

## Case Study

## An Introduction to Surgical Prehabilitation.

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This article aims to provide an initial introduction to the concept of surgical prehabilitation and the evidence from significant studies. Prehabilitation is an area of growing interest for all specialties involved with perioperative patient care. A search of ClinicalTrials.gov reveals that there are at least 17 completed studies of surgical prehabilitation between 2005 and 2018 of which 7 were completed since 2017. There are at least 27 currently recruiting investigating prehabilitation for surgical patients. The principles of prehabilitation and biological rationale for its use are discussed, and an overview of the components of prehabilitation and in particular the evidence for exercise prehabilitation. For context, a case example is included of how prehabilitation may be considered and implemented in a specific patient population - in this case for abdominal aortic aneurysm patients. Finally, the most pertinent research questions yet to be answered in order to successfully implement prehabilitation are discussed.

**Principles of Prehabilitation****Definition of Prehabilitation**

Prehabilitation was originally an academic term to describe the concept of preoperative rehabilitation and is being used more in the clinical environment to mean the process of enhancing the functional capacity of an individual to withstand a stressful physiological event<sup>1</sup>. For surgical patients, this will refer to the process between the diagnosis and decision for surgery to the operation itself. The term 'functional capacity' here will be dependent on a number of factors including the patient's cardiorespiratory function and muscle reserve, and the patient's comorbidities, any presence of anaemia, smoking history, psychological profile and nutritional status<sup>2</sup>. The preoperative period is an ideal window of opportunity to identify these modifiable risk factors and intervene to try and mitigate their negative effects<sup>3</sup>. Although prehabilitation may be applied to any surgical patient, its use is mainly to optimise patients at high risk from surgery. Patients deemed to be at high risk for surgery have a significantly increased mortality rate. The 2011 report, 'Knowing your risk' by the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) (after elective and emergency surgery in the UK), found that although the high-risk group made up just 20% of the patient population, more than half of all postoperative co-morbidities, and 79% of all deaths were found in this high-risk patient group<sup>4</sup>.

**Physiological Rationale of Prehabilitation**

The process of undergoing an operation is seen as a traumatic stimulus to the body which triggers a stress response and leads to significant physiological disturbance<sup>2</sup>. This has physiological manifestations that can be beneficial, for increasing oxygen demand through a catabolic process as part of the stress response, but can also be a contributor to less desirable effects which may lead to postoperative complications<sup>5</sup>. Major surgery provokes a strong inflammatory response which can increase the oxygen requirement of the patient by over 50%, from an average resting oxygen consumption of 110 ml.min<sup>-1</sup>.m<sup>-2</sup> (or less in an elderly patient) to an average of 170 ml.min<sup>-1</sup>.m<sup>-2</sup> in the postoperative period<sup>6</sup>.

The majority of patients can meet this increased oxygen demand by increasing cardiac output and tissue oxygen extraction, which reduces the risk of the adverse effects of the inflammatory response to surgery<sup>6</sup>. Patients with higher aerobic fitness levels can meet the demands of increasing oxygen delivery, induced by surgery, without exhausting their physiological parameters<sup>7</sup>. Survivors of major surgery and critical illness tend to have higher cardiac index (CI), oxygen delivery (DO<sub>2</sub>) and oxygen consumption (VO<sub>2</sub>) than non-survivors<sup>8</sup>. However, there will be a significant number of patients who do not have the physiological or 'functional reserve' to be able to increase their cardiac output to the required level and will therefore be in a state of oxygen debt postoperatively. This will have adverse consequences on organ function, and a resultant higher risk of morbidity and mortality.

Specific postoperative complications will have different contributing patient-related factors such as pre-existing lung disease on postoperative pulmonary complications, or factors related to wound healing such as obesity and diabetes on the risk of wound infection. However, a patient's ability to meet the physiological demands of surgery, namely meeting the increased oxygen demand, is thought to be related to baseline cardiorespiratory fitness, which is also referred to as functional capacity in this context. Measurement of baseline cardiorespiratory fitness, or functional capacity, using exercise testing has shown worse postoperative outcomes for those with decreased ability to meet the oxygen demands of the body during exercise<sup>9</sup>. Similarly, prehabilitation involving exercise interventions to improve functional capacity in patients before surgery have been shown to reduce postoperative complications and improve postoperative recovery, supporting the hypothesis that overall patient functional capacity is an important predictor of surgical

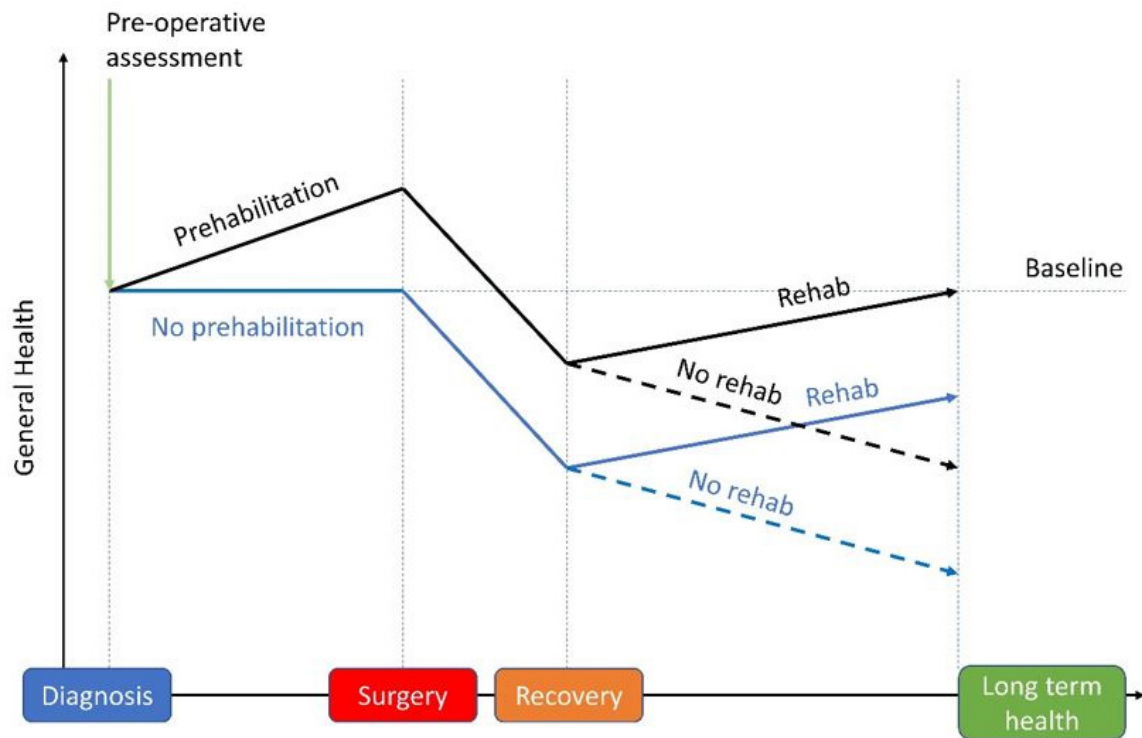


Figure 1 Timeline of possible outcomes before and after surgery with the addition of prehabilitation and rehabilitation interventions. Adapted from Bloom.<sup>1</sup>

outcomes<sup>2</sup>. It is thought that a patient who has previously undergone consistent exercise, has been exposed to a state of 'ischaemic preconditioning' whereby the body has undergone adaptive responses, such as improved ability for tissues to extract oxygen, to meet the increased oxygen demand. This exposure to consistent exercise could reduce the impact of the relatively ischaemic conditions of surgery.

Elements of perioperative care aim to reduce some of the negative effects of this stress response to surgery, but focus to date has mainly been directed to intraoperative technique and anaesthesia, and postoperative 'enhanced recovery' protocols. With the growing interest in the preoperative period as a golden time for patient optimisation, the value of preoperative rehabilitation or 'prehabilitation' is being recognised as an intervention that can improve surgical outcomes<sup>2</sup>. This concept is illustrated in Figure 1, showing the effect of surgery on baseline health postoperatively, and in the long term, and the potential for improved outcomes with prehabilitation.

### Components of Prehabilitation

Several prehabilitation interventions are being researched and some have been adopted into clinical practice. A survey of prehabilitation interventions available in the UK by the Macmillan Cancer Support charity shows that physical activity is always present as an element of prehabilitation for cancer patients, dietary support and psychological wellbeing are often present; with anaemia management, smoking cessation and alcohol reduction, respiratory exercises, medication and comorbidities review being sometimes present<sup>1</sup>. Other elements have included preoperative optimisation of pain management, gait and balance, fatigue, cognitive function, urinary and bowel function and motivational interviewing<sup>1</sup>. The main components are discussed below, bearing in mind that the key first step of prehabilitation is preoperative assessment

to include a baseline individualised risk assessment in order to identify the high risk patients who would benefit most from prehabilitation.

### Patient education and psychosocial support

Patient education before surgery and emphasis on improving psychological well-being, especially before cancer surgery, are being increasingly incorporated into routine preoperative care, with recommendations from the NICE guidelines and Macmillan Cancer Support<sup>1</sup>. The aim is to reduce patients' levels of anxiety and depression before and after surgery, with some evidence that it may also improve clinical outcomes such as length of stay, from its possible effect on cortisol levels, immune function and wound healing<sup>10</sup>. There is some evidence that preoperative patient education reduces patient anxiety and fear pre- and postoperatively, improves pain and patient satisfaction outcomes and maybe even length of stay<sup>11</sup>. Enhanced recovery programs will often have a strong preoperative counselling component where the patient is educated on the process of enhanced recovery and the expectations postoperatively<sup>12</sup>. Common 'interventions' available in current care would be talking to a cancer support worker, visiting a cancer charity centre for further information, joining a local cancer support group, or participating in a 'surgery school' event at the hospital where patients undergoing a similar operation would come for a day of education. Further individual counselling may consist of stress management training such as relaxation techniques, which have been used as part of trials of multi-modal prehabilitation before cancer surgery<sup>13,14</sup>.

Preoperative psychological intervention has been used in non-cancer surgery. A trial of preoperative cognitive behavioural therapy to manage anxiety and depression in patients before coronary artery bypass grafting showed significantly reduced hospital length of stay, and patient

anxiety and depressive scores at time of discharge compared to usual care<sup>15</sup>. A 2015 systematic review of seven studies (including six RCTs) of preoperative psychological intervention before surgery for cancer, concluded that there was some positive effect on immunologic function (in two studies), but no effect on clinical outcomes (length of stay, complications and analgesia use)<sup>10</sup>. Several studies showed a positive effect of psychological interventions on patient reported outcomes related to anxiety, depression and quality of life indicators, but the results are heterogenous with no trend towards a significant effect that is sustained postoperatively.

Aside from the use of preoperative psychological intervention for improving patients' stress management; it is also likely to be important in the delivery of exercise interventions which often require the patient to undergo a process of behaviour modification. Although not strictly psychological counselling, understanding the psychology behind motivators and barriers to exercise is an important consideration when delivering prehabilitation in the form of exercise therapy<sup>1,16</sup>. Motivational interviewing as a method to encourage the patients to find their own motivation for doing exercise and to empower the patient to feel in control of their prehabilitation exercise program<sup>2,17</sup>.

### **Nutritional Prehabilitation**

Preoperative assessment should include identification of those patients with baseline malnutrition or at risk of postoperative malnutrition. Carbohydrate loading in the immediate preoperative period has been part of enhanced recovery protocols for several operations, with evidence it can reduce length of stay, but a more prolonged period nutritional support programme may be more physiological and of benefit to higher risk patients for surgery<sup>18</sup>. Those with preoperative malnutrition have a higher risk of postoperative morbidity and mortality and prolonged length of inpatient stay<sup>3</sup>. Patient who will undergo preoperative neoadjuvant chemo and with a diagnosis involving alimentary system will also have a higher risk of becoming malnourished by the time of surgery. The stress response to operation results in a state of insulin resistance due to increased gluconeogenesis. Patients can be in this hypermetabolic state for several weeks after surgery, which can result in protein loss evident as sarcopenia, which may affect functional capacity, fatigue levels and general postoperative recovery<sup>3</sup>.

Nutritional supplementation as part of prehabilitation for patients at high risk of malnutrition (identified using an objective screening tool such as the Nutrition Risk Screening tool 2002)<sup>19</sup> aims to top-up existing stores and better prepare the patient for the postoperative hypermetabolic state.

Evidence has shown nutritional prehabilitation consisting of 5 to 7 days of enteral nutritional supplementation in those at high risk of malnutrition can result in a 50% decrease in major postoperative morbidity compared to standard care<sup>3,20</sup>. The benefit of preoperative nutritional supplementation in well-nourished people is less clear<sup>3</sup>.

### **Exercise Intervention**

The theory behind preoperative exercise intervention is that better physical fitness preoperatively improves a patient's ability to meet the increased oxygen demand during and after surgery. Preoperative exercise intervention has been shown to improve a patient's intra- and postoperative ability to extract oxygen and tolerate the

ischaemic conditions of surgery, which lessens the impact of any deficit in oxygen delivery to the end organs.<sup>21</sup> Conversely, postoperative exercise intervention has not been shown to be of significant benefit to physical fitness levels or patient quality of life.

Prehabilitation in the form of preoperative exercise intervention was initially of interest in cardiothoracic surgery but is also being investigated in abdominal surgery. Since 2013, at least 13 systematic reviews of studies of prehabilitation in abdominal or cancer surgery have been published<sup>22-34</sup>. These interventions are mostly comprised of one or all of the following elements: inspiratory muscle training with the aim of reducing postoperative pulmonary complications (PPCs), aerobic exercise training (which can be low or high intensity, supervised or unsupervised), and muscle strengthening or resistance training. The evidence for exercise prehabilitation is summarised below.

### **Evidence for Exercise Prehabilitation**

A summary of recent, full (excluding pilot and feasibility studies) randomised controlled trials is listed in Table 1). The two most recent and significant RCTs of preoperative exercise intervention which used clinical outcomes as the primary outcome were in patients undergoing abdominal aortic aneurysm surgery and major abdominal surgery<sup>17,35</sup>. The trial of patients undergoing major abdominal surgery published by Barberan-Garcia et al. randomised 73 out of 144 patients to a personalised (with motivational interviewing techniques), combination program of both unsupervised and supervised exercise prehabilitation for high risk patients for 6 weeks before undergoing major abdominal surgery<sup>17</sup>.

41% of the operations were segmental colon resection followed by rectal resection (16%) and gastric bypass (10%). The primary outcome was the incidence of complications, defined as any deviation from the normal postoperative course and classified using the guidelines 'Standards for definitions and use of outcome measures for clinical effectiveness research in perioperative medicine: European Perioperative Clinical Outcome (EPCO) definitions'<sup>36</sup>. This is a more detailed classification system than the Clavien-Dindo classification used by most other studies and includes choices of complication category from 10 medical complications and 6 surgical complications.

The incidence of complications in the prehabilitation group was significantly lower than the control group (31% vs. 62%,  $p = 0.001$ ), accounted for by three complications with significantly lower incidence in the intervention group: cardiovascular complications, infection of uncertain source and paralytic ileus<sup>17</sup>. There was no significant difference in planned postoperative ITU stay, length of hospital stay, transfusion requirement or reintervention rate. Interestingly there was a significant increase in endurance time (as measured by time able to cycle at 80% power on a cycle ergometer) in the intervention group from baseline to pre-surgery. Mean endurance time increased from 325 seconds to 765 seconds in the prehabilitation group, and only increased from 323 seconds to 362 seconds in the control group<sup>17</sup>.

This is one of the few studies that have been adequately powered to detect a change in postoperative complications due to exercise intervention preoperatively. The results suggest some positive effect on reducing certain postoperative complications, and given that the supervised exercise component was conducted on an exercise bike, it is perhaps not surprising that endurance time on an exercise bike did improve in the intervention group, as evidence that

Author	Year	Journal	Operation	Total number of patients (number in intervention group)	Mean age (yrs)	Intervention(s)	Control group	Outcomes measured
Carli et al.	2010	British Journal of Surgery	Colorectal surgery	112 (58)	60	Daily 30 minutes of cycling (at home, bike provided) Weight training 3 times a week, unsupervised One home visit and weekly telephone call	Walk daily for 30 minutes Deep breathing exercises 5 minutes a day One home visit and weekly telephone call	6 MWT HADS Complications Physical activity questionnaire
Gillis et al.	2014	Anaesthesiology	Colorectal cancer resection	77 (38)	66	Aerobic and resistance exercises Home based, unsupervised Moderate intensity Relaxation exercises 4 weeks before surgery	Rehabilitation, same procedures as intervention group 6 weeks after surgery	6MWT Self-reported physical activity SF-36 HADS Post-operative complications
Jensen et al.	2015	Scandinavian Journal of Urology	Radical Cystectomy (mini laparotomy or robotic assisted)	107 (50)	70	15 minutes on a step trainer Six different muscle strength and endurance exercises Twice a day Home based, step trainer provided, unsupervised 2 week duration Telephone call after 1 week	Standard of care with enhanced recovery principles	Length of stay 90 day complication rate
Barakat et al.	2016	Annals of Surgery	AAA surgery (open or endovascular)	124 (62)	73.4	Aerobic and resistance exercise classes 3 x 1 hour a week Hospital supervised 6 weeks	Standard care Normal lifestyle Avoid any additional unsupervised exercises	Primary: composite endpoint of cardiac, pulmonary and renal complications Secondary: length of hospital and critical care stay, occurrence of SIRS, APACHE II score, 30 day mortality, transfusion > 4 units, reoperation, CPET at the beginning and end of postoperative period
Danne et al.	2016	British Journal of Surgery	Liver resection for colorectal metastases	38 (20)	62	12 x 30 minute exercise sessions on a cycle ergometer Moderate to vigorous intensity Supervised 4 week period		Primary: change in VO2 max from baseline Secondary: SF-36, duration critical care stay, complications, inpatient stay, readmission
Barberan-Garcia et al.	2017	Annals of Surgery	Major abdominal surgery	144 (73)	71	Personalised program based on health conditions and social circumstances Motivational interviewing Unsupervised home exercises and walking Supervised high intensity cycle ergometer 1-2 sessions per week	Standard of care including physical activity recommendation, nutrition counselling +/- dietician intervention if malnourished, advice on smoking cessation and alcohol intake IV iron if anaemic	Primary: number of patients with postoperative complications Critical care stay duration Endurance time on cycle ergometer at 90% of peak oxygen uptake 6MWT SF-36 HADS

Table 1 Summary of randomised controlled trials of prehabilitation mainly involving exercise intervention in major abdominal surgery patients. (APACHE II, Acute Physiology and Chronic Health Evaluation II; HADS, Hospital Anxiety and Depression Scale; SF-36, Short Form 36 health questionnaire; SIRS, systemic inflammatory response syndrome; 6MWT, Six minute walk test)

prehabilitation has increased functional capacity. However, the results did not report on the adherence to the non-supervised component of the prehabilitation. The mean attendance to the supervised component was 12 (SD = 6) sessions in 6 (SD = 2) weeks. Measurement of compliance to the home-based personalised component relied on patients using a pedometer to report step count and reporting on the intensity of any walks or home-based functional activity in a diary. The authors also concluded that use of information technology could enable assessment of surgical risk and management of the perioperative period<sup>17</sup>.

The second recent and significant RCT of exercise prehabilitation was published by Barakat et al. who randomised 62 out of 124 patients to completely supervised exercise intervention, for one hour, three times a week for 4 weeks, preoperatively in patients undergoing elective open and endovascular abdominal aortic aneurysm repair<sup>35</sup>. This was compared to standard treatment and the primary outcome was a composite outcome comprised of renal, pulmonary and cardiovascular complications. The incidence of these complications was significantly lower in the exercise group compared to the control group (22.6% vs. 41.9%,  $p = 0.021$ )<sup>35</sup>. The largest reduction was for isolated cardiac and renal complications. Patients in the intervention group also had a shorter length of hospital

stay, but no other statistically different results for any of the other secondary outcomes: length of ITU stay, APACHE II severity of disease score, transfusion requirement and reoperation rate<sup>35</sup>. Concerning compliance to the exercise intervention, 11 patients randomised to exercise did not attend any classes, and 18 patients out of 62 attended all 18 classes. Patients randomised to exercise who attended more than 75% of the classes had a significantly lower incidence of postoperative complications compared to those who attended less than 75%. Both of these two RCTs have provided further evidence that preoperative exercise intervention can increase functional capacity and reduce postoperative complications.

### Case Example: Prehabilitation Before Abdominal Aortic Aneurysm Repair and Real-Life Clinical Considerations

#### Summary of current evidence for pre-operative intervention for AAAs

Recent studies investigating the benefits of pre-operative exercise in patients undergoing AAA repair have mainly investigated aerobic capacity and exercise tolerance changes pre-operatively with minimal studies recording data comparing post-operative aerobic changes, initial post-

operative complications or length of stay. Furthermore, there are no studies investigating the long-term effects on functional outcomes or quality of life. The minimal studies which do review post-operative data indicate there may be a reduction in post-operative complications such as atelectasis, cardiac and renal complications in those who engage in pre-operative exercise, however there were no statistically significant changes. In addition, data which is vital in NHS care planning such as length of stay is also minimally discussed, with nil significant difference between groups when this is reviewed<sup>37,38</sup>.

When looking at types of intervention used in current evidence, there are variations across each paper in terms of exercise modality, intensity and length of programmes. The difference in these ranges from two-week durations of inspiratory muscle training to a year of increased activity levels, with a multitude of different programmes in between. This makes comparing results and data significantly difficult, with the added challenge of investigating different outcomes. Though there are papers that suggest patients who have increased physical activity levels pre-operatively, do better post-operatively than those who do not, this cannot be attributed to specific interventions and could be related to numerous other factors within their lifestyle, in addition to their activity levels<sup>37-40</sup>.

The lack of current evidence or significant results provides a wide range of potential research opportunities. In terms of intervention, it is important to know the best type of exercise intervention and whether increased general activity such as walking is as beneficial as a supervised, targeted exercise programme which incorporates cardiovascular and strength components. When discussing duration, it is important to factor in the pre-operative period in which patients may have to implement this kind of intervention, some may have a shorter time to surgery than others, and therefore may not gain the same benefit from prehabilitation as those with a longer lead-time to surgery. The evidence is not conclusive on whether a longer, moderate duration exercise regime is more beneficial versus a shorter period of high intensity training. The benefit of more intense supervision in a hospital setting versus remote supervision or community based training is also not known. More information is also required on the longer term impact from prehabilitation on patients' functional outcomes and quality of life after surgery.

## Research Questions

In practice, it can be seen from the case example that implementation of prehabilitation has several challenges. These include how to measure baseline fitness and physical activity level; how to ensure compliance to exercise intervention; what quantity and intensity of exercise needs to be prescribed for a particular patient; and how to assess whether the exercise has actually improved fitness.

Across the number of the systematic reviews of prehabilitation studies, most have concluded that there is limited evidence in demonstrating physiologic improvement in patients undergoing prehabilitation and it is difficult to show an improvement in clinical outcomes such as postoperative mortality, length of stay and postoperative complications. This may be due to a number of factors including: lack of adherence to the exercise programme, difficulty in choice of physiological endpoint to measure, difficulty ascertaining which components

of the exercise regime contribute to an optimal exercise program, difficulty defining the optimal time duration of prehabilitation necessary, lack of consideration for which patients would benefit most from prehabilitation and lack of distinction between types of operation including open versus laparoscopic surgery<sup>27,31,41,42</sup>. These are issues which should be addressed in future prehabilitation studies and are discussed below.

## Patient Selection for Prehabilitation

Given that the benefits of prehabilitation are to improve postoperative outcomes, and that it is known the high-risk surgical patients comprise the majority of those who have adverse postoperative outcomes, effective prehabilitation may only be shown if there is accurate risk stratification of patients for inclusion into prehabilitation interventions. Few previous studies have used patient risk stratification as part selection for inclusion into an individual trial<sup>45</sup>. As patients predicted to be higher risk are most likely to benefit from prehabilitation, a more rigorous approach would be to use a validated screening tool or preoperative cardiopulmonary exercise testing to risk stratify higher risk patients into prehabilitation programs.

In the trial from Barberan-Garcia and colleagues, a risk stratification method was used in their study inclusion criteria<sup>17</sup>. Only high risk patients were eligible which was defined as: age over 70 years, and / or ASA grade III/IV; and Duke's Activity Index score  $\leq$  46 and undergoing major elective abdominal surgery<sup>17</sup>. This may be why this study is one of the first to show a reduction in postoperative complication rate in the exercise group. Preoperative exercise testing with CPET could be used for patient selection for prehabilitation but this has limitations. CPET may not be available in all centres, is resource intensive, and for patients with a abdominal aortic aneurysm over 7cm, CPET is contraindicated due to the risk of cardiovascular events with exercise.

## Types of Interventions Used

Most of the literature has focused on exercise intervention for prehabilitation for surgical patients. Inspiratory muscle training and aerobic exercise training has the most evidence to suggest benefit preoperatively. However, the direction of prehabilitation is likely to be multimodal. Given the multiple factors that contribute to surgical risk and postoperative course, investigating just one aspect of prehabilitation and expecting to see significant changes in postoperative outcomes would not be productive. When faced with a comorbid elderly population undergoing a range of intra-abdominal operations, both open and laparoscopic, benign and oncological, there is currently no single preoperative intervention that has been shown to lead to an improvement in both clinical outcomes and quality of life outcomes<sup>44,45</sup>. Most systematic review and guidance documents agree the approach needs to be multidisciplinary and multimodal<sup>1,27,46,47</sup>. Future trials of separate individual components of prehabilitation are unlikely to show clear benefits in clinical outcomes, and the future direction of research in this area should be based on the concept of implementing a perioperative care pathway that is an aggregation of marginal gains<sup>48,49</sup>. The initiation and compliance and success of any prehabilitation interventions will be influenced by behavioural, psychological, physiological, environment and social factors, which should all be considered when designing a prehabilitation exercise intervention<sup>2,45</sup>.

## Patient Compliance to Prehabilitation Interventions

The issue of compliance or adherence to the exercise intervention is only reported in half of the studies included in the two systematic reviews, with even less reporting adequate adherence. One study found a low compliance rate of 16% of the patients that had completed the exercise programme as measured by home visits and telephone calls<sup>50</sup>. Another study measured a high compliance of 97% of attendance at training sessions in the hospital in the intervention group, but with regards to the home based training programme, patients were given pedometers which recorded no difference in steps undertaken between the control and intervention group<sup>51</sup>. Although an intensive programme of hospital based exercise interventions may result in a higher compliance, this may not be pragmatic, cost effective, or desirable for the patients to engage in as part of their prehabilitation and therefore ensuring greater compliance with non-hospital based exercise interventions warrants investigation.

Previous RCTs and feasibility studies have shown it is feasible to recruit into exercise trials, but this type of intervention may well be self-selecting those who are already motivated to do exercise. In a feasibility study of prehabilitation before radical prostatectomy, of the 99 patients who declined to participate out of 185 eligible patients, 39 patients likely declined due to lack of interest, and 25 patients declined due to distance to travel<sup>52</sup>. Pragmatic studies should have methods to include patients into prehabilitation who are not interested in exercise.

## Intensity of Exercise Intervention

The prescribed exercise as part of prehabilitation in earlier trials were mostly based on moderate to high intensity exercise with the goal of increasing functional capacity quickly in a relatively short period of time before surgery<sup>50,53–55</sup>. More recently, the merit of low to moderate intensity exercise has been considered. Trials have increasingly incorporated a mixture of high intensity and lower intensity exercise programs, with inclusion of muscle strengthening exercises or resistance training<sup>17,52,56</sup>. A study which used peak oxygen uptake as a measure of physiological improvement after a period of preoperative exercise intervention in patients undergoing colorectal surgery showed no significant difference between those receiving exercise intervention and the control group<sup>50</sup>. A possible reason for this is that  $VO_2$  peak in the elderly is hard to increase, as it naturally declines with age. It is more likely that regular exercise of a lower intensity compared to those used in these prehabilitation trials can slow the rate of decline in their  $VO_2$  peak<sup>57</sup>.

The mean age of the patients undergoing abdominal surgery in these trials is above 60 years and therefore considerations should be made for how to best implement prehabilitation in this population. The recent systematic review of prehabilitation studies in major abdominal surgery by Hijazi and colleagues has recommended:

*'A daily exercise intervention that is amenable to patients with minimal disruption and can be undertaken in their local environment is desirable. This is likely to achieve better compliance rates as well and therefore be more effective.'*<sup>42</sup>

The authors also recommended:

*'The type of exercise intervention may need to be tailored to the patient and their environment. The amount of exercise needs to be standardised to allow patients to hit daily targets which should be adjusted to their age and weight.'*

*Whether this activity should be kept static or increased in intensity is unclear, but it is intuitive that a patient easily hitting their daily targets should have these extended.'*<sup>42</sup>

## Duration of Exercise Intervention

With regards to the optimal duration of a prehabilitation, this is influenced by urgency of operation required, with oncology operations having a shorter preoperative time frame in which to implement prehabilitation. The duration of the intervention in the 7 randomised controlled trials included in two recent systematic reviews ranged from the day before to a maximum of 6 weeks<sup>27,28</sup>. When discussing prehabilitation in regards to patients undergoing AAA repair, the time to surgery will vary significantly as this depends wholly on the size or expansion rate of the AAA on regular surveillance. The NHS abdominal aortic aneurysm screening programme standard AAA-S15 states that patients with an aorta  $\geq 5.5$ cm should aim to be operated by a vascular surgeon within  $\leq 8$  weeks of their last conclusive ultrasound scan<sup>58</sup>.

The current thinking is that prehabilitation exercise intervention is more effective in terms of improvement in physiological parameters if the duration is prolonged or the intensity or frequency is increased, however the optimal duration is not known.

## Conclusions

Prehabilitation is a burgeoning field of interest, however, being able to demonstrate significant clinical benefit in terms of improved postoperative outcomes in randomised controlled trials is difficult due to the complex nature of the intervention. Older, more comorbid patients may struggle to undergo exercise prehabilitation and the evidence for being able to improve their physiological parameters as measured by different forms of exercise testing is variable. However, trials of multimodal prehabilitation, where an accumulation of marginal gains from preoperative optimisation, are ongoing and more evidence is accumulating of the benefits to patients, not just in terms of complication rate and length of stay but also for patient quality of life and functional outcomes that may be gained from prehabilitation.

## Conflicts of interest

None.

## Funding

None.

## Consent

N/A

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