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A systematic review of exercise trials post stroke

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Objective: To perform a systematic review of exercise trials post stroke.
Design: A systematic review of controlled clinical trials.
Search strategy: MEDLINE, EMBASE, CINAHL, Amed, Sports Discus, Cochrane controlled trials register and PEDro were searched for relevant trials.
Inclusion criteria: Studies – randomized or quasi-randomized controlled clinical trials. Participants – Adults of any age with a clinical diagnosis of stroke. Interventions – Any cardiovascular exercise intervention aimed at improving cardiovascular fitness and/or function.
Outcomes: Impairment: gait speed, strength, endurance, balance, flexibility, tonus and exercise capacity. Disability: global dependency, functional independence. Extended activities of daily living. Quality of life. Death.
Data collection and analysis: Two independent reviewers categorized selected trials, documented the methodological quality and extracted the relevant data. Comparisons of cardiovascular exercise interventions versus no cardiovascular intervention were made. Statistical comparisons were carried out using a random effects model to calculate standardized mean differences.
Results: We identified three eligible trials. Small numbers and heterogeneous outcomes limited the analyses and comparisons. Based on the limited data available, we found that cardiovascular exercise post stroke was no better than no exercise with respect to disability, impairment, extended activities of daily living, quality of life and death.
Conclusion: Insufficient evidence was identified to establish if cardiovascular exercise has a positive effect on disability, impairment, extended activities of daily living, quality of life and case fatality post stroke.

Introduction

Survivors of stroke often have poor exercise capacity.[1,2] Although this may in part be due to the normal ageing process,[3] the exercise capacity of stroke patients has been found to be approximately 40% below that of age- and gender-adjusted norms for sedentary individuals.[4] Stroke patients often have reduced mobility, and a reduction in exercise capacity can occur secondary to immobility.[5]

The energy expenditure required by patients with stroke to carry out daily functions, such as walking, is significantly greater than the normal

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energy expenditure for these tasks.[6,7] Hence limited exercise capacity is likely to further disable stroke patients in their ability to carry out routine functional tasks and extended activities of daily living. Furthermore, the documented reduction in cardiovascular fitness[2,8] may contribute to the increased risk of further stroke or myocardial infarction that stroke patients have in comparison with normal subjects.[9] Exercise has been proven to be beneficial post myocardial infarction in terms of reduction death and increasing revascularization.[10] Epidemiological studies suggest that up to 70% of stroke patients have some form of coexisting heart disease.[11]

The documented reduction in cardiovascular fitness leads to the hypothesis that cardiovascular training could be beneficial to patients following stroke. However, physical rehabilitation post stroke has tended to concentrate on improving quality of movement and function in reduction of disability[12,13] and cardiovascular training is not currently a routine part of the process of stroke rehabilitation. Further investigation is essential to determine whether cardiovascular exercise training could benefit stroke patients in terms of impairment and handicap, and whether it should be a routine component of the rehabilitation process.

We carried out a systematic literature review of randomized and quasi-randomized controlled trials in order to determine the effects of cardiovascular exercise training on selected outcomes.

Methods

Extensive literature searching was carried out to identify controlled clinical trials (randomized and quasi-randomized) of cardiovascular exercise post stroke. MEDLINE, EMBASE, CINAHL, Amed, Sports Discus, Pedro and the Cochrane controlled trials register were searched from 1985 until October 2001, using key words relating to stroke combined with key words relating to the possible interventions ('exercise therapy', 'exercise', 'rehabilitation', 'sports medicine', 'sports medicine mp', 'physical fitness', 'class$.tw', 'strength$.tw', 'train$.tw').

The full search strategy is available from the authors. The reference lists of all trials found using the search were searched for any relevant trials.

Identification of relevant trials

One reviewer read the titles of the identified references and eliminated obviously irrelevant studies. The abstracts of the remaining studies were obtained and, based on the inclusion criteria (Table 1), one reviewer ranked these as relevant, irrelevant or unsure. A second reviewer then independently ranked these trials using the same method. Any disagreements were resolved through discussion between the reviewers.

Two independent reviewers documented the methodological quality of studies and extracted relevant data. The following quality criteria were documented: randomization (allocation concealment); baseline comparison of groups; blinding of subjects and providers of care to treatment group; blinding of outcome assessor; reliability of outcome measures; possibility of contamination/cointervention by therapists providing intervention; completeness of follow-up; other potential confounders.

Data extraction was undertaken to document where possible: trial setting (i.e., hospital, community); details of participants (i.e., age, gender, side of hemiplegia, stroke classification, comorbid conditions, premorbid disability); inclusion and exclusion criteria; all assessed outcomes. Authors were contacted for clarification, or to provide missing data, where necessary.

Analysis

Comparisons were planned as cardiovascular exercise intervention versus (a) no intervention, (b) placebo exercise, (c) usual care. In addition, a number of subgroup analyses were planned to determine the relative efficacy of the various types of cardiovascular exercise (e.g., cycle ergometer, one-to-one exercise, treadmill training) and the effects of training in relation to length of time since stroke.

All outcomes analysed were presented as continuous data. Standardized mean differences and 95% confidence intervals were calculated using a random effects model.

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Table 1 Inclusion criteria for studies

Types of studies	Controlled trials, where participants were randomly assigned or quasi-randomly assigned Trials with or without blinding of participants, physiotherapists and assessors
Types of participants	Men and women of all ages Diagnosis of stroke defined by scan or medical practitioner
Types of intervention	Cardiovascular intervention aimed at improving cardiovascular fitness and/or function (exercise programme, cycle ergometer, treadmill)
Types of outcome measures	Global dependency Functional independence Gait speed Strength Endurance Balance Flexibility Tonus Exercise capacity Extended ADL Quality of life Death

Results

The electronic searching resulted in 18 934 potentially relevant trials. One reviewer disregarded obviously irrelevant trials from abstract or title. This left 16 potentially relevant trials. Of these 16 trials three were found to meet the criteria. Exclusion of the other 13 trials was primarily on the grounds of methodological quality and two of the trials had mixed pathologies; 11 reports were of nontrial methodologies and two recruited mainly nonstroke pathologies.[4,14–25]

Two of the three included trials compared cardiovascular exercise with no cardiovascular exercise[26,27]; the remaining trial compared cardiovascular exercise with a placebo intervention.[28] The types of cardiovascular exercise investigated were exercise programme[26,27] and cycle ergometer.[28] There were no disagreements between reviewers in terms of inclusion and exclusion criteria.

Details of the methodological quality of the included trials are provided in Table 2.

Details of the cardiovascular exercise interventions and types of participants are given in Table 3.

The three included trials all recorded different outcome measures. Based on the pre-stated list of relevant outcome measures, Table 4 illustrates the outcome measures for which data could be extracted.

The large number of heterogeneous outcome measures reported made it impossible to analyse all the documented data, and limited the potential for combination and comparison of outcome measures. There were insufficient data to carry out the preplanned subgroup analyses.

Data from Teixeira-Salmela *et al.*[26] and Duncan *et al.*[27] could be combined within meta-analysis for gait speed, extended activities of daily living (ADL) and quality of life outcomes; data from Potempa *et al.*[28] and Duncan *et al.*[27] could be combined within a meta-analysis for the functional independence outcomes. These analyses demonstrated that there were no significant differences between patients carrying out cardiovascular exercise and those not carrying out cardiovascular exercise. Standardized mean difference and 95% confidence intervals for each outcome are displayed in Table 4.

Although the meta-analyses demonstrated no significant differences between the outcomes of patients who did or did not carry out cardiovascular exercise, a number of statistically significant effects were reported in the results of the three individual trials. Teixeira-Salmela *et al.*[26]

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Table 2 Methods of included trials

Study	Duncan *et al.* (1998)[27]	Potempa *et al.* (1995)[28]	Teixeira-Salmela *et al.* (1999)[26]
Method of randomization	Randomized in blocks of 10 but does not state method	States randomly allocated but does not state method	States randomly allocated but does not state method
Patient blinded	No	Aware of type of intervention but does not state if explanation given to patient	No
Therapist blinded	No	Not stated	No
Assessor blinded	Yes	Not stated	Not stated
Time of follow-up assessment (used for analysis in review)	12 weeks	10 weeks	10 weeks
Relevant outcome measures reported	*10-metre walk[29] Berg balance scale[30] *36 Health Status Measurement (SF36)[31] *Fugl-Meyer[32] *Barthel[33] *Lawton ADL[34] 6-min walk test[35]	*Fugl-Meyer Maximum oxygen consumption ($V\text{O}_2$max) Weight Heart rate Blood pressure Carbon dioxide production ($V\text{CO}_2$ max) Expiration per minute (VE max) Respiratory exchange ratio (RER) Exercise time	*Gait speed (time to cover central 22 m) *Nottingham Health Profile[36] Pendulum test (Spasticity)[37] Strength *Human activity profile[38] Stair climbing[39]

* denotes outcomes included in the analysis.

reported statistically significantly positive effects of cardiovascular training for all assessed outcomes (gait speed, stair climbing, human activity profile, Nottingham health profile and isokinetic strength) in the intervention group ($p < 0.01$); Duncan *et al.*[27] found significant improvements in motor function ($p < 0.01$) and gait velocity ($p < 0.05$); Potempa *et al.*[28] found significant improvements in $V\text{CO}_2$ ($p = 0.01$), $V\text{O}_2$, workload and exercise time ($p = 0.0001$). Potempa *et al.*[28] also reported that a significant correlation existed between increase in $V\text{O}_2$ max and motor function.

Discussion

This review could not identify compelling evidence that cardiovascular exercise is beneficial to outcome following stroke. However it must be stressed that no evidence of effect is different from evidence of no effect.

Only three small studies met inclusion criteria, providing data from only 75 patients. Use of a large number of heterogeneous outcome measures limited the ability to combine results in meta-analyses. Although the results from the three individual studies do provide encouraging

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evidence that cardiovascular training may be able to improve outcomes in patients with stroke, this evidence is derived from very small numbers of patients carrying out a variety of different exercise programmes, in studies with possible methodological limitations. Further research is required to address the effectiveness of cardiovascular exercise in stroke patients.

Poor methodological quality led to the exclusion of a number of studies, and a lack of reported details (e.g., method of randomization, blinding or assessors, patients and therapists) makes it difficult to fully assess the quality of the included trials. A further limitation of all of the

Table 3 Participants and interventions used in included trials

Study	Duncan *et al.* (1998)[27]	Potempa *et al.* (1995)[28]	Teixeira-Salmela *et al.* (1999)[26]
Nos of subjects *x* = intervention *y* = control	20 *x* = 10 *y* = 10	42 *x* = 19 *y* = 23	13 *x* = 6 *y* = 7
Time post stroke	30–90 days	At least 6 months	Mean time since stroke 6.4 years
Type of intervention	One-to-one supervised exercise	Cycle ergometer	Class
Method of cardiovascular exercise	Exercise intervention within 5 days of baseline testing. Three home visits a week for 8 weeks. Patients then instructed to continue for another 4 weeks • 10-min warm-up • Proprioceptive neuromuscular facilitation or Theraband • Balance exercises 15 min • Upper limb functional activities 15 min • Progressive walking or cycle ergometer to aim for 20 min of sustained exercise	30-min session 3× week First 4 weeks gradually increased from 30% max effort to the 50% of the highest attainable effort for the last 6 weeks. Maximal effort was described as the point of voluntary exhaustion or an expiratory exchange ratio of >1.5.	Three mornings a week 10 weeks 60–90 min Heart rate monitored throughout. Exercise for home. Encouraged to perform these 3 times a week. 5–10-min warm-up – callisthenics mild stretching ROM exercises. Aerobics • Target heart rate (THR)=70% of max heart rate • First 5 weeks increase from 50 to 70% of THR Strength • Hip flex/ext/abduction • Knee flex/extension • Ankle dorsiflexion /plantar flexion
Method of placebo exercise	No exercise Assessed 2× a week to ascertain the patients' activity	10m week programme of passive Range Of Movement (ROM) Exercise	Lag control design
Amount of treatment	10 weeks 3× week 60 min (8 weeks supervised 4 weeks independent)	10 weeks 3× week 30 min per session	10 weeks 3× week 60–90 min

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included studies was the failure to include a long-term (i.e., six months to one year) follow-up to enable assessment of the maintenance of any changes in outcome. Future studies should be careful to address these important areas of methodological quality in order to reduce the potential for the introduction of bias. Any systematic review/meta-analysis is reliant on the quantity and quality of trial data identified. Although the lack of trials identified prevents this review from reaching any clear conclusions regarding the efficacy of cardiovascular exercise

Table 4 Cardiovascular exercise post stroke versus none: results of statistical comparisons

Outcome category	Outcome measures reported	Standardized mean difference (95% CI, random)	Studies with data included in analysis
Global dependency	Barthel Index	Insufficient data, therefore not estimable	
Functional independence	Fugl-Meyer Index	–0.27 (–1.91,1.37)	Duncan *et al.* (1998)[27] Potempa *et al.* (1995)[28]
Gait speed	Gait speed	0.24 (–0.45,0.94)	Duncan *et al.* (1998)[27] Teixeira-Salmela *et al.* (1999)[26]
Strength	Peak torque lower limb	Insufficient data, therefore not estimable	
Endurance	6-min walk test	Insufficient data, therefore not estimable	
Balance	Berg Balance Scale	Insufficient data, therefore not estimable	
Flexibility		Insufficient data, therefore not estimable	
Tonus	Pendulum test	Insufficient data, therefore not estimable	
Exercise capacity	VO_2 max	Insufficient data, therefore not estimable	
Extended ADL	Lawton Scale Human Activities Profile	0.49 (–0.71, 1.69)	Duncan *et al.* (1998)[27] Teixeira-Salmela *et al.* (1999)[26]
Quality of life	SF36 Nottingham Health Profile	1.00(–1.16,3.16)	Duncan *et al.* (1998)[27] Teixeira-Salmela *et al.* (1999)[26]
Death		Insufficient data, therefore not estimable	

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Clinical messages

- There is currently insufficient evidence from controlled clinical trials to conclude that cardiovascular exercise is beneficial for improving outcome following stroke.
- There is an urgent need for further trials to investigate the efficacy of cardiovascular exercise following stroke.

in patients with stroke, this should in no way diminish the importance of this research question or the results of this review.

The efficacy of cardiovascular exercise post stroke remains a clinically important question in terms of a patient's function, exercise capacity, quality of life and risk of future vascular events. This review indicates the need for more, high-quality, randomized controlled trials into the effects of cardiovascular exercise post stroke.

Conclusions

We could not identify evidence from randomized trials to confirm or refute the efficacy of cardiovascular exercise post stroke. Individual studies of cardiovascular exercise post stroke show significant improvements in impairment[26–28] and quality of life.[26] Further research is needed in this important area of stroke rehabilitation.

Future studies should ensure that they clearly define and monitor what is meant by 'cardiovascular exercise' and concentrate on the effects of cardiovascular exercise on function, quality of life and exercise capacity.

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