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REVIEW

Exercise Parameters and Outcome Measures Used in Cardiac Rehabilitation Programs Following Median Sternotomy in the Elderly: A Systematic Review and Meta-Analysis

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Objective The aim of this systematic review was to identify exercise parameters and outcome measures used in cardiac rehabilitation programs following median sternotomy, in the elderly cardiac population.

Data Sources Five (5) electronic databases were searched for relevant studies published in English after 1997.

Study Selection The screening process was completed by two independent researchers, with a third independent reviewer for overall agreement. Studies were selected if they included only cardiac patients aged ≥65 years who had undergone valve surgery and/or coronary artery bypass grafting via median sternotomy, and who had undertaken a postoperative cardiac rehabilitation exercise intervention assessing physical function and/or cognitive recovery as outcomes.

Abbreviations: 6MWT, six minute walk test; CPET/GXT, cardiopulmonary exercise testing/graded exercise test; MacNew, MacNew Heart Disease Health Related Quality of Life Instrument; SF-36, Medical Outcomes Study Short-form Health Survey; VO_{2peak}, peak maximal oxygen consumption

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Data Extraction Two researchers independently completed the data extraction and quality assessment. Quality was assessed using a modified Downs and Black tool.

Data Synthesis In total, 11 articles were included for appraisal with respect to the quality of the study. Only two randomised controlled trials were suitable for meta-analysis. A higher volume of exercise was shown to have a positive effect on functional recovery, assessed using the 6-minute walk test (6MWT) (mean difference = 26.97 m; 95% confidence interval [CI], 6.96–46.97; $p = 0.008$; $I^2 = 0\%$). No significant improvement was shown between additional exercise compared to standard care in improving VO_{2peak}, maximal power output or quality of life. No studies evaluated the effect of exercise on cognitive recovery.

Conclusions Exercise significantly improves functional recovery in the post-surgical elderly cardiac population, however uncertainty still exists with regard to which modes of exercise and their specific parameters are most effective in improving cognitive recovery.

Keywords Sternotomy • Cardiac rehabilitation • Cardiac surgery • Cognitive Impairment

Introduction

In the early 1900s, cardiac rehabilitation was strictly bed-rest due to the prohibition of all voluntary movements for a minimum of 6–8 weeks [1,2]. Concern regarding the high prevalence of thromboembolic and respiratory complications lead to the inclusion of 1–2 hours of sitting out of bed in the 1940s [3], and the transition to a conservative walking program in the 1950s, following the realisation that prolonged hospitalisation decreased physical work capacity [4,5]. Throughout the 1970s, a minimal physical exertion approach continued to be implemented, as a precautionary measure to avoid increases in arterial hypoxaemia, arrhythmias and sudden cardiac death [2,6]. Fast forward to the new millennium and the benefits of multidisciplinary cardiac rehabilitation programs, early moderate intensity aerobic exercise [7] and high intensity aerobic training [8,9] are supported by robust evidence and are now recommended within current cardiac rehabilitation guidelines [6,10–12].

Despite advances in interventional cardiology, each year over 1.5 million cardiac operations are performed using the median sternotomy incision, worldwide [13]. Patients undergoing this procedure are typically elderly with multiple comorbidities [14], placing them at a higher risk of postoperative complications, including permanent cognitive impairment. Up to 50% of patients have evidence of mild cognitive impairment prior to undergoing surgery [15] and 15–40% of patients experience permanent cognitive impairment, 3 months or longer after surgery [16–18]. This is significant as mild cognitive impairment is considered a precursor to dementia and cardiac surgery patients are at a 30% accelerated risk of progressing to dementia within 7.5 years after surgery, significantly impacting upon independence and quality of life [19–21].

Exercise interventions, inclusive of aerobic and resistance training, have been reported in the literature to have beneficial effects on exercise capacity, inflammation, autonomic function, muscular strength, balance, morbidity, mortality and quality of life in the elderly; and as such, are an integral part of cardiac rehabilitation following cardiac surgery [22,23]. It has been hypothesised that progressive resistance training augments the effects on insulin-like growth factor-1, insulin sensitivity, and mediates inflammation and neurotrophic factor pathways associated with cognitive decline and sarcopaenia [24,25], which is a factor in increased falls risk, functional decline and frailty in this population [26]. Despite evidence to support the safety and efficacy of moderate intensity exercise [7], that utilises the upper limb and trunk, strict movement and lifting restrictions are enforced postoperatively, in the form of sternal precautions to prevent sternal complications. These factors pose a challenge to health professionals in regards to exercise prescription within cardiac rehabilitation, to promote postoperative recovery. Current sternal precautions inadvertently promote physical inactivity, which can increase the risk of postoperative complications, depression, weight gain, further cardiovascular disease risk, and delay postoperative recovery [27].

A review of cardiac rehabilitation guidelines worldwide reported that aerobic training was the focus of international exercise guidelines, however it was prescribed inconsistently with respect to intensity, duration and frequency [28]. Price et al. (2016) also noted that recommendations for resistance training were not routinely included in cardiac rehabilitation guidelines or position statements [28]. Furthermore, guidelines were generalised to all cardiac patients, with little variation in exercise prescription between clinical conditions [28]. However, cardiac rehabilitation is not a ‘‘one size fits all approach’’ [29]. There are considerations for the safe implementation of exercise for every cardiac condition, such as time from the event and the intervention administered; and, other patient-specific considerations, such as age, gender, comorbidities, cultural beliefs, premorbid condition, exercise preferences and cost. To date, there are no systematic reviews that have investigated exercise parameters and outcome measures in the elderly following cardiac surgery via a median sternotomy. Thus, investigation of exercise in specific cardiac populations is warranted to further establish what exercise prescription (mode, frequency, intensity and duration) will optimise recovery following cardiac surgery, to inform clinicians in tailoring exercise programs to the individual patient [30].

Therefore, the specific research questions for this systematic review were:

1 What is the optimal timing and mode of exercise prescription for maximal functional and cognitive recovery following median sternotomy?
2 Does the current literature regarding cardiac rehabilitation following a median sternotomy meet Australian, American and European cardiac rehabilitation guidelines?
3 Is there any consistency in the cognitive and physical function outcome measures used in cardiac rehabilitation and are they used to inform exercise prescription?

Method

This review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and is registered on the International prospective register of systematic reviews (PROSPERO No. CRD42018098617).

Data Sources

The search strategy consisted of three key concepts: cardiac surgery type; exercise intervention; and cognitive or functional outcomes. For each concept, keywords and Medical Subject Heading Indexing (MeSH) term were combined with the Boolean ''OR'' operator and concept search results combined with the ''AND'' operator *(see Appendix A for electronic database search strategy)*.

The following electronic databases were searched for literature spanning a 20-year period from 1 January 1997 to 28 September 2018: PubMed, Medline, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINAHL) and SportsDiscus. In addition, a search for ongoing studies was conducted on the following trial registries: Clinical Trials Registry (www.clinicaltrials.gov), World Health Organisation (WHO) International Clinical Trials Registry Platform (ICTRP) (apps.who.int/trialsearch/), and Australian New Zealand Clinical Trials Registry (www.anzctr.org.au).

The reference lists of all relevant publications were searched for any additional references or unidentified trials, however publications remained limited to English only, due to not having the resources to translate the publications. Grey literature was also excluded.

Eligibility Criteria

All studies published in English between 1997-current that reported on an adult (≥65 years) population with coronary artery disease who have undergone cardiac surgery via median sternotomy (i.e. coronary artery bypass graft or valve replacement), were eligible for the review, irrespective of sex or ethnicity.

Studies where an exercise intervention was delivered with the focus of improving a patient's functional recovery and/or cognitive function were included. The intervention could be provided in an inpatient, outpatient, home-based or community-based setting, with no restrictions on the length of the intervention, program intensity or type of exercise.

Where intervention groups were compared to a control group, the trials were only included if the control intervention consisted of treatment as usual (e.g. standard medical care) or no intervention.

The inclusion of any type of co-intervention was permitted, provided the co-interventions were delivered to both study groups equally. The possible introduction of confounding variables will be discussed.

Study Selection

One reviewer (JP) screened the titles of all publications obtained from the searches for inclusion. Titles needed to appear potentially relevant to the study area. Abstracts of the publications identified for potential inclusion were independently assessed by two review authors (JP & MP), to determine publication language; cardiac population; exercise intervention and outcome measures. All identified articles were marked as ''retrieve'' and full text electronic copies were stored. Publications were excluded and marked accordingly if they did not meet the inclusion criteria. If all inclusion information could not be obtained from the abstract, the full text articles were read and independently screened for inclusion by two reviewers (JP & MP). A third reviewer (RK) was consulted where any disagreement occurred.

Data Extraction

Data extraction and risk of bias assessment were completed independently by two reviewers (JP & MP). The Law and MacDermid Quantitative Review form and guidelines [31] were used to extract data from the included studies, whilst a modified Downs & Black tool [32], which can be used to assess both randomised and non-randomised controlled trials, was used to determine study quality and risk of bias. Study quality was classified according to corresponding Downs and Black score ranges of excellent (26–28); good (20–25); fair (15–19); and poor (≤14) [32]. Any agreement was resolved by discussion.

Where data was presented both numerically and graphically, the numerical data was used to reduce the risk of result misinterpretation when estimating from the figures. Authors were contacted requesting clarification of the missing information where unclear or insufficient data was reported.

For the purpose of this review, exercise intervention will be defined as any planned and structured physical activity program developed with the intention of improving physical conditioning and modifying outcomes. Outcomes are included, but will not be limited to, cognitive function, functional independence, exercise capacity, and muscular strength.

Data Synthesis and Meta-Analysis

Given the wide range of exercise interventions and outcome measures used across studies, we first summarised the exercise prescription variables, including program length and exercise duration, frequency, intensity and mode; and then summarised the outcome measures used to assess the exercise interventions. Meta-analysis was conducted when two or more studies reported the same units of outcome measurements. Only randomised controlled trials which provided pre- and post-intervention data were included for meta-analysis.

Data were pooled using a fixed-effect model, unless high heterogeneity (I^2 >50%) was evident, in which case a random-effects model was used. Statistical heterogeneity was assessed using the I^2 statistic. Meta-analysis results were reported as means and 95% confidence intervals (CIs). Analyses were performed in Review Manager (RevMan V.5.3, The Cochrane Collaboration). Subgroup meta-analysis stratified by different aspects/components of cardiopulmonary capacity and quality of life were performed. A p-value<0.05 was considered to indicate statistical significance.

Results

Study Selection

The database and reference list searches identified 2,720 unique references for possible inclusion. Review of the titles and abstracts identified 194 for full-text review, of which, 11 publications met the criteria for inclusion (Figure 1) [33–43].

Study Characteristics

The 11 studies that were appraised included 1,797 patients with coronary artery disease, who had undergone coronary artery bypass grafting, valvular surgery or a combination of both procedures [33–43]. Three (3) studies were randomised controlled trials [34,36,38] and eight were experimental trials [33,35,37,39–43]. Of the three randomised controlled trials, two shared common outcome data [34,36], and therefore met the criteria for meta-analysis. A summary of included study characteristics and exercise intervention details are shown in Table 1. Individual quality components and overall quality analysis are shown in Figure A.1. Three (3) studies were deemed of good quality [34,38,41], six of fair quality [33,35–37,39,42] and two of poor quality [40,43]. The weakest areas were the lack of power calculations and reporting of confounding (selection bias). As many studies did not adequately report specific aspects of their study design, they may have been potentially graded as a lower level of quality.

Intervention Exercise Prescription

All 11 studies included aerobic training in their exercise intervention, whilst eight also stated inclusion of resistance training [33,34,37–42]. Program duration varied from 1 week to 6 months, with four studies having implemented a

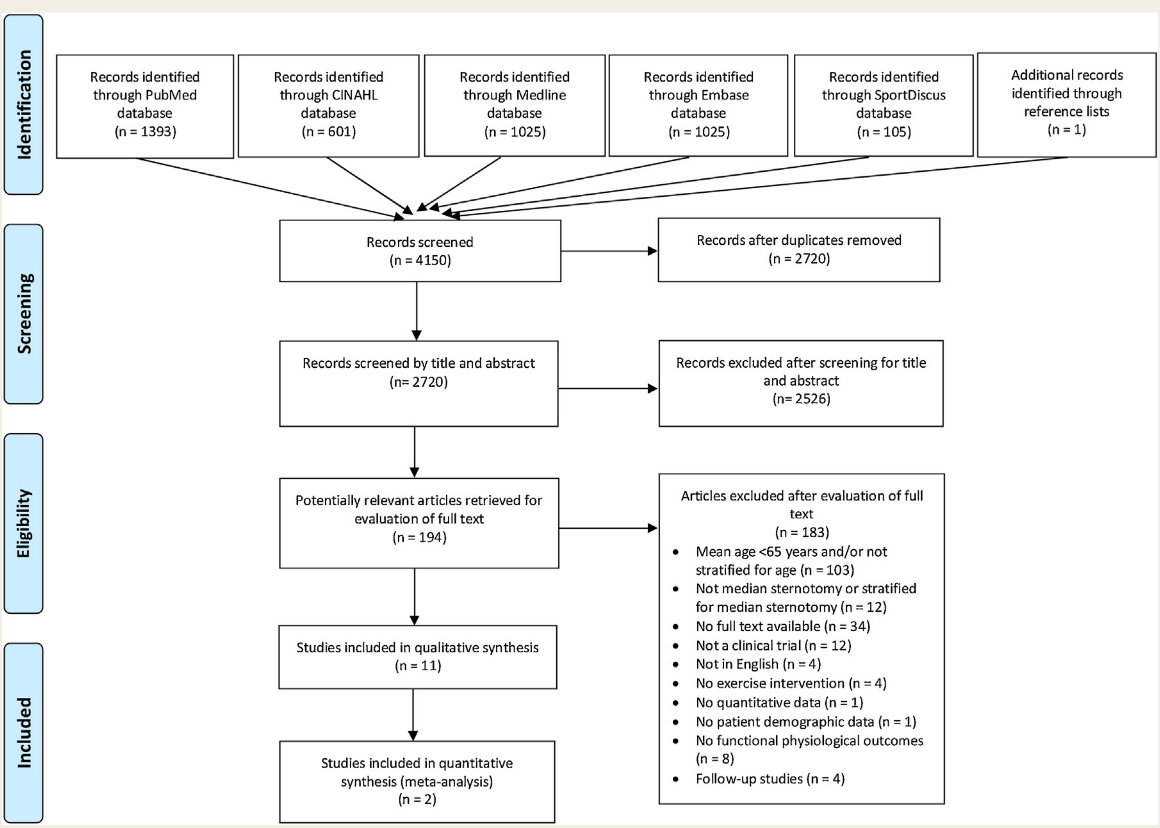

Figure 1 The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart outlining the selection of studies included in the systematic review with meta-analysis.
Abbreviations: CINAHL, Cumulative Index to Nursing and Allied Health Literature; EMBASE, the Excerpta Medica Database.

Table 1 **Study characteristics and exercise intervention details of included studies.**

Author	Country	Design	n=	Age	Cardiac Procedure	Frequency/Program Duration	Time	Intensity	Mode
Brubaker et al. (2003) [33]	USA	Experimental	52	73	CABG	3×/week for 12 weeks	60 minutes	50–70% HR_{max} Borg RPE 11–13/20	AT, RT
Busch et al. (2012) [34]	Germany	RCT	173	78	CABG	5×/week for 3 weeks	~60–90 minutes	1 set of 8-12 repetitions, 60% 1 repetition maximum 13/20 Borg RPE	AT, RT, Calisthenics, Balance
Dolansky et al. (2004) [35]	USA	Experimental	89	76	CABG	3×/week for 12 weeks	60 minutes	*Not stated*	AT
Eder et al. (2010) [36]	Austria	RCT	73	73	CABG	Daily for 4 weeks	~60 minutes	Starting at 50% max. power output	AT, Calisthenics
Macchi et al. (2007) [37]	Italy	Experimental	300	67	CABG VS	Daily for ~8–12 days	120 minutes	65–75% HR_{max}	AT, RT, Stretching
Molino-Lova et al. (2013) [38]	Italy	RCT	140	74	CABG, VS, CABG & VS	3×/week for *Duration not stated*	30 minutes	*Not stated*	AT, RT, Flexibility, Balance, Coordination
Morisawa et al. (2017) [39]	Japan	Experimental	30	76	CABG, VS, CABG & VS	1–2×/day, 5–7×/week for 8 weeks	120 minutes/day	*Not stated*	AT, RT, ADL training
Onishi et al. (2009) [40]	Japan	Experimental	32	66	CABG	1–2×/week for 6 months	60 minutes	Anaerobic threshold Borg RPE 11-13/20	AT, RT, Stretching
Opasich et al. (2010) [41]	Italy	Experimental	240	74	CABG, VS, CABG & VS	1–2×/day for 2–4 weeks	60 minutes	Borg RPE 12–13/20	AT, RT, Flexibility, Balance
Savage et al. (2015) [42]	USA	Experimental	576	65	CABG, VS	3×/week for 3 months	45–60 minutes	70–85% HR_{peak} 65-75% VO_{2peak} Borg RPE 12–14/20	AT, RT
Willoughby et al. (1997) [43]	USA	Experimental	92	69	CABG	3×/week for 12 weeks	30–55 minutes	65-85% HR_{max} Borg RPE 14-16	AT

Abbreviations: RCT, randomised controlled trial; CABG, coronary artery bypass grafting; VS, valve surgery; RPE, rating of perceived exertion; AT, aerobic training; RT, resistance training; ADL, activities of daily living; HR_{max}, heart rate maximum; HR_{peak}, peak heart rate; VO_{2peak}, peak oxygen consumption.

12-week cardiac rehabilitation program [33,35,42,43]. Exercise frequency ranged from daily to once weekly for anywhere between 30 and 120 minutes, with five studies prescribing thrice weekly sessions [33,35,38,42,43] and five stating an exercise session duration of 60 minutes [33,35,36,40,41]. Furthermore, preferred exercise intensity was stated as being a light to moderate intensity, determined by a Rating of Perceived Exertion (RPE) of 11–14/20 on the Borg 6–20 scale, in five studies [33,34,40–42].

Outcome Measures

Eight (8) outcome measures were used to assess the effects of the exercise interventions (Table A.1). Quality of life was assessed using the Medical Outcomes Study Short-form Health Survey (SF-36) [33,35,39,42] or MacNew Heart Disease Health Related quality of life Instrument (MacNew) [34,36]. Six-minute walk test (6MWT) [34,36,37,39,41], short physical performance battery or the timed up and go [34,41] were used to assess functional capacity. Cardiopulmonary exercise testing or graded exercise test (CPET/GXT) [33,34,36,40,42,43] were used to measure exercise capacity. Muscular strength was measured using handgrip dynamometry [39,42] or isometric knee extension [34,39]. Of the eight outcome measures used in the included studies, CPET/GXT is the only outcome measure recommended for use in the Australian [10], American [44] and European [11,45] exercise testing guidelines for cardiac rehabilitation. Cognitive recovery was not monitored or assessed in any of the included studies.

Standard Care Versus Standard Care Plus Additional Training

Two randomised controlled trials shared three common outcome measures, which were CPET/GXT, MacNew and 6MWT. Eder et al. (2010) evaluated the effect of additional aerobic exercise to standard care [36], consisting of 60 minutes daily, for 4 weeks; as opposed to Busch et al. (2012) who evaluated the effect of additional resistance and balance exercise, performed for 60–90 minutes, five times per week for 3 weeks [34]. Both standard care groups performed aerobic and calisthenics exercises. Meta-analysis revealed that a higher volume of exercise, compared to standard care, did not significantly improve cardiopulmonary capacity or health related quality of life. However, functional capacity was significantly improved with the additional of a higher volume of exercise.

Effect of a Higher Volume of Exercise on 6MWT Distance

Two (2) studies compared additional exercise to standard care assessed 6MWT distance as a measure of functional capacity [34,36]. Pooling results across studies indicated that a higher volume of training significantly improves 6MWT distance compared to standard care alone, with no evidence of statistical heterogeneity (mean difference = 26.97 m; 95% CI, 6.96–46.97; p = 0.008; I^2 = 0%) (Figure 2). Furthermore, the addition of resistance and balance training significantly improved functional capacity beyond that of additional aerobic training alone.

Effect of a Higher Volume of Exercise on Cardiopulmonary Capacity

Maximal power output and VO_{2peak} were used to assess cardiopulmonary capacity. Meta-analysis showed that, whilst a higher volume of training was associated with a trend towards improvement in cardiopulmonary capacity, it did not reach statistical significance (mean difference = 0.72; 95% CI, -0.07–1.52; p = 0.07; I^2 = 0%) (Figure 3) [34,36].

Effect of a Higher Volume of Exercise on Quality of Life

Pooling results of both studies [34,36] indicated that, overall, there was no significant difference between standard care and additional exercise in relation to quality of life, assessed using the MacNew (Figure 4). Differences between the two groups were not statistically significant in any domain.

Exercise Prescription Compliance With International Guidelines

Three studies lacked sufficient detail to determine whether they met the Australian, American and European guidelines (Table A.2. Compliance with guidelines and Table A.3. International guidelines) [35,38,39]. The aerobic training

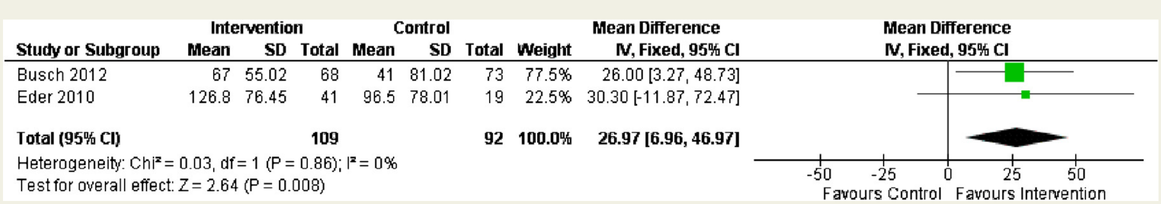

Figure 2 Effect of additional exercise to standard care on 6-minute walk test distance. The solid vertical line indicates no effect. The solid squares indicate the mean difference and are proportional to the weights used in the meta-analysis. The diamond indicates the weighted mean difference, and the lateral tips of the diamond indicate the associated confidence intervals (CI). The horizontal lines represent the 95% CI.

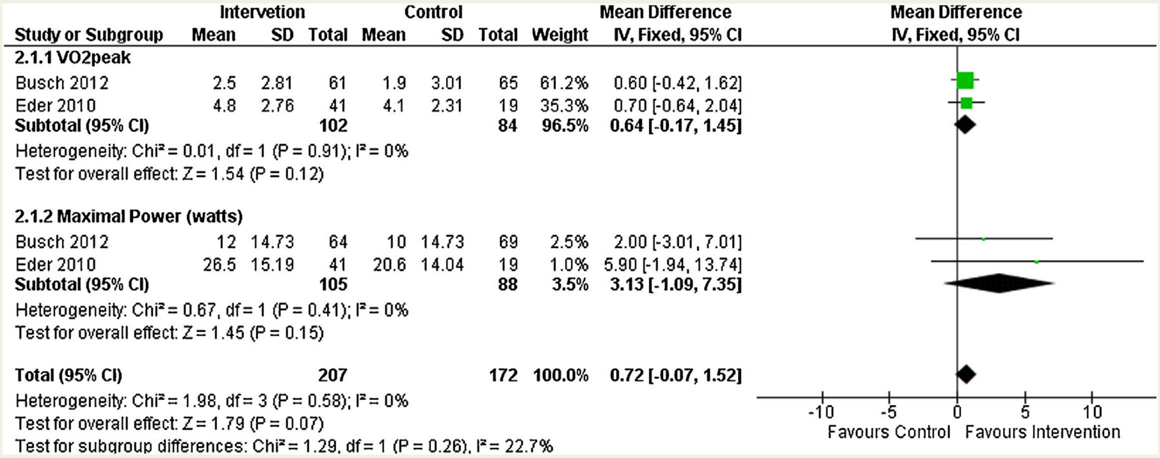

Figure 3 Effect of additional exercise to standard care on cardiopulmonary capacity, assessed via peak oxygen consumption (VO_{2peak}) and maximal power output. The solid vertical line indicates no effect. The solid squares indicate the mean difference and are proportional to the weights used in the meta-analysis. The diamond indicates the weighted mean difference, and the lateral tips of the diamond indicate the associated confidence intervals (CI). The horizontal lines represent the 95% CI.

described in the Onishi et al. [40] study did not meet any of the guidelines, whilst the remaining seven studies met at least two of the three international guidelines for aerobic training [33,34,36,37,41–43]. Despite eight studies reporting resistance training to be included within their program, the intervention details were insufficient to determine whether they adhered to international resistance training guidelines.

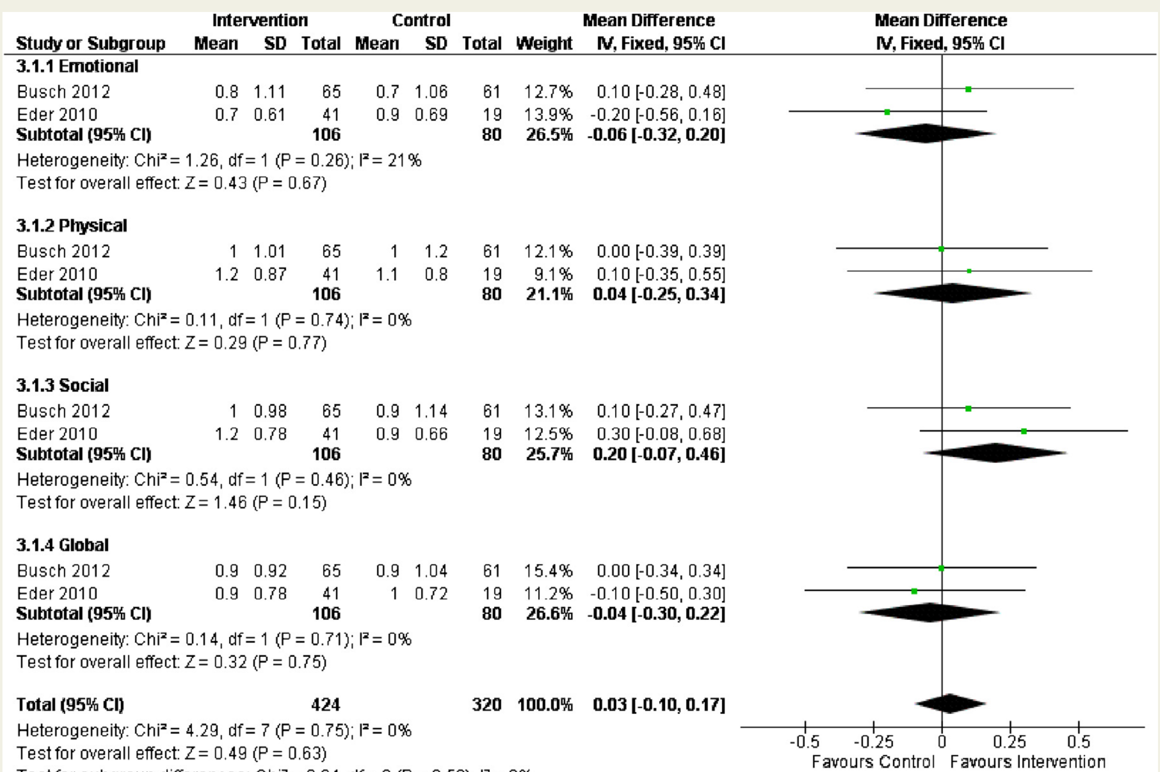

Figure 4 Effect of additional exercise to standard care on quality of life. The solid vertical line indicates no effect. The solid squares indicate the mean difference and are proportional to the weights used in the meta-analysis. The diamond indicates the weighted mean difference, and the lateral tips of the diamond indicate the associated confidence intervals (CI). The horizontal lines represent the 95% CI.

Discussion

Our review showed that aerobic training has been the primary focus of research into the recovery of elderly median sternotomy patients over the past 20 years. However, there was significant variability in the exercise frequency, intensity, program length and session duration prescribed. Furthermore, no consistent outcome measures were used to assess exercise intervention effect, and its impact of function and cognition. Consequently, we were unable to determine the optimal timing and mode of exercise prescription for optimal functional and cognitive recovery following a median sternotomy.

The included studies were conducted in the USA, Germany, Austria, Italy and Japan, which perhaps explains the variance in exercise intervention design. In addition, in this systematic review we found that whilst some studies met aspects of the Australian, American or European cardiac rehabilitation guidelines, none were consistent across all guidelines. This is further explained by the differing guidelines in each geographical region, which is supported by the finding by Price et al. (2016) that there is no consensus on cardiac rehabilitation exercise guidelines, globally [28]. Furthermore, international cardiac rehabilitation guidelines for exercise prescription and exercise testing are not tailored to specific cardiac populations [28]. This poses a potential problem, as cardiac surgeries via median sternotomy have inherent risks that do not exist with less invasive procedures, such as percutaneous coronary interventions, myocardial infarction or acute coronary syndromes. These risks include compromised recovery, sternal complications, wound infection and considerations for the method of sternal closure. In particular, LaPier et al. (2007) have reported that cardiac surgery patients can experience deficits in their physical function for 6–12 months following surgery [46], whilst 15–40% of patients continue to experience permanent cognitive impairment for 3 months or longer after surgery [16–18].

Outcome Measures Used in Cardiac Rehabilitation

The Australian guidelines are the most comprehensive and multi-faceted of the three international guidelines used in this review, including recommended outcome measures for aerobic, strength, function/balance, walking speed and upper limb exercise capacity. Only CPET/GXT is recommended for exercise testing in all three international guidelines (Table A.4.) [10,11,44,45]. Despite the Short Physical Performance Battery (SPPB) and isometric knee strength tests being used in this population, they are not recommended in any of the guidelines [10,11,44,45]. Furthermore, meta-analysis was able to be conducted using results from the MacNew, however, it is not an outcome measure that has been validated in the cardiac surgery population.

Assessment of cognitive function was a key focus of this review, given the high prevalence of postoperative cognitive impairment. However, it is not currently recommended as part of routine cardiac rehabilitation evaluation [10,11,44,45], which is mostly likely why it has not been investigated in this population [10,11,44,45].

Exercise Prescription for Optimal Cognitive Recovery

Despite emerging evidence regarding the impact of cardiac surgery on cognitive function and the benefits of exercise on cognitive recovery, none of the included studies assessed cognitive recovery in relation to cardiac rehabilitation. As such, this review was unable to determine what exercise prescription optimised postoperative cognitive recovery, nor what outcomes measures evaluated cognitive recovery in the elderly cardiac population. Australian guidelines recommend that cognitive assessment should be undertaken ‘if clinically indicated’. However, this is problematic as preoperative cognitive impairment often goes undiagnosed and unrecognised, and the guidelines fail to establish criteria for when cognitive assessment is clinically indicated in this population. Royse et al. (2017) identified that 30–50% of patients show evidence of cognitive impairment, without a pre-existing diagnosis [15]. This is significant, as postoperative cognitive impairment is more prevalent than cerebral complications, such as cerebral infarction and transient ischaemic attacks (1.3%) [47,48]. Moreover, it accelerates risk of progression to dementia by 30% within 7.5 years of surgery [19–21].

There is experimental evidence exercise interventions of only one session per week result in improved cognitive function (memory, focus and reaction time) and may present as an effective primary prevention strategy for cognitive decline and the progression to dementia [22,24]. Moderate intensity resistance training accelerates improvements in cardiovascular fitness, cognitive function, muscle function quality (mass, quality and strength), induction and regulation of growth factors, and modulation of systemic inflammation [22,23]. A decline in cognitive function can not only lead to an increased risk of progression to dementia, but also a greater reliance on family and carers for assistance with activities of daily living. Therefore, monitoring of cognitive recovery should be conducted preoperatively, providing a baseline comparator for postoperative cognitive assessment; and the effect of exercise on cognitive recovery investigated.

Exercise Prescription for Optimal Functional Recovery

This review has found that higher volumes of exercise training can lead to significant improvements in functional capacity, however no differences were found between additional exercise and standard care in improving cardiopulmonary capacity or quality of life. Higher physical activity levels have also been shown to correlate to a 28% reduction in cognitive decline [49]. However, our review found that exercise is typically prescribed at a low-moderate intensity. This finding is supported by a Cochrane review of cardiac rehabilitation for coronary heart disease by Anderson et al. (2016), which found that standard care traditionally involves low intensity aerobic exercise and at times low resistance weights [50]. The commencement of early, moderate-intensity aerobic exercise following cardiac surgery has been shown to be safe, and significantly improves functional and aerobic capacity [7,51]. However, the effects of early moderate intensity resistance training following cardiac surgery are unknown.

Our review noted greater improvements in functional capacity with the addition of resistance and balance training to standard care, as opposed to the addition of aerobic exercise alone. This could suggest that shorter cardiac rehabilitation programs, consisting of both aerobic and resistance training, may lead to greater improvements in postoperative recovery than longer duration aerobic training programs. This finding reflects the Australian, American or European guidelines, which recommend the inclusion of both aerobic and resistance training within cardiac rehabilitation programs (Table A.3.) [10,11,44,45]. However, we were unable to establish whether any of the studies met the international resistance training guidelines, as insufficient exercise prescription detail was reported.

Whilst resistance training may lead to greater improvements in both physical and cognitive postoperative recovery, the findings of this review emphasise the lack of research in this area. Thus, future research is required to investigate the safety and efficacy of specific resistance training following median sternotomy procedures and its effect on cognitive function in the elderly cardiac population.

Study Limitations

Several limitations need to be acknowledged. The searches were limited to publications written in English due to a lack of resources and personnel able to translate. Furthermore, publications were excluded if there was no full text available due to the lack of sufficient detail required for interpretation. This may have led to the exclusion of additional studies, potentially affecting the results of this review. The quality of the included studies also limited the strength of the results of this review. Common weaknesses in study design were the small sample sizes, lack of a control group, randomisation and blinding. Blinding of outcome assessors was inconsistently reported, thus increasing risk of bias and decreasing overall study design quality. The assessment of bias was also limited due to incomplete reporting in all of the study types; therefore the effect of exercise could have potentially been underestimated in this review. Due to the lack of consistency amongst the outcome measures used, and the lack of presence of a control group in the majority of studies, meta-analysis was limited to two studies. The varying international exercise prescription and exercise testing guidelines, and inconsistent outcome measures used, poses a potential challenge for interpretation of future research. These factors limit the strength of the conclusions drawn. Future studies should include reliable and valid outcome measures of cognition and cognitive recovery to evaluate the impact of various modes, intensities, frequencies and durations of exercise programs following cardiac surgery. This is particularly important in the elderly population due to the higher incidence of preoperative and postoperative cognitive impairment. In addition, future research should incorporate large sample sizes with consistent outcome measures, given the robust evidence to support exercise as an intervention in this population.

Conclusion

Higher volumes of exercise training improves physical recovery in the elderly cardiac population compared to standard care, following median sternotomy. However, more clarity is needed in regard to the exercise parameters (frequency, program duration, session duration, mode and intensity) that are most effective in optimising physical and cognitive recovery.

PROSPERO Registration Number

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Competing Interests

Nil to declare.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.hlc.2019.05.098.

References

[1] Mallory G. The speed of healing of myocardial infarction: a study of the pathologic anatomy in seventy-two cases. Am Heart J 1939;18:647.
[2] Wenger NK. Rehabilitation of the coronary patient. Churchill Livingstone; 1992.
[3] Levine SA, Lown B. Armchair treatment of acute coronary thrombosis. J Am Med Assoc 1952;148(16):1365–9.
[4] Newman LB, Andrews MF, Koblish MO, Baker LA. Physical medicine and rehabilitation in acute myocardial infarction. AMA Arch Intern Med 1952;89(4):552–61.
[5] Rose G. Early mobilization and discharge after myocardial infarction. Mod Concepts Cardiovasc Dis 1972;41(12):59–63.
[6] Cardiovascular AAo, Rehabilitation P. Guidelines for cardiac rehabilitation and secondary prevention programs. Human Kinetics; 2004.
[7] Hirschhorn AD, Richards DA, Mungovan SF, Morris NR, Adams L. Does the mode of exercise influence recovery of functional capacity in the early postoperative period after coronary artery bypass graft surgery? A randomized controlled trial. Interact Cardiovasc Thorac Surg 2012;15(6):995–1003.
[8] Quindry JC, Franklin BA, Chapman M, Humphrey R, Mathis S. Benefits and risks of high-intensity interval training in patients with coronary artery disease. Am J Cardiol 2019.
[9] Taylor JL, Holland DJ, Spathis JG, Beetham KS, Wisløff U, Keating SE, et al. Guidelines for the delivery and monitoring of high intensity interval training in clinical populations. Prog Cardiovasc Dis 2019.
[10] HeartOnline. Exercise: Exercise Prescription.[Cited 2018 20 July]. Heart Online Toolkit]. Available from: Canberra: ACT: National Heart Foundation of Australia; 2018, http://www.heartonline.org.au/articles/exercise/exercise-prescription.
[11] Piepoli MF, Corra U, Adamopoulos S, Benzer W, Bjarnason-Wehrens B, Cupples M, et al. Secondary prevention in the clinical management of patients with cardiovascular diseases. Core components, standards and outcome measures for referral and delivery: a policy statement from the cardiac rehabilitation section of the European Association for Cardiovascular Prevention & Rehabilitation. Endorsed by the Committee for Practice Guidelines of the European Society of Cardiology. Eur J Prev Cardiol 2014;21(6):664–81.
[12] Rehabilitation AAoCP. Guidelines for cardiac rehabilitation and secondary prevention programs, 5th ed. Human Kinetics; 2013.
[13] Kolh P, Windecker S, Alfonso F, Collet JP, Cremer J, Falk V, et al. 2014 ESC/EACTS Guidelines on myocardial revascularization: the Task Force on Myocardial Revascularization of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS). Developed with the special contribution of the European Association of Percutaneous Cardiovascular Interventions (EAPCI). Eur J Cardio Thoracic Surgery 2014;46(4):517–92.
[14] Nag N, Turbic A, Solman N, Shardey G, Baker R, Newcomb A, et al. ANZSCTS National annual report, 2016. ANZSCTS National Cardiac Surgery Database Program; 2016.
[15] Royse CF, Saager L, Whitlock R, Ou-Young J, Royse A, Vincent J, et al. Impact of methylprednisolone on postoperative quality of recovery and delirium in the steroids in cardiac surgery trial: a randomized, double-blind, placebo-controlled substudy. Anesthesiology 2017;126(2):223–33.
[16] Moller JT, Cluitmans P, Rasmussen LS, Houx P, Rasmussen H, Canet J, et al. Long-term postoperative cognitive dysfunction in the elderly ISPOCD1 study. ISPOCD investigators. International study of post-operative cognitive dysfunction. Lancet 1998;351(9106):857–61.
[17] Royse AG, Royse CF, Ajani AE, Symes E, Maruff P, Karagiannis S, et al. Reduced neuropsychological dysfunction using epiaortic echocardiography and the exclusive Y graft. Annals Thorac Surg 2000;69(5):1431–8.
[18] Newman MF, Kirchner JL, Phillips-Bute B, Gaver V, Grocott H, Jones RH, et al. Longitudinal assessment of neurocognitive function after coronary-artery bypass surgery. N Engl J Med 2001;344(6):395–402.
[19] Evered LA, Silbert BS, Scott DA, Maruff P, Ames D. Prevalence of Dementia 7.5 years after coronary artery bypass graft surgery. Anesthesiology 2016;125(1):62–71.
[20] Albert MS, DeKosky ST, Dickson D, Dubois B, Feldman HH, Fox NC, et al. The diagnosis of mild cognitive impairment due to Alzheimer's disease: recommendations from the National Institute on aging-Alzheimer's association workgroups on diagnostic guidelines for Alzheimer's disease. Alzheimers Dement 2011;7(3):270–9.
[21] Ellis KA, Szoeke C, Bush AI, Darby D, Graham PL, Lautenschlager NT, et al. Rates of diagnostic transition and cognitive change at 18-month follow-up among 1,112 participants in the Australian Imaging, Biomarkers and Lifestyle Flagship study of ageing (AIBL). Int Psychogeriatr 2014;26(4):543–54.
[22] Liu-Ambrose T, Nagamatsu LS, Graf P, Beattie BL, Ashe MC, Handy TC. Resistance training and executive functions: a 12-month randomized controlled trial. Arch Intern Med 2010;170(2):170–8.
[23] Borde R, Hortobagyi T, Granacher U. Dose-response relationships of resistance training in healthy old adults: a systematic review and meta-analysis. Sports Med 2015;45(12):1693–720.
[24] Vaynman S, Ying Z, Gomez-Pinilla F. Hippocampal BDNF mediates the efficacy of exercise on synaptic plasticity and cognition. Eur J Neurosci 2004;20(10):2580–90.
[25] Cotman CW, Berchtold NC, Christie L-A. Exercise builds brain health: key roles of growth factor cascades and inflammation. Trends Neurosci 2007;30(9):464–72.
[26] Tse L, Bowering JB, Schwarz SKW, Moore RL, Sztramko R, Barr AM. Incidence and risk factors for impaired mobility in older cardiac surgery patients during the early postoperative period. Geriatr Gerontol Int 2015;15(3):276–81.
[27] Durstine JL, Painter P, Franklin BA, Morgan D, Pitetti KH, Roberts SO. Physical activity for the chronically ill and disabled. Sports Med 2000;30(3):207–19.
[28] Price KJ, Gordon BA, Bird SR, Benson AC. A review of guidelines for cardiac rehabilitation exercise programmes: is there an international consensus? Eur J Prev Cardiol 2016;23(16):1715–33.
[29] Ades PA. Cardiac rehabilitation and secondary prevention of coronary heart disease. N Engl J Med 2001;345(12):892–902.
[30] Redfern J, Maiorana A, Neubeck L, Clark AM, Briffa T. Achieving coordinated secondary prevention of coronary heart disease for all in need (SPAN). Elsevier; 2011.
[31] Law MC, MacDermid J. NJ: Slack Incorporated. In: Evidence-based rehabilitation: a guide to practice: Thorofare. Third edition, 2014;2014.
[32] Hooper P, Jutai JW, Strong G, Russell-Minda E. Age-related macular degeneration and low-vision rehabilitation: a systematic review. Can J Ophthalmol 2008;43(2):180–7.
[33] Brubaker C, Witta EL, Angelopoulos TJ. Comparison of changes in exercise tolerance and quality of life between congestive heart failure and coronary artery bypass graft patients following a hospital-based cardiac rehabilitation program. J Exerc Physiol 2003;6(1):18.
[34] Busch JC, Lillou D, Wittig G, Bartsch P, Willemsen D, Oldridge N, et al. Resistance and balance training improves functional capacity in very old participants attending cardiac rehabilitation after coronary bypass surgery. J Am Geriatr Soc 2012;60(12):2270–6.
[35] Dolansky MA, Moore SM. Effects of cardiac rehabilitation on the recovery outcomes of older adults after coronary artery bypass surgery. J Cardiopulm Rehabil 2004;24(4):236–44.
[36] Eder B, Hofmann P, von Duvillard SP, Brandt D, Schmid JP, Pokan R, et al. Early 4-week cardiac rehabilitation exercise training in elderly patients after heart surgery. J Cardiopulm Rehabil Prev 2010;30(2):85–92.
[37] Macchi C, Fattirolli F, Lova RM, Conti AA, Luisi ML, Intini R, et al. Early and late rehabilitation and physical training in elderly patients after cardiac surgery. Am J Physical Med Rehabil 2007;86(10):826–34.
[38] Molino-Lova R, Pasquini G, Vannetti F, Paperini A, Forconi T, Polcaro P, et al. Effects of a structured physical activity intervention on measures of physical performance in frail elderly patients after cardiac rehabilitation: a pilot study with 1-year follow-up. Intern Emerg Med 2013;8(7):581–9.
[39] Morisawa T, Ueno K, Fukuda Y, Kanazawa N, Kawaguchi H, Zaiki R, et al. Significance of sequential cardiac rehabilitation program through inter-hospital cooperation between acute care and rehabilitation hospitals in elderly patients after cardiac surgery in Japan. Heart Vessels 2017;32(10):1220–6.
[40] Onishi T, Shimada K, Sunayama S, Ohmura H, Sumide T, Masaki Y, et al. Effects of cardiac rehabilitation in patients with metabolic syndrome after coronary artery bypass grafting. J Cardiol 2009;53(3):381–7.
[41] Opasich C, Patrignani A, Mazza A, Gualco A, Cobelli F, Pinna GD. An elderly-centered, personalized, physiotherapy program early after cardiac surgery. Eur J Cardiovasc Prev Rehabil 2010;17(5):582–7.
[42] Savage PD, Rengo JL, Menzies KE, Ades PA. Cardiac rehabilitation after heart valve surgery: comparison with coronary artery bypass graft patients. J Cardiopulm Rehabil Prev 2015;35(4):231–7.
[43] Willoughby DS, Roozen M, Barnes R. Effects of aerobic exercise on the functional capacity and cardiovascular efficiency of elderly post-CABG patients. J Aging Phys Act 1997;5(2):87.
[44] Pescatello LS. ACSM's guidelines for exercise testing and prescription, Ninth edition, Philadelphia: Wolters Kluwer/Lippincott Williams & Wilkins Health; 2014, 2014.

[45] Corra U, Piepoli MF, Carre F, Heuschmann P, Hoffmann U, Verschuren M, et al. Secondary prevention through cardiac rehabilitation: physical activity counselling and exercise training: key components of the position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation. Eur heart J 2010;31(16):1967–74.

[46] LaPier TK. Functional status of patients during subacute recovery from coronary artery bypass surgery. Heart Lung 2007;36(2):114–24.

[47] Ahlgren E, Aren C. Cerebral complications after coronary artery bypass and heart valve surgery: risk factors and onset of symptoms. J Cardiothorac Vasc Anesth 1998;12(3):270–3.

[48] Roach GW, Kanchuger M, Mangano CM, Newman M, Nussmeier N, Wolman R, et al. Adverse cerebral outcomes after coronary bypass surgery. Multicenter Study of Perioperative Ischemia Research Group and the Ischemia Research and Education Foundation Investigators. N Engl J Med 1996;335(25):1857–63.

[49] Hamer M, Chida Y. Physical activity and risk of neurodegenerative disease: a systematic review of prospective evidence. Psychol Med 2009;39(1):3–11.

[50] Anderson L, Oldridge N, Thompson DR, Zwisler AD, Rees K, Martin N, et al. Exercise-based cardiac rehabilitation for coronary heart disease: cochrane systematic review and meta-analysis. J Am Coll Cardiol 2016;67(1):1–12.

[51] Doyle M, Indraratna P, Brown MM. Early aerobic exercise after coronary artery bypass surgery: a systematic review. Heart Lung Circ 2017;26 (Supplement 3):S365.