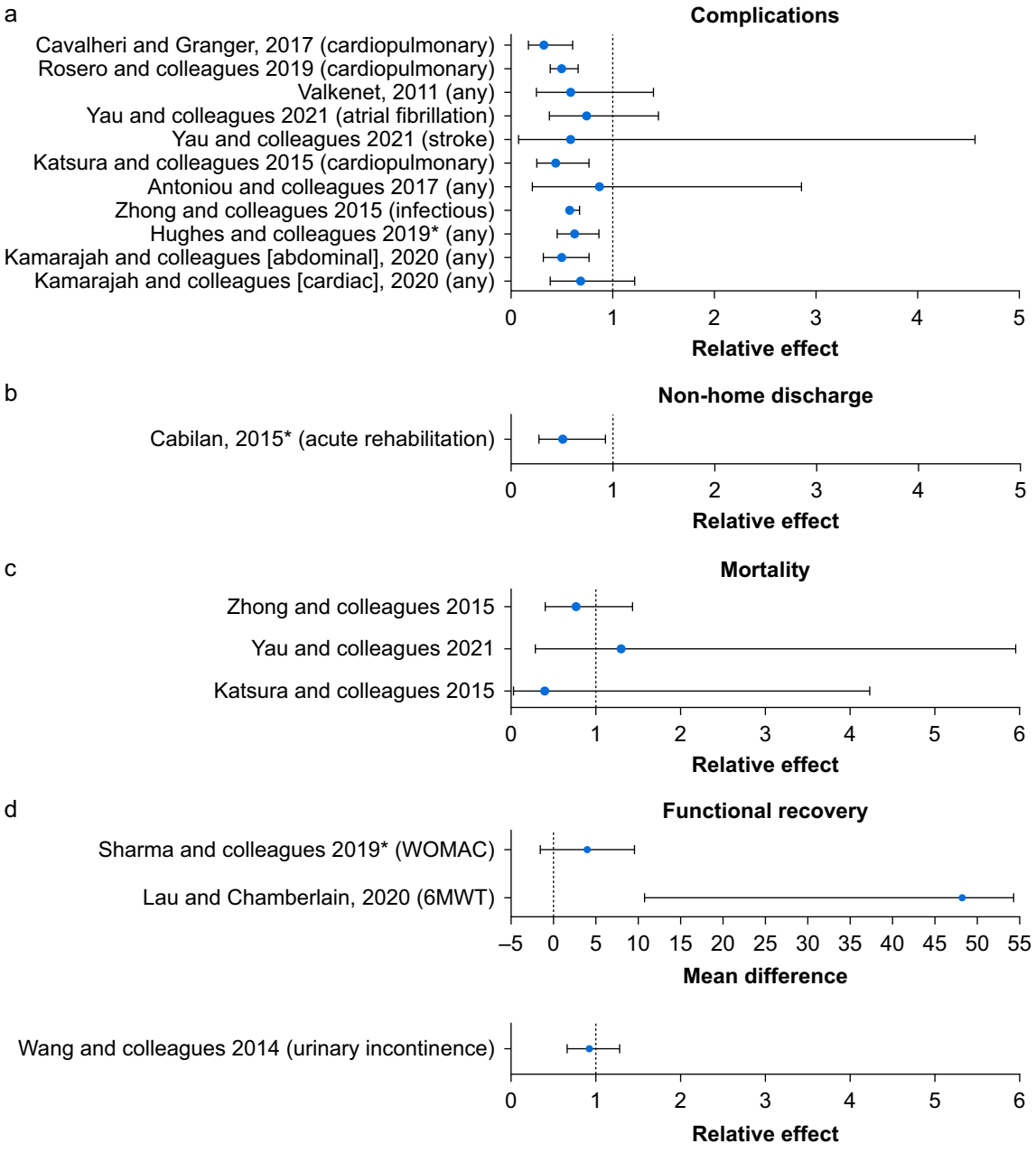


Fig 3. Forest plots of pooled effect measures from included systematic reviews and meta-analyses of randomised trial data informing certainty of evidence ratings. Estimates left of the dotted vertical line (which indicates the null value) indicate an estimate favouring prehabilitation.

substantial heterogeneity was identified across and within reviews focused on different prehabilitation interventions. For example, exercise-focused reviews included interventions that comprised a variety of exercise types (e.g. strength, aerobic, and respiratory muscle training), locations, and supervisory approaches. Nutrition-focused reviews included interventions that ranged from provision of general advice to personalised supplementation. Most reviews combined multiple intervention subtypes, precluding our ability to clearly identify the most efficacious intervention designs or to determine if multicomponent interventions are in fact required. However, regardless of design, high rates of adherence are likely key to successful prehabilitation.[98,99] In included reviews, adherence rates were generally moderate (~70%), but these were widely variable. Finally, the minimum and maximum durations of prehabilitation programmes were also variable, although, where reported, most reviews reported programmes of at least a duration of 5 weeks, which

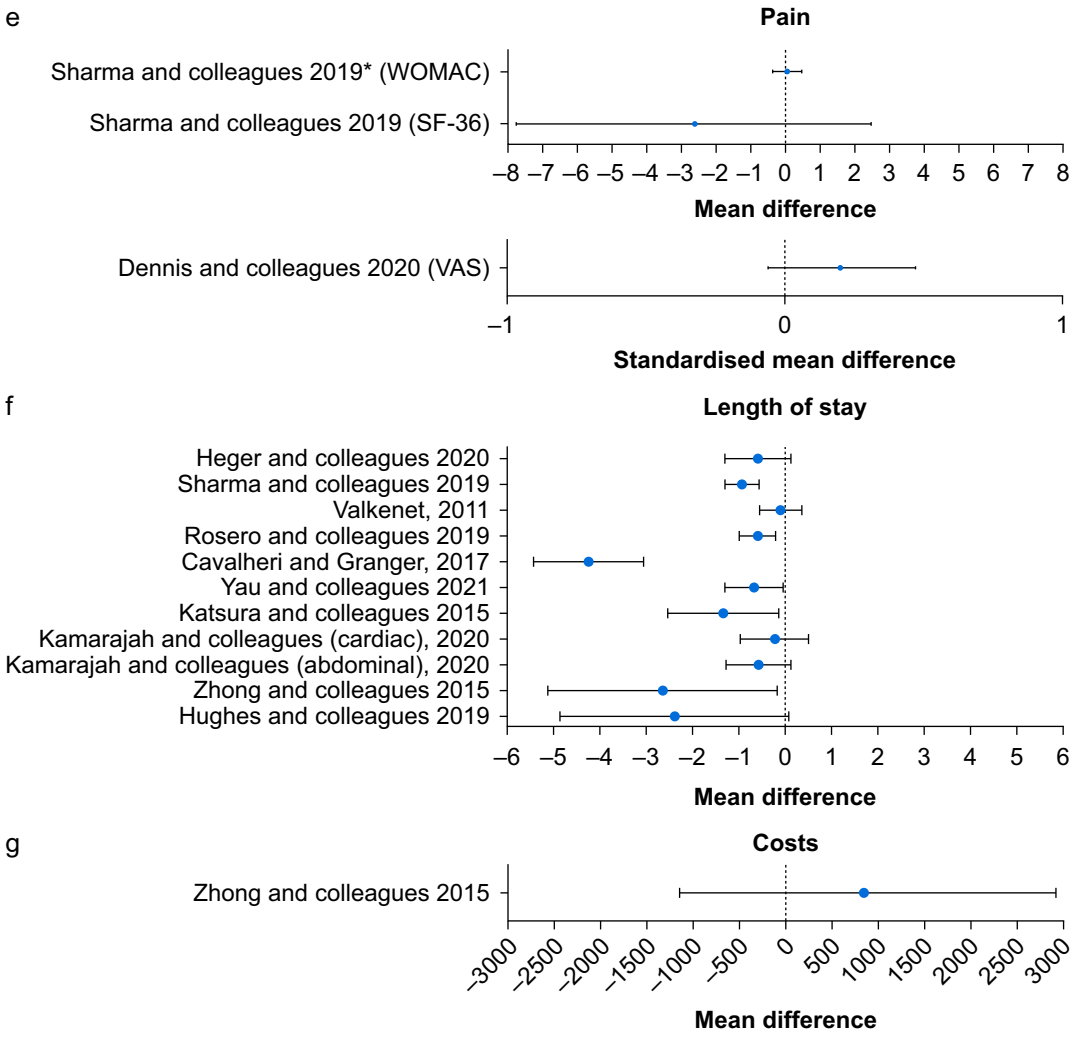


Fig 3. *Continued*

may exceed acceptable wait times for urgent diagnoses, such as cancer.[100–102]

Whilst future research is required to address the uncertainty around each component of successful prehabilitation, such research must address the methodological limitations identified in this umbrella review. First, based on risk-of-bias assessments presented in included reviews, most trials underlying the systematic reviews informing our umbrella review were at high risk of bias. Whilst some sources of bias are challenging to address in prehabilitation (e.g. blinding of participants), examples exist of trials that have used strategies, such as active rehabilitation, or provision of activity guidance to attempt to blind control participants.[98,103,104] Nutritional supplements may be easier to blind.[105] Other strategies, such as cluster randomisation, should be considered with caution and their use clearly justified.[106] Blinding of outcome assessors is feasible and should result in more robust results, regardless of study design. At the systematic review level, most of the 55 included reviews had multiple critical issues. Most commonly, reviews did not pre-specify a protocol, did not adequately address study-level risk of bias when interpreting their results, and failed to assess for publication bias. For both future trials and reviews, development of consensus around how prehabilitation is defined and developing core outcome sets would aid in supporting a more robust evidence base. Such efforts will require active engagement of patient and knowledge user partners.

Strengths and weaknesses

Our protocol was developed and our review was performed, according to principles of integrated knowledge translation.[107,108] This meant that patients and knowledge users were engaged as research partners from inception to guide planning, conduct, interpretation, and reporting of this review. Our protocol was pre-specified, and our peer-reviewed search strategy was applied to eight bibliographic databases. All stages of the review were performed in duplicate, using

	Surgery type						Intervention type	
	Mixed	Orthopaedic	Cancer	Non-cancer abdominal	Cardiovascular	Other	Exercise	Nutrition
Health								
Complications	●	●	●	●	●		●	●
Non-home discharge	1/2	●					●	
Functional recovery	0/1	●	●	●	0/1		●	
Disability	0/1	0/2					0/3	
Quality of life	0/4	0/2	0/11	0/2	1/2		14/21	4/7
Delirium or cognifive dysfunction								
Cancer recurrence			0/1					0/1
Mortality	●	0/5	0/2	0/1	0/2		●	●
Intervention adverse events	0/1		0/1	0/1			0/3	
Experience								
Pain	0/1	●	1/2				●	
Satisfaction	0/1					1/1		
Experience			1/1				1/1	
Likelihood to recommend								
Costs								
Length of stay	●	●	●	●	●		●	●
Readmissions	0/2		0/4				0/3	
Costs of care	●	1/1	2/2		1/2		2/3	●

Legend

Meta-analyses of randomised trial data				Narrative syntheses and reviews of mixed designs			
Direction of effect		**GRADE certainty**		**Direction of effect**		***n/N***	
	Protective	●	Very low		Protective	Numerator	No. of studies with effect
	No effect	●	Low		No effect	Denominator	Total studies
	No data	●	Moderate		No data		

Fig 4. Evidence map. GRADE, Grading of Recommendations Assessment, Development and Evaluation.

best practice methods for umbrella reviews. We also used standard approaches to assess risk of bias at the review level, and in applying the GRADE approach to assess the certainty of available evidence. Our interpretation of findings of this review was directly infomred by formal team meetings to review findings and identify key areas of importance relevant to our diverse group of stakeholders.

The limitations of our review should be considered. As prehabilitation is a relatively new and growing field of study, our focus on systematic reviews (*vs* individual clinical studies) means that our findings are based on evidence that may not capture newly published primary studies. Even the newest included systematic reviews typically captured studies only up to 6–12 months before publication, creating a time lag. Whilst we did find consistent signals of benefit, benefit was not apparent for all surgical subtypes. Umbrella reviews can include systematic reviews with overlapping included trials, which can lead to double counting of evidence.[37] Fortunately, this was not a common issue in our review and did not impact our syntheses. Prehabilitation interventions are heterogeneous and are often multimodal (i.e. combine exercise, nutrition, or other modalities). For example, reviews that focused on exercise prehabilitation often included primary studies of prehabilitation programmes that combined exercise with other modalities. This means that our secondary syntheses based on the intervention type specified by included reviews may not allow precise isolation of the specific impacts of nutrition or exercise. Additionally, there was heterogeneity in how some

outcomes were defined. For example, various methods exist for capturing postoperative complications[109–111]; some studies focused on organ system-specific complications (e.g. cardiac or pulmonary), whilst others included assessed any type of medical or surgical complication. Finally, whilst we engaged patient partners and knowledge users throughout the research process, we cannot claim to have consulted all relevant stakeholder groups (e.g. government and payers).

Conclusions

Prehabilitation may reduce the risk of complications and non-home discharge, improve functional recovery, and shorten length of stay for adult patients undergoing surgery. However, available evidence is mostly low or very low certainty and heterogeneous. For patients undergoing surgery to derive the greatest future benefit from prehabilitation, methodologically robust clinical trials and knowledge synthesis are required to identify optimal approaches to patient selection, intervention design, adherence strategies, and intervention duration. Development of core outcome sets and common definitions, along with meaningful patient and knowledge user partnership, will likely expedite development of a robust evidence base.

Authors' contributions

Conception: DIM, MG, LB, BH, JS, ALG, NB, CG.
Design: all authors.
Data acquisition: DIM, KB, JS, ALG, NB.
Data analysis: all authors.
Data interpretation: all authors.
Drafting/revising/approving of final paper: all authors.

Declarations of interest

The authors declare that they have no conflicts of interest.

Funding

Supported by a project grant from the Canadian Institutes of Health Research. Use of Distiller SR was supported by The Ottawa Hospital Anesthesia Alternate Funds Association. Daniel I McIsaac receives salary support from The Ottawa Hospital Anesthesia Alternate Funds Association and from a Research Chair at the University of Ottawa Faculty of Medicine.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.bja.2021.11.014.

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Handling editor: Jonathan Hardman