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Review

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Impact of exercise training in patients after CHD surgery: a systematic review and meta-analysis of randomised controlled trials

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Abstract

Background: The goal of this meta-analysis is to evaluate the effects of exercise training on long-term health and cardiorespiratory fitness in participants with CHD after surgery and to investigate the optimal type of exercise training for post-operative patients and how to improve adherence to it. *Methods:* We searched the Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, and Web of Science from the date of the inception of the database through August 2021. *Results:* Altogether, 1424 records were identified in the literature search. Studies evaluating outcomes between exercise training and usual care among post-operative patients with CHD were included. The assessed outcomes were quality of life and cardiorespiratory fitness. We analysed heterogeneity by using the I^2 statistic and evaluated the evidence quality according to the recommendation by the Cochrane Collaboration. Nine randomised controlled trials were included. The evidence showed that exercise interventions increased peak oxygen consumption (mean difference = 2.29 [95% CI 0.43, 4.15]; $p = 0.02$, $I^2 = 0\%$). However, no differences in scores of health-related quality of life and pulmonary function were observed between the experimental and control groups. *Conclusions:* In conclusion, participation in a physical exercise training programme was safe and improved fitness in patients after surgery for CHD. We recommend that post-operative patients with CHD participate in physical exercise training. Additional research is needed to study the various forms of exercise training and their impact on quality of life.

In the current era, the proportion of children and adolescents with CHD surviving into adulthood has dramatically increased due to medical and surgical remarkable progress,[1,2] which has resulted in patients after CHD surgery showing long-term morbidity as reflected by reduced health-related quality of life,[3] cardiopulmonary fitness,[4] and activity declined with age.[5]

As we know, exercise training is an efficient way of improving aerobic capacity and pulmonary function in children and adolescents after the surgical procedure.[6] And exercise is not only a way for assessment but also considered therapy for CHD post-operative patients.[7] Moreover, the American Heart Association recognises that patients with CHDs should emphasise the importance of daily physical activity and decreasing sedentary behaviour as appropriate for the patient's clinical status.[8] Furthermore, children and adults are recommended to perform moderate to vigorous exercise for ≥60 minutes a day, even in patients with CHD after surgery by current public health guidelines.[9]

Few studies have focused on the effects of physical activity interventions for people after surgery for CHD.[10–17] However, these studies included small numbers of patients and had different conclusions, which made the exact effects of physical activity not sure. Additionally, a systematic review mainly focused on cardiorespiratory fitness and health-related quality of life,[18] although people with CHD were included, which has no post-operative participants. Indeed, due to a lack of knowledge of the exercise training for people with CHD, specialist paediatric cardiac clinics' physical activity recommendations are not adequately discussed. And to our knowledge, there were few systematic reviews and meta-analyses of randomised clinical trials that have discussed the optimal type of exercise training and how to improve adherence to exercise training in post-operative CHD patients thus far.

This study aimed to systematically review the published controlled trials to evaluate the effects of exercise training on long-term health and cardiorespiratory fitness in participants with CHDCHD after surgery and to investigate the optimal type of exercise training for post-operative patients and how to improve adherence to it.

Materials and method

This review was completed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines[19] and is registered with PROSPERO (CRD42021284613).

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Eligibility criteria

Eligible studies of this report met all following criteria: (1) reported paediatric (5 to 18 years old) or adult populations (>18 years old) after surgery for CHD; (2) should be exercise training as the intervention; (3) were randomised controlled trials; (4) compared to standard/usual care in individuals after surgery for CHD.

The main outcomes of interest were long-term health quality, as the quality of life determined by the Short-Form 36 item [SF-36] health survey and CHD-TNO/AZL Adult Quality of Life [CHD-TAAQOL] questionnaire, and cardiorespiratory fitness measured by peak oxygen consumption (peak VO_2, ml/kg/min).

Information sources and search strategy

Two independent authors (M.Y He and W. Zhang) searched The MEDLINE (accessed through PubMed), EMBASE, the Cochrane Library, and Web of Science were searched on 14 August 2021 for relevant studies, using the same unique search algorithm for each database, which were published up to July 2021 without any language restrictions. Search terms using a controlled vocabulary (Mesh terms and entry terms for MEDLINE) included three parts: study design, participants, and interventions. Box 1 (Supplementary File) lists the Mesh and entry words that were utilised.

Study selection

Duplicate articles were removed in the first step. Two investigators (M.Y He and W. Zhang) independently screened titles and abstracts for inclusion from the remaining references. Full texts and results were then retrieved and separately reviewed by the same reviewers for eligibility according to inclusion and exclusion criteria. Disagreements can be settled by discussion or consulting with the third author (Q. Wang).

Data extraction and analysis

Two authors (M.Y. He and W. Zhang) developed a data extraction form independently and extracted data from published reports, taking into account the following study characteristics: participants, such as average age and gender, intervention description, such as sample size, frequency, intensity, duration, and follow-up time, and outcomes. Any further information was obtained from the original authors by e-mail.

Quality of meta-analysis evidence

The quality of evidence was independently evaluated by two researchers (M.Y He and W. Zhang) according to the Cochrane Risk of Bias tool, which includes selection bias, performance bias, detection bias, attrition bias, reporting bias, and other biases.[20]

Statistical assessment

All included studies were assessed using Review Manager Version 5.4 (Cochrane Collaboration) and Stata/MP version 16.0. The I^2 test was used to assess the degree of heterogeneity among the results, with values ≥50% indicating significant heterogeneity. Fixed effects models were employed for no or low heterogeneity, whereas random-effects models were used for moderate and high heterogeneity. Continuous data were analysed as mean differences and 95% confidence intervals (CIs), as well as forest plots. In several studies, where data were reported as medians and interquartile ranges, we replaced them with means and standard deviations according to validated equations.[21,22] To assess the contribution of individual studies to the degree of heterogeneity, a sensitivity analysis was performed, which comprised generating the meta-analysis estimate after excluding one study at a time. Egger's regression asymmetry test and a funnel plot were used to evaluate publication bias. A p-value <0.05 was deemed statistically significant

Results

Characteristics of population

1424 abstracts were identified after the initial search, from which 67 were considered as possibly relevant and retrieved for full text assessed according to eligibility criteria. We have shown the PRISMA flow diagram of studies in Figure S1.

This study contained just 8 randomised controlled trials[10,12–17,23] with a total of 371 participants, including both genders. Correction of tetralogy of Fallot, Fontan circulation, and atrial switch technique or a systemic right ventricle for transposition of the great arteries were all included in the CHD surgical research. And Tetralogy of Fallot, Fontan, and transposition of the great arteries are the most common kinds of CHD. Table 1 shows that the samples in the final 8 papers ranged from 17 to 93, with a mean age of 13 to 40.1 years. The participants in three randomised controlled trials were adolescents and youngsters, whereas the participants in the other five randomised controlled trials were adults.

Exercise training

The information on exercise training for included studies was pooled into Tables 1 and 2.

Type and intensity

There were several sorts of exercise training, but they mostly engaged in aerobic exercise training at home, which primarily consisted of cycling and brisk walking. And peak VO_2 and heart rate, which were monitored using a heart rate monitor, were the primary determinants of their intensity. Only one [randomised controlled trial23] combined aerobic and resistance training, to investigate its effects on the performance and oxygenation of peripheral muscular measured by utilising maximal voluntary contraction, limited time at 50% maximal voluntary contraction, the half time of recovery, and the recovery speed to maximal oxygenation.

Duration

The majority of the included randomised controlled trials had a 12-week follow-up period. One of the studies[12] lasted 10 weeks, while another lasted 24 weeks.[13] Patients of all included randomised controlled trials were followed up right away after the training programme. Training occurred 1–5 times each week, with the most occurring three times per week. Each training session lasted anywhere from 10 to 60 minutes. In one randomised controlled trials, the duration and frequency of the intervention, which was separated into three stages, steadily increased over time.[13]

Supervision and compliance

There were three experiments under the supervision of the instructor and two of them reported a high similarly attendance rate, which was 89%. Three studies with no supervision and only one of them showed a compliance rate of 67.7%. The percentage of expected training units determined from the patient's training regimen was used to calculate training compliance. One of the

Table 1. Characteristics of the included studies

Study (Author, Y)	CHD surgery	Gender (% male)	Age	Sample (I, T)	Outcome measures	Death events	Recruitment
Therrien, 2003[10]	Repaired TOF	55.56	35.0 ± 9.5	9,18	Peak VO_2,	No	40%
Dulfer, 2014[14]	Repaired TOF, Fontan	72.2	15.2	56,93	TAAQOL, SF-36	NP	26%
Westhoff-Bleck, 2013[13]	Atrial switch procedure for TGA	41.94	29.9 ± 3.1	24,48	Peak VO_2	No	41.74%
Duppen, 2015a[15]	Repaired TOF	76.00	15 ± 3	56,93	Peak VO_2, HRQOL	NP	25.69%
Duppen, 2015b[15]	Fontan						
Winter, 2012[12]	systemic right ventricle for TGA	38	31 ± 10	28,54	PeakVO_2, SF-36, CHD-TAAQOL	No	38.30%
Novakovic, 2018a[17]	Repaired TOF	22	36.2 ± 6.8	10,30	Peak VO_2, SF-36	No	48.29%
Novakovic, 2018b[17]	Repaired TOF	44	40.1 ± 10.4	10,30	Peak VO_2, SF-36		
Moalla, 2012[23]	Repaired TOF, Fontan, surgical operation for TGA	NP	13.0 ± 1.4	10,18	Peak VO_2	NP	NP
Avila, 2016[16]	Repaired TOF	69	35 (28, 42)	13,17	Peak VO_2,	No	NP

The mean± standard deviation, median (interquartile range), or mean presented of age. I: intervention; T: total; SD: standard deviation; Peak VO_2: peak oxygen consumption; TOF: tetralogy of Fallot; HR: heart rate; TAAQOL: TNO/AZL Adult Quality of Life; SF-36: Short-Form 36 item; TGA: transposition of the great arteries; HRQOL: Health-related quality of life; NP: not reported. Death events included the development of arrhythmias, bodily injury, need for hospitalisation, cardiac arrest, and death.

randomised controlled trials involved hospital and home aerobic exercise sessions, with a supervised exercise programme in the hospital and a 73% adherence rate. Patients were often reached via phone calls or e-mails from researchers to ensure adherence to the training.

Recruitment and death event

The recruiting data were presented in six of the nine papers, with participation rates ranging from 26% to 48.29%. The time-consuming nature of the research, according to Duppen et al,[15] was the major reason for not participating. The drop-out rate was shown in 7 out of 8 publications, ranging from 0% to 28.57%. Personal, job-related, and experiment itself (rejections of second examination and training programme) factors were among them. There were no adverse events discovered. During the experimental period, both Westhoff-Bleck et al[13] and Therrien et al[10] found non-malignant arrhythmias during the experimental period. There was no need for intervention in any of these incidents and they were unrelated to exercise training.

Outcome results

Quality of life

Three studies used validated questionnaires to measure the quality of life.[12,14,17] was no statistically significant change between the exercise training and the control group on SF-36 (physical component and mental component) and CHD-TAAQOL (impact, symptoms, and worries) scales, as demonstrated in Figure S2. Continuous training was exclusively related to gains in the mental domain of the SF-36, according to Novakovic et al.[17]

Cardiorespiratory fitness

Maximal cardiorespiratory fitness was assessed in seven out of eight (87.5%) studies using peak VO_2. There was a slight but significant increase in the peak VO_2 of 2.29 ml/kg/min ([95%CI, 0.43,4.15], $I^2 = 0\%$, n = 238) between the experimental and control groups (Fig 1).

Sensitivity analysis

We did not undertake sensitivity analyses since there was no heterogeneity in the quality of life and peak VO_2 between the exercise and control groups.

Subgroup meta-regression analysis

We ran a subgroup analysis of peak VO_2 and found no significant difference both the training duration of 12 weeks (mean difference = 1.95[95%CI −0.50 to 44.40], $I^2 = 0\%$, n = 161) and patients of repaired TOF only (mean difference = 1.90[95%CI −1.02 to 4.83], $I^2 = 0\%$, n = 113, as illustrated in Figure S3.

Publication bias

Publication bias of including randomised controlled trials was evaluated by Egger's test and graphed with funnel plots as shown in Figure S4. There was no evidence of publication bias for peak VO_2 in the present study (p = 0.804).

Risk of bias

The risk of bias in outcomes across all studies was low or unclear located in Figure S5. However, three studies had a high risk of bias in allocation concealment (selection bias) because of non-blinded allocation[17] and recruitment significantly depended on patients' willingness[10,12] though all included studies were randomised clinical trial studies. Furthermore, the authors reported poorly the details regarding whether participants and personnel were blinded and information regarding whether investigators were blinded, which resulted in unclear biases in performance and detection.

Discussion

The main result of this systematic review and meta-analysis shows that peak VO_2 was increased after exercise training for post-operative patients with CHD when compared to usual care and it was certainly safe for these patients. However, there were little

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Table 2. Characteristics of the experimental intervention in the trials included in the review

Study (Author, Y)	Intervention	Modality	Intensity	Duration of each session	Follow-up time	Frequency (*per week)	Supervision	Drop-out	Compliance
Therrien, 2003[10]	Aerobic and home-based exercise programme	Cycling and brisk walking	60 to 85% of baseline peak VO2/maximal HR	50 min/30 min	12 weeks	3	Supervised/ unsupervised	22.22%	73%
Dulfer, 2014[14]	Aerobic exercise programme	Brisk walking /jogging/running/ bicycle/dynamic play	60–70 % HR resting	60 min	12 weeks	3	Yes	28.57%	89%
Westhoff-Bleck, 2013[13]	Aerobic exercise training	Cycling	HR corresponds to 50% of peak oxygen uptake	Phase I:10/15 min Phase II:15/20 min Phase III:30 min	24 weeks	Phase I (3) Phase II (5) phase III (5)	No	20.8%	67.7%
Duppen, 2015a[15]	The standardised aerobic exercise training programme	Brisk walking /jogging/running/bicycle exercises/dynamic play	60–70 % HR resting	60 min	12 weeks	3	Yes	3.2%	89%
Duppen, 2015b[15]									
Winter, 2012[12]	Home-based aerobic consecutive exercise training	Step aerobics	75%–90% of maximal heart rate	42 min	10 weeks	3	No	14.29%	NP
Novakovic, 2018a[17]	High-interval training programme	Cycling or speed walking	80% of HR peak in high-intensity exercise	42 min	12 weeks	2–3	NP	NP	92.90%
Novakovic, 2018b[17]	The moderate continuous training programme	Cycling or speed walking	70% of HR peak in continuous intensity	42 min	12 weeks	2–3	NP		89.20%
Moalla, 2012[23]	Home-based aerobic cycling training	Cycling	HR equal VAT	60 min	12 weeks	3	No	0	NP
Avila, 2016[16]	combined aerobic and resistance training	Combined dynamic and resistance training	70%–80% of maximal HR	60 min	12 weeks	1–2	Yes	0	NP

Peak VO_2: peak oxygen consumption; HR: heart rate; NP: not reported; VAT: ventilatory anaerobic threshold. The drop-out rate is just for the intervention group.

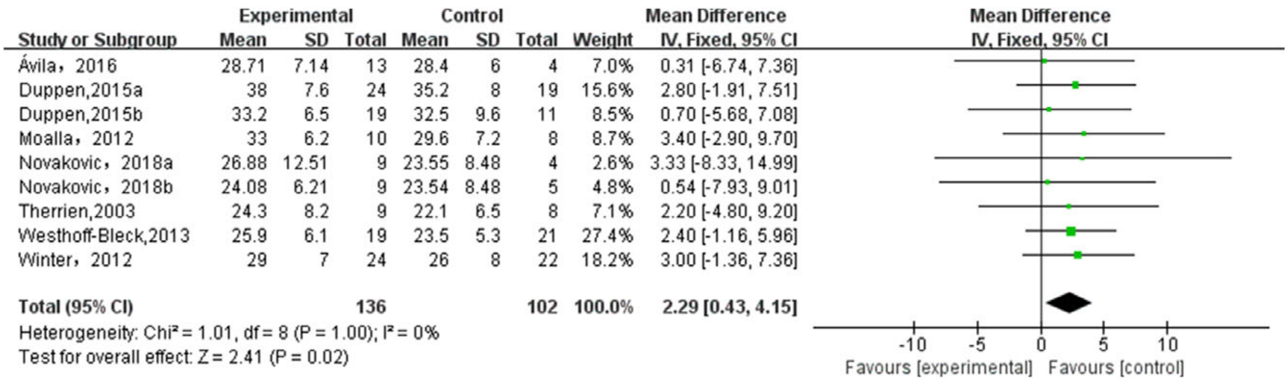

Figure 1. Exercise training versus controls: VO_2 peak. Review Manager (RevMan) version 5.

or no effects on questionnaire scales of quality of life (HRQOL and CHD-TAAQOL). Additionally, the risk of bias presented in the study was low or unclear, and no publication bias was found.

The maximal measure of CRF is one of the strong and independent predictors of hospitalisation and morbidity.[24] In the current study, maximal cardiorespiratory fitness increased by a mean difference of 2.29 ml/kg/min. Multi-adjusted Cox regression showed a 15% lower risk for the diagnosis of or death from coronary heart disease, or coronary revascularisation per 3.5 ml/kg/min higher peak VO_2 in a healthy and fit population.[25] Currently, there is no consensus regarding what the prognostic implication is of an increase of 2.29 ml/kg/min in post-operative patients with CHD. However, our findings indicated an increase in peak VO_2 compared with the control group, which was consistent with a recent systematic review of exercise training in patients with CHD[18] and Gomes-Neto et al.[6] Subgroup analysis reported no difference in peak VO_2, and the small sample size may be one of the reasons.

Patients after surgery for CHD have significantly lower HRQOL in physical health, and psychosocial health summary scores than healthy controls, according to a cross-sectional survey.[26] We assessed it using SF-36, which were public domain questionnaires that included physical and mental components, and CHD-TAAQOL which assessed cardiac-specific aspects of patients with CHD including worries, symptoms, and impact score. No significant differences on the SF-36 and CHD-TAAQOL scales were found between the exercise training and control group. We speculated that this may be due to the small sample size and the fact that most patients had the best-possible scores at baseline. Conversely, Dulfer et al[14] reported that participation in an exercise programme improved the HRQOL of post-operative patients with CHD, especially in those with low baseline HRQOL.

There appears to be agreement on the intensity and duration of the exercise programme, which was primarily based on heart rate at peak VO_2 and lasted 12 weeks. And following it under the supervision of a trained physiotherapist seems to be preferable to no supervision. However, there are complicated and different elements of physical activity and family social support was one of the identified correlated variables.[27] Sutherland et al. also claimed that home exercise training programmes might be just as beneficial as hospital-based instruction.[28] Furthermore, as we know, home-based programmes can make an individual adaptation to training programmes easier, and parents play a significant part in their children's capacity to adapt to living with a chronic illness. Therefore, family-based exercise training involving parents should be introduced into the follow-up rehabilitation of post-operative CHD patients.

This meta-analysis has the benefit of including only randomised controlled studies, which helped to eliminate bias. The outcomes of this study demonstrated potential external and ecological validity in all age categories, kinds of CHD, and modalities of physical activity intervention. Indeed, we were able to examine the influence of exercise training on peak VO_2 and quality of life in a larger research sample and correct various confounding factors using a meta-analysis of diverse publications.

The current study, however, has some possible shortcomings. Firstly, the age range is wide, encompassing both children and adults, which might be addressed with bigger sample size and stratified analysis. Second, participant and personnel blinding, as well as outcome evaluation, were insufficiently recorded. It is impossible to blind an exercise intervention, and just a few writers have attempted to blind trial staff to participant allocation during randomisation. What's more, the quartiles of some values were transformed to standard deviation, according to Wan et al[21] and Luo et al[22]; nonetheless, a possible bias should not be ruled out. Finally, while all of the intervention groups received exercise training, the precise intervention measures used in each trial differed. As a result, the consequences of various treatments could not be ruled out nor could the potential impact be explained.

Conclusion

Our meta-analysis revealed that exercise training should be considered an efficient method of improvement of peak VO_2 in patients after surgery for CHD. Participation in the physical exercise training programme was safe. We recommend that post-operative patients with CHD participate in physical exercise training. To study different forms of exercise training and their effects on quality of life, further research is urgently needed, especially bigger samples and well-designed prospective randomised controlled trials.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/S1047951122003201

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Conflicts of interest. None.

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