

REVIEW ARTICLES

Preoperative aerobic exercise training in elective intra-cavity surgery: a systematic review

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Editor's key points

- Preoperative interventions which improve postoperative outcome are an important focus for quality improvement programmes.
- This review addressed whether implementing a preoperative aerobic exercise training intervention improves outcome after intra-cavity surgery.
- Ten studies were identified from 2443 candidate abstracts; hence, more evidence is required.
- Preoperative aerobic exercise training improves physical fitness and appears to be feasible and safe.

Summary. Reduced physical fitness is associated with increased risk of complications after intra-cavity surgery. Aerobic exercise training interventions improve physical fitness in clinical populations. However, it is unclear whether implementing a preoperative aerobic exercise training intervention improves outcome after intra-cavity surgery. We conducted a systematic review (Embase and PubMed, to April 2011) to address the question: does preoperative aerobic exercise training in intra-cavity surgery result in improved postoperative clinical outcomes? Secondary objectives were to describe the effect of such an intervention on physical fitness and health-related quality of life (HRQL) and report feasibility, safety, and cost-effectiveness. Ten studies were identified from 2443 candidate abstracts. Eight studies were small (<100 patients) and all were single centre. Seven studies reported clinical outcomes. Two studies were controlled trials and two used a sham intervention group. One study in cardiac surgery demonstrated reduced postoperative hospital and intensive care length of stay in the intervention group. Eight studies showed improvement in ≥ 1 measure of physical fitness after the intervention. HRQL was reported in five studies; three showed improved HRQL after the intervention. The frequency, duration, and intensities of the exercise interventions varied across the studies. Adherence to exercise interventions was good. Two exercise-related adverse events (transient hypotension) were reported. Evidence for improved postoperative clinical outcome after preoperative aerobic exercise training interventions is limited. However, preoperative aerobic exercise training seems to be generally effective in improving physical fitness in patients awaiting intra-cavity surgery and appears to be feasible and safe.

Keywords: cardiopulmonary exercise; CPET; prehabilitation; preoperative exercise training

Poor physical fitness, measured by exercise testing, reflects reduced physiological reserve and is predictive of a complicated postoperative period.^{1–4} Aerobic exercise training is beneficial in improving physical fitness in a variety of clinical populations;^{5–8} even over a short time period, aerobic exercise training augments cardiac,⁹ respiratory,¹⁰ and musculoskeletal¹¹ function. Therefore, implementing an aerobic exercise training intervention between the decision for surgery and the surgical procedure appears to be a plausible intervention to improve outcome in 'unfit' patients.^{12–13}

Physical conditioning in preparation for surgery is termed prehabilitation¹² and encompasses strength training,¹¹ breathing exercises,^{14–15} and whole body aerobic exercise training.¹² Although quite different in practice, prehabilitation techniques have a common goal in accelerating postoperative recovery by improving physiological reserve through physical intervention.

Previous reviews of prehabilitation are limited by the number of included studies^{12–16} and heterogeneity of prehabilitation techniques and surgery types.¹⁶ Importantly, a few

controlled trials reporting outcome measures after preoperative aerobic exercise training have been identified. The aim of this systematic review is to evaluate the outcomes (exercise and clinical), methods, health-related quality of life (HRQL), feasibility, safety, and cost-effectiveness in studies that have utilized a preoperative aerobic exercise training intervention in patients awaiting intra-thoracic and intra-abdominal surgery.

Methods

We conducted a systematic search (PubMed and Embase) of clinical trials of preoperative aerobic exercise training in patients awaiting intra-cavity surgery. Abstracts were independently screened by two investigators and reviewed against inclusion and exclusion criteria. Data were extracted by one investigator in accordance with predefined criteria. The *primary hypothesis* was: aerobic exercise training before elective intra-cavity surgery improves postoperative clinical outcome. The *secondary hypotheses* were: aerobic exercise training before major surgery improves physical fitness and HRQL and is feasible, safe, and cost-effective.

We defined *aerobic exercise training* as a prescribed period of aerobic physical activity, involving large muscle groups with a minimum of three planned exercise sessions and each session lasting >10 min, during the time period leading to surgery. We defined *intra-cavity surgery* as elective intra-abdominal and intra-thoracic surgery. The *primary outcome* was death after surgery. *Secondary outcome* measures included: any other measure relating to patient clinical outcome after surgery (e.g. postoperative morbidity, length of hospital stay), change in physical fitness after aerobic exercise training, HRQL, feasibility (adherence, compliance), safety [reported training-related adverse events (AEs)], and cost-effectiveness.

Search strategy

Searches were performed on PubMed (1950 to April 19, 2011) and Embase (1974 to April 19, 2011) using search terms defined by the reviewers (Supplementary Appendix S1). A hand search of the literature was conducted by the lead author using the reference lists of relevant original articles and review articles. Two investigators (A.F.O., M.W.) independently reviewed the abstracts and titles of the studies found in the initial search. After agreement on the primary selection of papers, full-text versions were accessed and reviewed against the following predefined inclusion and exclusion criteria.

Inclusion criteria

Studies recruiting human adult participants awaiting major cardiac, respiratory, or gastrointestinal surgery were included in this review. Studies were eligible for inclusion if the intervention was a preoperative aerobic exercise training intervention evaluated using objective measures of physical fitness. Measures of physical fitness included, but were not restricted to: peak oxygen uptake ($\dot{V}O_2$ peak), the highest oxygen uptake measured during a symptom limited

maximal exercise test; the anaerobic threshold (AT), the oxygen consumption at which muscle energy synthesis during exercise is no longer wholly fuelled by aerobic metabolism; and 6 min walk distance (6MWD), the maximum distance walked in 6 min.

Exclusion criteria

Studies which solely investigated the effects of strength training or respiratory muscle training were excluded. Studies investigating the effects of postoperative aerobic exercise training, aerobic exercise training in patients <18 yr, and animal studies were excluded. Studies which duplicated data that had been reported in an earlier publication and studies that did not report measures of physical fitness were also excluded.

Data extraction and analysis

Data were extracted by the lead author using a pro-forma. The *study characteristics* data included: the journal and country of publication, the number of centres involved in the study, the study design, and a quality measure. The *patient characteristics* data extracted were: age, gender, and surgical type. The *primary outcome* variable was mortality after surgery (longest follow-up). *Secondary outcomes* included mortality (all other timeframes), morbidity, physical fitness, HRQL, adherence, safety, and cost-effectiveness. The *exercise outcomes* data extracted were: objective and subjective measures of physical fitness. The *aerobic exercise training characteristics* data extracted were: the frequency, intensity, mode, and duration of the exercise intervention. Meta-analyses were performed if three or more studies with clinical and statistical homogeneity were identified.

Quality assessment

The quality of the included studies was evaluated by using a checklist designed to assess the methodological quality of randomized and non-randomized studies.¹⁷ The checklist comprised 27 questions under the headings: reporting, external validity, internal validity, and power. Each question was scored out of 1, except question 5 which was scored out of 2 and question 27 which was scored out of 5, giving a total score of 33. High scores reflect high-quality studies. The studies were scored independently by two authors (A.F.O., M.W.) and discrepancies were resolved by discussion between all authors.

Results

Data presentation and analysis

The initial literature search yielded 2443 candidate abstracts (Embase; 1564, PubMed; 873, duplicates; 372, hand search; 6). After review of the candidate abstracts by two independent reviewers (A.F.O., M.W.), 28 potentially eligible full-text articles were requested (initial search; 22, hand search; 6). Eighteen of the 28 full text articles were identified as ineligible (Supplementary Appendix S2). The remaining 10 studies were included in this review (initial search; 9, hand search; 1) (Fig. 1). A brief

overview of each included study is provided in Supplementary Appendix S3. Meta-analyses were not performed due to the clinical and statistical heterogeneity of the included studies.

Included studies

The literature search initially identified 12 studies that met the predefined criteria. However, two studies were identified as a duplicate publication and were excluded from the review. We used follow-up data from one study which presented HRQL data for the patients enrolled in the preoperative exercise training study by Jones and colleagues.¹⁸ The remaining 10 studies, containing 524 patients, were included in this review. The search identified studies using preoperative aerobic exercise training interventions with reported measures of physical fitness which have been performed in patients undergoing gastrointestinal (five studies, 219 patients),^{19–23} thoracic (four studies, 59 patients),^{18 24–26} and cardiac (one study, 246 patients)²⁷ surgery. Study characteristics of the included studies are presented in Table 1. All studies were single centre and the median number of patients recruited was 20.5; only two studies recruited more than 100 patients. Two studies used a control group,^{22 27} and two used a sham intervention.^{20 21} Seven of the 10 studies were published within the last 5 yr (Table 1). The mean patient age ranged from 55 to 71 yr across the studies.

Excluded studies

Eighteen of the 28 studies, where full-text articles were obtained, were excluded for the following reasons: methods papers (two), appropriate physical fitness measures not reported (four), the participants were not exclusively surgical patients (surveillance abdominal aneurysms, palliative cancer treatment) (three), data already presented in an original study by Jones and colleagues (three),¹⁸ postoperative

rehabilitation (two), non-surgical procedure (one), abdominal exercises (one), and letter to the authors that did not present original data (one). A full reference list of these studies is provided in Supplementary Appendix S2. Table 2 provides a brief description of the five studies that were excluded for not reporting objective measures of physical fitness.

Quality assessment

The quality of each study was evaluated by using a checklist designed to assess randomized and non-randomized trials. Quality assessments are reported in Supplementary Appendix S4. The median methodological quality score for the included studies was 17 out of 33. The large randomized controlled trial (RCT) scored highest for methodological quality, 27 out of 33. The two smallest studies scored the lowest for methodological quality.^{19 25} The external validity and statistical power sections of the checklist scored poorly across the studies.

Clinical outcomes

Mortality data were reported in four studies; two studies reported that there was no mortality but did not state the length of the follow-up period.^{24 25} One RCT reported one death at 6 months post-operation but did not state the randomization group that the patient was allocated to.²⁷ One study reported 75% mortality in the 'unfit' group vs 4% mortality in the 'fit' group at 3 months but was underpowered to detect a difference between the groups.¹⁹ Secondary clinical outcome measures after surgery were reported in seven studies; three of these studies did not report control/sham intervention group data and it is not therefore possible to interpret the effect of the intervention on secondary clinical outcome measures.^{18 24 25} Arthur and colleagues²⁷ reported a significantly shorter hospital and intensive care unit length of stay in the intervention group. Asoh and Tsuji reported that of the four patients deemed 'unfit' at surgery, despite aerobic exercise training, all developed postoperative complications and two died of heart failure within 30 days of their operation. In the group deemed to be 'fit', 12% developed postoperative complications and one died within 3 months of the operation due to inoperable gastric cancer.¹⁹ Two studies found no differences between the intervention and sham intervention group in postoperative clinical outcome measures^{20 21} (Table 3).

Physical fitness outcomes

The measures of physical fitness before and after the exercise intervention are presented in Table 4. Eight studies reported a significant improvement in at least one measure of physical fitness. Primary measures of physical fitness varied between studies; $\dot{V}O_2$ peak,^{18 24 26 27} predicted $\dot{V}O_2$ peak,^{21 23} peak work rate (WR peak);²² the highest work rate achieved during a symptom limited maximal exercise test, 6MWD,^{20 25} and steady-state heart rate achieved.¹⁹ Four of six studies showed significant improvement in $\dot{V}O_2$ peak with aerobic exercise training.

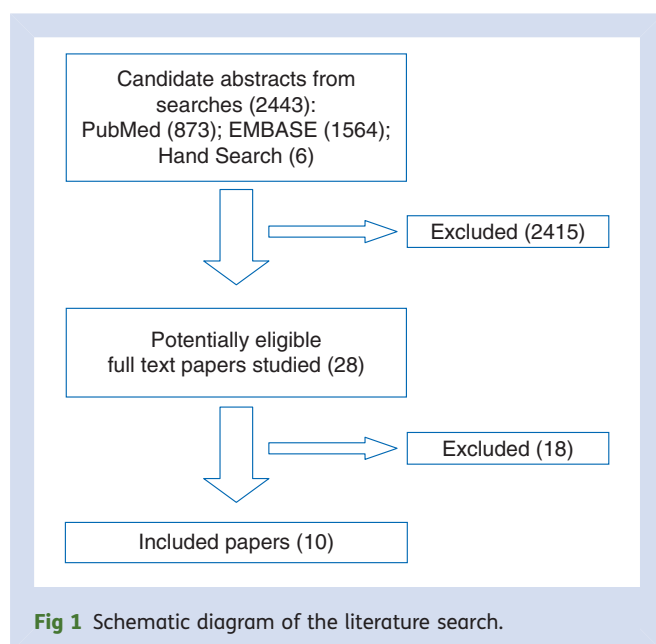


Table 1 Study characteristics. RCT, randomized controlled trial; RIT, randomized intervention trial comparing intervention with sham intervention; F, female; I, intervention; C, control; S, sham intervention; NR, no record; NSCLC, non-small cell lung cancer

Study	Country	Journal	Study design	Number of centres	Number of patients	Mean age (yr)	Patient surgery group	Exercise intervention
Arthur and colleagues ²⁷	Canada	<i>Annals of Internal Medicine</i>	RCT with concealed randomization	Single	246 (37F)	I: 62 C: 64	Coronary artery bypass graft	Aerobic interval
Asoh and Tsuji ¹⁹	Japan	<i>The Japanese Journal of Surgery</i>	Observational	Single	29 (NR)	68	Gastrointestinal	Aerobic continuous
Bobbio and colleagues ²⁴	Italy	<i>European Journal of Cardio-Thoracic Surgery</i>	Observational pilot	Single	12 (2F)	71	Lung cancer ($\dot{V}O_2$ peak <15 ml kg ⁻¹ min ⁻¹)	Aerobic continuous, strength, breathing exercises
Carli and colleagues ²⁰	Canada	<i>British Journal of Surgery</i>	RIT	Single	112 (47F)	I: 61 S: 60	Colorectal	Aerobic continuous, strength
Cesario and colleagues ²⁵	Italy	<i>Lung Cancer</i>	Observational pilot	Single	8 (NR)	NR	Lung cancer (deemed unfit for surgery)	High intensity continuous, breathing and abdominal muscle exercises
Debigaré and colleagues ²⁶	Canada	<i>American Heart Journal</i>	Observational	Single	19 (7F)	61	Lung volume reduction (emphysema)	Aerobic continuous, strength
Dronkers and colleagues ²¹	Holland	<i>Clinical Rehabilitation</i>	Single-blind RIT	Single	42 (11F)	I: 71 S: 69	Gastrointestinal cancer	Aerobic continuous, strength, breathing exercises
Jones and colleagues ¹⁸	Canada	<i>Cancer</i>	Observational	Single	20 (14F)	65	Lung cancer (NSCLC)	Aerobic continuous and interval
Kim and colleagues ²²	Canada	<i>The Tohoku Journal of Experimental Medicine</i>	RCT (2:1, I:C)	Single	21 (8F)	I: 55 C: 65	Colorectal	Aerobic continuous
Timmerman and colleagues ²³	Holland	<i>Physiotherapy Theory and Practice</i>	Observational	Single	15 (3F)	59	Gastrointestinal	Aerobic continuous

HRQL outcomes

HRQL was reported for five studies; four studies reported HRQL within the article included in this review,^{20 21 26 27} Jones and colleagues²⁸ presented HRQL data in a later publication. Each study used a different questionnaire to assess HRQL; Hospital Anxiety and Depression Scale (HADS),²⁰ EORTC quality of life questionnaire,²¹ Chronic Respiratory Questionnaire (CRQ),²⁶ Medical Outcomes Study 36-item Short Form Survey (SF-36),²⁷ and Functional Assessment of Cancer Therapy-Lung cancer (FACT-L) scale.²⁸ Carli and colleagues²⁰ reported improved HADS depression score in the intervention group but not in the sham intervention group ($P=0.045$). Dronkers and colleagues²¹ reported that there was no change in EORTC scores after the intervention or sham intervention. Debigaré and colleagues²⁶ reported increases in every dimension of CRQ after preoperative aerobic exercise training; dyspnoea ($P<0.001$), fatigue ($P<0.01$), emotion ($P<0.01$), and mastery ($P<0.001$). Arthur and colleagues²⁷ reported that the physical composite score of the SF-36 worsened more in the control group than the intervention group ($P=0.04$). Peddle and colleagues²⁸ reported that HRQL measured by the FACT-L scale did not change after preoperative aerobic exercise training.

Characteristics of exercise intervention

Characteristics of the interventions (frequency, intensity, and duration) are reported in Table 5. The frequency of the exercise sessions ranged from 2 to 14 sessions per week and lasted between 20 and 180 min per session. The duration of the interventions ranged from 1 to 12 weeks. Nine of the aerobic exercise training studies utilized continuous aerobic exercise for part or all of the exercise session; one study used only interval aerobic exercise.²⁷ Strength training, involving weight lifting, was incorporated into four of the training interventions.^{20 21 24 26} Breathing exercises were incorporated into three of the training interventions.^{21 24 25}

The intensity of the preoperative aerobic exercise training component of the interventions varied across studies. One study required patients to exercise continuously, keeping heart rate below 130 beats min⁻¹.¹⁹ Seven studies used intensities based on an initial exercise test.^{18 20 23–27} Intensities between 40% and 85% of maximum heart rate (HRmax), heart rate reserve (HRR); HRmax minus resting heart rate, WRpeak, functional capacity, and $\dot{V}O_2$ peak were used. Two studies used a combination of the Borg score, 11–16, and 40–65% HRR or 55–75% HRmax.^{21 22} One study included one interval exercise session per week

Table 2 A brief overview of studies excluded from this review for not reporting objective measures of physical fitness. RCT, randomized controlled trial; I, intervention; C, control; CABG, coronary artery bypass graft; QALY, quality-adjusted life year; METS, metabolic equivalents; COPD, chronic obstructive pulmonary disease

Study	Country	Journal	Overview
Furze and colleagues (2009)	UK	<i>International Journal of Cardiology</i>	A single-centre RCT (n=204; I: 100, C:104) investigating the effects of the HeartOp program 6 weeks before CABG surgery on postoperative outcome. The HeartOp program consisted of a two part booklet containing educational information regarding CABG surgery, a relaxation programme, a goal setting log, and an activity diary. Patients were encouraged to perform daily walking exercises. The control group were provided with standard advice about their operation and were informed how to reduce cardiovascular risk factors. Goal setting was not used in the control group. There were no differences in length of hospital stay or anxiety between groups. Depression, physical functioning (CLASP mobility scale), and cardiac beliefs were significantly different in favour of the intervention group. There were three adverse events (I: 1, C: 2). Adherence was not reported. Twenty-two patients dropped out of the study (I: 12, C: 10). The intervention was deemed to be cost-effective in terms of £ per QALY
Herdy and colleagues (2008)	Brazil	<i>American Journal of Physical and Medical Rehabilitation</i>	A single-centre RCT (n=56; I: 29, C: 27) investigating the effects of in-hospital pre- and postoperative rehabilitation on postoperative outcome in patients awaiting CABG surgery. The exercise intervention was performed daily for ≥ 5 days before operation and used intensities eliciting 2 METS and progressing to 4 METS based on phase 1 cardiac rehabilitation exercises. Respiratory exercises were also included in the intervention. The control group was given no formal exercises except for specific prescriptions from the medical team. Hospital length of stay, pneumonia, atrial fibrillation/flutter, pleural effusion, atelectasis, and time to extubation were significantly fewer in the intervention group. There were 28 preoperative adverse events (I: 16, C: 12), these patients were excluded from the final analysis. Adherence to the exercise programme was not reported
Mooney and colleagues (2007)	UK	<i>European Journal of Cardiovascular Surgery</i>	A single-centre interventional study (n=7) investigating the effects of a 12 week exercise training programme, education, and psychological treatment on anxiety and subjective measures of physical fitness in patients awaiting CABG surgery. Exercise intensities were determined by an initial treadmill exercise test. No objective measures of fitness were reported. Patients reported lower anxiety levels and improved physical fitness (subjective) after the exercise intervention. One patient dropped out of the intervention and was not included in the final analysis. Adherence and adverse events were not reported
Rosenfeldt and colleagues (2011)	Australia	<i>BMC Complementary and Alternative Medicine</i>	A single-centre randomized controlled trial (n=117; I: 60, C: 57) investigating the effects of physical exercise and mental stress reduction therapy on postoperative outcome in patients awaiting CABG or heart valve surgery. The first 2 weeks of the exercise sessions consisted of two hospital-based and at least two home-based exercise sessions per week, lasting between 30 and 60 min at low to moderate exercise intensities. The remaining weeks leading up to surgery consisted of four home-based exercise sessions lasting ≥ 30 min at low to moderate intensities. There were no differences in hospital length of stay, atrial fibrillation, or physical quality of life. Mental quality of life was improved at 6 weeks after operation compared with baseline in the intervention group but there were no differences observed between the intervention and control groups. Adherence and adverse events were not reported
Sekine and colleagues (2005)	Japan	<i>The Japanese Journal of Thoracic and Cardiovascular Surgery</i>	A single-centre cohort controlled trial (n=82; I: 22, C: 60) investigating the effects of pre- and postoperative exercise training and physiotherapy on postoperative outcome in lung cancer patients with COPD awaiting tumour resection. The intervention group performed breathing exercises (>5 times per day) and were encouraged to walk >5000 steps per day for 2 weeks before surgery. Postoperative rehabilitation started immediately after the operation and was adjusted depending on the status of the patient. The control group was a retrospective cohort of patients from the same institution who had COPD and lung resection surgery for cancer without pre- and postoperative rehabilitation. There were no operation-related deaths in either group at 30 days post-operation. Hospital length of stay was shorter and FEV ₁ was less impaired in the intervention group. There were no differences in postoperative pulmonary complications between groups. Adherence and adverse events were not reported

in addition to four continuous exercise sessions per week. The interval exercise session involved exercise at 100% $\dot{V}O_2$ peak for 30 s followed by a 60 s rest, repeated 10–15 times.¹⁸

The preoperative aerobic exercise training sessions were performed in-hospital for six of the studies, at home for

three of the studies, and a combination of hospital and home aerobic exercise training for one of the studies.

Feasibility

The dropout rate for the primary aerobic exercise training intervention, excluding control arms, ranged from 0% to

Table 3 Clinical outcomes. *Significant difference ($P < 0.05$); †group allocation not reported; NR, no record; Fit, achieved plateau in HR during a constant load exercise test; Unfit, did not achieve plateau in HR during a constant load exercise test; I, intervention; C, control; S, sham intervention

Study	Postoperative complications (patients)	Length of hospital stay [days (sd)]	In-hospital mortality (patients)	Long-term mortality (patients)
Arthur and colleagues ²⁷	NR	I: 5* C: 6	NR	1 (within 6 months) [†]
Asoh and Tsuji ¹⁹	'Fit': 3/25, 'Unfit': 4/4	NR NR	'Fit': 0/25, 'Unfit': 2/4	'Fit': 1/25 (within 3 months) 'Unfit': 3/4 (within 3 months)
Bobbio and colleagues ²⁴	8/11	17.5 (14.8)	NR	0 (follow-up period not stated)
Carli and colleagues ²⁰	NR	I: 11.9 (34.6) S: 6.6 (3.6)	NR	NR
Cesario and colleagues ²⁵	2/8	NR	NR	0 (follow-up period not stated)
Dronkers and colleagues ²¹	I: 9 SI: 8	I: 16.2 (11.5) S: 21.6 (23.7)	NR NR	NR NR
Jones and colleagues ¹⁸	7/20	NR	NR	NR

17%. Reasons for dropout included: fatigue, sickness, no longer having surgery, having surgery at another institution, myocardial infarction, undergoing a surgical procedure not related to the study, COPD exacerbation, death of spouse, or unable to participate due to work commitments. Adherence was reported in six of the studies. In five of the studies, adherence was reported as a percentage of the total number of exercise sessions completed and ranged from 72% to 97%.^{18 21–23 26} One study reported 16% adherence; this was calculated by the number of patients that completed the proposed 3.5 h per week of physical activity for every week of their training intervention.²⁰

Safety

There were two exercise-related AEs; decrease in systolic arterial pressure >20 mm Hg.¹⁸ There were 15 AEs reported that occurred outside of aerobic exercise training. Twelve were in patients awaiting CABG surgery; eight AEs were in the control group, and four AEs were in the intervention group.²⁷ The AEs were: unstable angina (five control, one intervention), myocardial infarction (two control, one intervention), and undiagnosed worsening status (one control, two intervention). Three AEs were in patients awaiting lung volume reduction surgery and were due to exacerbation of COPD.²⁶

Cost-effectiveness

There were no data on cost-effectiveness.

Discussion

The principal finding of this review was that preoperative aerobic exercise training was associated with reduced

postoperative length of stay in one study of patients undergoing cardiac surgery. However, it remains uncertain whether this intervention is effective in improving postoperative clinical outcome for other intra-thoracic or intra-abdominal surgeries. The secondary findings identified that preoperative aerobic exercise training improved at least one measure of physical fitness in the majority of studies and benefited or maintained preoperative HRQL. Preoperative aerobic exercise training appeared to be a feasible and safe intervention. There were no data on cost-effectiveness.

Clinical outcomes

Four studies reported mortality; however, the quality of reporting was poor and therefore no conclusions can be drawn from these data. Secondary postoperative clinical outcome measures were reported in seven studies; however, six of the seven studies were observational or included a sham intervention group and therefore the clinical meaning of these outcome measures is limited. The one large ($n > 100$) RCT included in this review reported clinical outcome measures and found a reduced hospital and intensive care length of stay in the intervention group.²⁷ As such, no firm conclusions regarding the primary objective of this review could be made, other than in cardiac surgery where preoperative aerobic exercise training was associated with a reduced length of hospital stay in one study.

Physical fitness outcomes

Eight of 10 studies reported improvement in at least one reported measure of physical fitness after preoperative

Table 4 Change in objective measures of physical fitness. I, intervention; C, control; S, sham intervention; N, non-significant; HR, heart rate; Unfit, unable to achieve a plateau in HR during a constant load exercise test; TTE, time to exhaustion during a constant load exercise test; $\dot{V}O_2$, submax oxygen consumption during a constant load submaximal exercise test

Study	Number of patients	Measure of physical fitness	Group	Baseline [mean (sd)]	Post intervention [mean (sd)]	Change (%)	Improvement
Arthur and colleagues ²⁷	246 (37F)	$\dot{V}O_2$ peak (ml min ⁻¹)	I	1327.6 (320)	NR	N/A	N
			C	1201.2 (288)	NR	N/A	N
Asoh and Tsuji ¹⁹	11 (NR)	Achieved steady-state HR	I	11 of 29 'unfit'	4 of 29 'unfit'	N/A	7 of 11
Bobbio and colleagues ²⁴	12 (2F)	$\dot{V}O_2$ peak (ml kg ⁻¹ min ⁻¹)	I	13.5 (1.3)	16.3 (1.9)	21	<i>P</i> <0.001
		AT (ml kg ⁻¹ min ⁻¹)	I	10.1 (1.9)	13.4 (3.3)	33	<i>P</i> <0.02
		WR peak (W)	I	65 (14)	79 (19)	22	<i>P</i> <0.001
Carli and colleagues ²⁰	112 (47F)	6MWD (m)	I	474.3 (15.1)	463.6 (18.5)	-2	N
			S	494.1 (15.5)	502.8 (15.8)	2	N
		$\dot{V}O_2$ peak (ml min ⁻¹)	I	1395 (76)	1529 (88)	10	<i>P</i> =0.003
			S	1400 (71)	1511 (84)	8	<i>P</i> =0.007
Cesario and colleagues ²⁵	8 (NR)	6MWD (m)	I	261 (97)	340 (66)	30	<i>P</i> <0.05
Debigaré and colleagues ²⁶	19 (7F)	$\dot{V}O_2$ peak (ml min ⁻¹)	I	630 (172)	698 (207)	11	<i>P</i> <0.05
		WR peak (W)	I	37.6 (12.1)	44.7 (16.2)	19	<i>P</i> <0.05
		6MWD (m)	I	354 (116)	425 (110)	20	<i>P</i> <0.01
		TTE (s)	I	201 (162)	710 (668)	253	<i>P</i> <0.01
		Predicted $\dot{V}O_2$ peak (ml kg ⁻¹ min ⁻¹)	I	29.4 (9.5)	27.6 (6.5)	-6	N
Dronkers and colleagues ²¹	42 (11F)		S	31.6 (6.5)	32.9 (6.9)	4	N
Jones and colleagues ¹⁸	20 (14F)	$\dot{V}O_2$ peak (ml kg ⁻¹ min ⁻¹)	I	15.7 (3.7)	18.0 (3.4)	15	<i>P</i> =0.002
		6MWD (m)	I	438 (77)	478 (75)	11	<i>P</i> =0.03
		WR peak (W)	I	82 (24)	91 (30)	11	N
Kim and colleagues ²²	21 (8F)	$\dot{V}O_2$ peak (ml kg ⁻¹ min ⁻¹)	I	21.5 (10.1)	20.9 (8.7)	-3	N
			C	20.3 (4.6)	19.9 (5.6)	-2	N
		WR peak (W)	I	103 (57)	117 (57)	14	<i>P</i> <0.05
			C	109 (39)	109 (39)	0	N
		$\dot{V}O_2$ submax (ml kg ⁻¹ min ⁻¹)	I	18.9 (8.5)	16.9 (7.4)	-11	<i>P</i> <0.05
			C	17.5 (4.7)	17.0 (4.7)	-3	N
		6MWD (m)	I	436 (64)	467 (80)	7	N
			C	478 (99)	504 (103)	5	N
Timmerman and colleagues ²³	15 (3F)	Predicted $\dot{V}O_2$ peak (ml kg ⁻¹ min ⁻¹)	I	25 (0.5)	33 (0.9)	32	<i>P</i> =0.002

aerobic exercise intervention. These data are promising; however, control groups were used in only two studies, thus limiting the strength of the finding. Several exercise measures were used to quantify improvement in physical fitness. $\dot{V}O_2$ peak and AT are probably the most widely accepted measures of physical fitness used for physical fitness assessment and preoperative risk assessment. However, only six studies reported $\dot{V}O_2$ peak and four used $\dot{V}O_2$ peak for primary assessment of change in physical fitness, one study reported AT, but no studies reported AT as a primary assessment of change in physical fitness. Consistency in these measures across the literature is fundamental for comparison of effects across studies. For a detailed discussion of appropriate methods to measure change in physical fitness, we direct the reader to Palange and colleagues.²⁹ Interestingly, two studies did not show an improvement in $\dot{V}O_2$ peak after aerobic exercise training;^{22 27} the reason for this is unclear. Kim and colleagues²²

demonstrated improved submaximal physical fitness despite no improvement in $\dot{V}O_2$ peak, and Arthur and colleagues²⁷ reported improved clinical outcome despite no improvement in $\dot{V}O_2$ peak. Submaximal markers of fitness, such as those measured by Kim and colleagues²² or AT, may therefore have a role in measuring improvement in physical fitness in this setting.

Health-related quality of life

Preoperative aerobic exercise training was associated with improved dimensions of HRQL in three^{20 26 27} of the five studies that reported HRQL.^{20 21 26-28} Dronkers and colleagues²¹ reported that HRQL did not change in the intervention or sham intervention group during the preoperative period. Peddle and colleagues²⁸ also reported that there was no improvement in HRQL after preoperative aerobic exercise training. The absence of appropriate comparator groups in either

Table 5 Frequency, duration, intensity, AEs, and adherence of the exercise intervention. F, female; NR, not reported; HR, heart rate; WR peak, peak work rate; $\dot{V}O_2$ peak, peak oxygen consumption; Borg, rating of perceived exertion; HR peak, maximum heart rate; AT (anaerobic threshold); HRR (heart rate reserve). *Data were imputed for the nine patients who dropped out from the study

Study	Number of patients	Number of patients in the intervention group	Length of intervention [weeks (sd)]	Frequency (per week)	Duration (minutes per session)	Hospital/home intervention	Intensity of aerobic exercise	Exercise adverse events	Non-exercise adverse events	Adherence (%)	Dropout (number of patients)
Arthur and colleagues ²⁷	246 (37F)	123 (16F)	8	2	90	Hospital	30 min: 40–70% functional capacity	NR	12	NR	10
Asoh and Tsuji ¹⁹	29 (NR)	11 (NR)	1–3	14	20	Hospital	20 min: HR < 130 beats min ⁻¹	0	NR	NR	0
Bobbio and colleagues ²⁴	12 (2F)	12 (2F)	4	5	90	Hospital	30 min: 50–80% WR peak	NR	NR	NR	0
Carli and colleagues ²⁰	112 (47F)	58 (24F)*	7.7 (7.6)	7	20–45	Home	20–30 min: >50% HR peak	NR	NR	16% fully adhered	9
Cesario and colleagues ²⁵	8 (NR)	8 (NR)	4	5	180	Hospital	80% WR peak	NR	NR	NR	0
Debigaré and colleagues ²⁶	19 (7F)	19 (7F)	10–12	5	36 (8)	Home	15–45 min: \geq 50% $\dot{V}O_2$ peak	0	3	97%	4
Dronkers and colleagues ²¹	42 (11F)	22 (7F)	2–4	7	60	Hospital (2 sessions) and home (5 sessions)	20–30 min: 55–75% HR max or Borg 11–13	0	NR	In-hospital was 97%	3
Jones and colleagues ¹⁸	20 (14F)	20 (14F)	4–6	5	30–40	Hospital	Continuous 20–30 min: 60–65% $\dot{V}O_2$ peak or at AT; interval 15 × 30:60s 100% $\dot{V}O_2$ peak : active recovery	2	NR	72%	2
Kim and colleagues ²²	21 (8F)	14 (5F)	3.8 (1.2)	7	20–30	Home	20–30 min: 40–65% HRR or Borg 11–16	0	NR	74%	2
Timmerman and colleagues ²³	15 (3F)	15 (3F)	5	2	120	Hospital	30–50 min: 65–85% HRR	0	NR	84%	0

study means that it could not be determined whether preoperative aerobic exercise training attenuated a decline in HRQL, as observed by Arthur and colleagues.²⁷ Preoperative aerobic exercise training did not reduce HRQL in any of the studies where it was reported, and increased at least one dimension of HRQL in the majority of studies.

Characteristics of exercise intervention

The frequency, duration, and intensity of preoperative aerobic exercise training interventions varied significantly between studies; however, the majority of studies showed an improvement in physical fitness. This may encourage investigations into the design of an optimal preoperative aerobic exercise training intervention. Important considerations for the design of an optimal intervention should include: safety, tolerability, time effectiveness, and achieving clinically meaningful improvements in physical fitness.

Feasibility

Aerobic exercise training was feasible and well tolerated and adherence, when reported, was generally high with few drop-outs from the intervention groups. In one study, greater adherence was associated with larger improvements in physical fitness.¹⁸ In a separate study, patients who travelled >4000 steps had larger improvements in fitness, regardless of group allocation.¹⁴

Safety

There were two minor exercise-related AEs and 15 non-exercise related AEs. Twelve of the non-exercise related AEs were reported in one study, with more events occurring in the control group (eight) than the intervention group (four).²⁷ Despite the low event rates, the safety of preoperative aerobic exercise training is not fully understood. A recent pilot study in patients with small abdominal aortic aneurysms (AAA), a representative AAA surgical population, reported a cardiac arrest during aerobic exercise training.³⁰ The patient was successfully resuscitated by trained medical staff. This is the only serious AE reported in the preoperative exercise testing and training literature that the authors are aware of, but it would seem prudent to continue with supervised aerobic exercise training interventions until the risks are better understood.

Cost-effectiveness

The absence of data on cost-effectiveness is notable and such data should be included in future evaluations of exercise interventions before surgery.

Excluded studies

Five studies that incorporated preoperative aerobic exercise training interventions were excluded because objective measures of physical fitness were not reported (Table 2). One study reported that there were no deaths in either group 30 days after surgery. Two studies showed reduced postoperative hospital length of stay in the exercise intervention

group, two studies reported that postoperative hospital length of stay was similar in the intervention and control groups, and one study did not report hospital length of stay. Owing to the various preoperative aerobic exercise training programmes utilized within the included and excluded studies of this review, we believe that we were justified in excluding studies that did not report objective measures of physical fitness. Objectively measuring physical fitness to evaluate the overall effect of the different preoperative aerobic exercise training interventions enables a more balanced comparison between the interventions and clinical outcomes. It is possible, as we have observed in this review, that clinical outcome measures after exercise intervention can be improved despite no improvement in certain measures of physical fitness. However, until we understand better the underlying mechanisms that relate physical fitness and postoperative clinical outcome, measures of physical fitness should be considered the gold standard for evaluating the effect of a preoperative aerobic exercise training programme.

Strengths and weaknesses of the study

The strengths of this article are that it provides an up-to-date review of the current prehabilitation literature incorporating aerobic exercise training in patients awaiting major intra-abdominal and intra-thoracic surgery. This review was conducted in a rigorous manner using specific search terms to identify relevant articles. Bias was minimized by having two investigators independently screening candidate articles using predefined criteria. Prehabilitation is a broad term encompassing various interventions with different theoretical underlying mechanisms but have a common goal to improve postoperative clinical outcome. Narrowing the focus to a specific area of prehabilitation, aerobic exercise training, provided meaningful analysis of the practicalities of the intervention and a clearer understanding of its effectiveness.

Limitations of this review include the small number of included studies and limitations in the design and conduct of these studies, highlighted by the quality assessment checklist (Supplementary Appendix S4). Most were small ($n < 100$) studies without comparator groups or *a priori* sample size calculations. Furthermore, all included studies were conducted at a single centre and therefore the external validity of each study is uncertain. We excluded five studies because measures of physical fitness were not reported (Table 2). It is possible that these five studies containing 466 patients could alter the conclusion of this systematic review. The variety of interventions and outcome measures across studies made inter-study comparisons difficult. Finally, in two of the studies, a sham intervention was used as a control group; this may have underplayed the effect of preoperative aerobic exercise training in these studies. The limitations of the review reflect the limitation of the preoperative aerobic exercise training literature base. Most of the studies (7/10) were conducted within the last 5 yr,

suggesting increasing interest in this area. Understanding of the effectiveness of preoperative aerobic exercise training in improving physical fitness and surgical outcome is likely to improve as more high-quality studies are published.

Strengths and weaknesses in relation to other studies

Carli and Zavorsky¹² first reviewed the concept of prehabilitation for intra-abdominal and orthopaedic surgery. Two preoperative aerobic exercise training studies were identified.¹⁹ The authors acknowledged the limited number of studies and concluded that preoperative aerobic exercise training appeared beneficial in patients awaiting cardiac and abdominal surgery. More recently, Valkenet and colleagues¹⁶ reviewed the effects of preoperative interventions on surgical outcome. The authors included a broader range of preoperative interventions including aerobic exercise, breathing exercise, and limb strength training. The authors' conclusion was similar to that of Carli and Zavorsky. In the present study, we identified the benefits of preoperative aerobic exercise training in cardiac patients; however, in patients awaiting intra-abdominal surgery, the data were less clear. Prehabilitation for joint replacement surgery was excluded in the present review for three reasons. First, because prehabilitation, in this context, is predominantly focused on strength and mobility, which is conceptually different from preoperative aerobic exercise training. Secondly, patients before joint replacement surgery may have joint-related mechanical or pain limitations to exercising. Thirdly, when compared with surgery where a body cavity is opened, outcome after orthopaedic surgery is better for a given operative severity (blood loss, operation length).³¹ We included non-controlled studies in the present review as we thought it appropriate to review methods of all available studies and safety and feasibility were important outcomes. By doing this, we have highlighted inconsistencies in methods and the reporting of results. We hope that identifying these inconsistencies will improve the overall quality of future studies investigating preoperative aerobic exercise training.

Implications for clinicians, researchers, and policymakers

Preoperative aerobic exercise training appears to be a safe intervention, and may improve HRQL. The evidence base for preoperative aerobic exercise training remains small; however, the feasibility of the intervention has been demonstrated in this review and should provide a foundation for further research. There were a variety of exercise interventions utilized in the included studies; nonetheless, in the majority of these studies, preoperative aerobic exercise training was effective in improving physical fitness. The only large randomized controlled study demonstrated that preoperative aerobic exercise training reduced postoperative length of stay after cardiac surgery.²⁷ However, high quality, adequately powered multi-centre trials are required before

implementation of preoperative aerobic exercise training into current clinical practice.

The primary hypothesis of this systematic review is not adequately addressed by the current published literature in this area. In order to achieve this, adequately powered, multi-centre preoperative aerobic exercise trials with appropriately structured aerobic exercise interventions and meaningful measures of exercise and clinical outcome are required and also cost-effectiveness evaluation. The best method of aerobic exercise training to induce the greatest short-term improvement in physical fitness in this population remains unclear.

Conclusion

Preoperative aerobic exercise training appears to be beneficial in patients awaiting cardiac surgery, but the effect in patients before major intra-thoracic and intra-abdominal surgeries is uncertain. In general, most studies showed the intervention to be effective in improving physical fitness and HRQL was improved or maintained. Preoperative aerobic exercise training was safe, feasible, and well tolerated. The optimal design of preoperative aerobic exercise training intervention remains unclear. Future studies should report appropriate measures of clinical outcome, physical fitness, and cost-effectiveness and be adequately powered to determine the effects of aerobic exercise training on post-operative clinical outcome.

Supplementary material

Supplementary material is available at *British Journal of Anaesthesia* online.

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