Research paper

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Arm cycle ergometer for spinal cord injury

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The Research Team are unable to ensure that the information listed below provides an accurate & up-to-date snapshot of these matters

Research question: What is the efficacy of the use of arm ergometer to assist with maximising and maintaining the strength and functions of arms for a person living with a spinal cord injury (complete/incomplete)?

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1. Contents

2. Summary

The arm cycle ergometer (ACE) is an aerobic exercise device suitable for people with limited lower limb function.

There is moderate quality evidence that exercise programs using ACE can improve cardiorespiratory fitness. There is low certainty evidence that ACE is effective for improving upper limb muscle strength, upper limb function and quality of life. This is due to few studies investigating these outcomes and low quality of existing studies.

The majority of studies reviewed report low quality evidence due to small and unrepresentative samples, risk of bias and uncontrolled study designs.

3. Arm cycle ergometer

The arm cycle ergometer or arm crank ergometer is a pedal machine designed for upper limb use. The device may also be called an arm bike, arm cycle or hand cycle, with context differentiating between the stationary exercise machine and the mode of transportation. The terms arm ergometer, upper body ergometer or upper limb trainer are also sometimes used interchangeably with ACE (Picincu, 2020; Alison, 2015; Amanda, 2013), though these terms are technically more general and can include rowing ergometers as well.

ACE is used as an alternative aerobic exercise device for people unable to use equipment designed for the lower limbs. It can also be used as a device to measure cardiovascular fitness in clinical or research contexts (Alison, 2015). ACE can also be found in mainstream gyms and fitness centres (Amanda, 2013).

4. Cardiorespiratory fitness

While there is notably varying quality of reviews, most studies find significant improvements in cardiorespiratory fitness following ACE intervention. The most comprehensive systematic review of the effectiveness of ACE for people with Spinal Cord Injury (SCI) found moderate certainty evidence that ACE is effective in improving cardiorespiratory fitness (Chiou et al, 2022). This is in line with recent clinical trials which find low to moderate evidence in support of the efficacy of ACE for improvement of cardiorespiratory fitness (Linde et al, 2023; Froehlich-Grobe et al, 2022; Farkas et al, 2022). Previous systematic reviews find found lower quality but still positive evidence in support of ACE for improvement of cardiorespiratory fitness (Eitivipart et al, 2019; Gaspar et al, 2019).

Mate et al (2023) compared efficacy of ACE alone and together with FES-cycling to improve cardiovascular fitness. They found maximum rate of oxygen absorption ($V0^2$) was higher for ACE combined with FES-cycling compared with either ACE alone or FES-cycling alone, while the effect size for ACE was slightly largely than for FES-cycling alone. This largely agrees with earlier reviews, which found ACE combined with FES-cycling produced the largest effects compared with either ACE or FES-cycling alone (Figoni et al, 2020; Eitivipart et al, 2019). However, Figoni et al (2020) found larger effects for FES-cycling compared to ACE delivered.

Two recent systematic reviews have investigated use of ACE in the context of high intensity interval training (HIIT). Both reviews present low-quality evidence that HIIT using ACE alone or combined with functional electrical stimulation (FES) cycling is effective in improving cardiorespiratory fitness (Da Silva et al, 2023; Dolbow et al,2022). Neither review compared efficacy of ACE alone or together with FES-cycling.

With a couple of exceptions (Chiou et al, 2023; Froehlich-Grobe et al, 2022), most studies investigating effects of ACE on cardiorespiratory fitness note the low quality of the evidence (Da Silva et al, 2023; Mate et al, 2023; Dolbow et al,2022; Figoni et al, 2020; Eitivipart et al, 2019). This is mainly due to small and unrepresentative samples (e.g. overrepresentation of males), few studies overall and lack of controlled trials. Heterogeneity is also a major reason for lack of certainty around improvements in $V0^2$. Figoni et al (2020) list some of the factors:

> the heterogeneity of exercise modes (arm-crank ergometry, wheelchair ergometry/propulsion, handcycling), levels of SCI (C3-C8), completeness of SCI (American Spinal Injury Association Impairment Scale, AIS AD), and training status (trained and untrained) – all factors are known to be important determinants of $V0^2$peak (p.692).

5. Arm strength and function

There are fewer studies which focus on the impact of ACE on functional outcomes like arm strength and function compared to those which investigate cardiorespiratory fitness. The available literature is also more equivocal.

A review from Selph et al (2021) found one moderate quality randomised control trial (RCT) showing no significant improvement in function after ACE, though several studies do show some improvements in function and strength. It is also possible that cardiorespiratory fitness correlates with functional independence in people with SCI (Maher et al, 2017) though this has not yet been established in the literature on ACE exercise interventions.

The review from Chiou et al (2022) found very low certainty evidence that ACE exercise programs can improve arm strength and function. They found that two studies showed improvements in wheelchair propulsion distance, though with widely diverging effect sizes. Other primary studies not included in the Chiou et al review also find some functional improvement after ACE. A small 2014 study of 19 people with SCI found improvements in the Functional Independence Measure (FIM) after ACE training (Dost et al, 2014). More recently, Williams et al (2020) found some marginal improvements in sitting balance after ACE training.

Chiou et al (2022) also found a single small sample pilot study (Graham et al, 2019) to support the efficacy of ACE in improving muscle strength. Graham et al showed that around 40 minutes per week of HIIT and 90 minutes of moderate intensity training using ACE is sufficient to improve upper body strength. Eitivipart et al (2019) found evidence that muscle strength may be improved from arm ergometry training alone at moderate to vigorous effort over 30 min 3 times per week. However, this is based on low quality evidence and a very low confidence rating. The authors report conclusive evidence from 7 systematic reviews that ACE used in combination with resistance training can improve upper limb muscle strength. However, muscle strength is also improved with resistance training alone (Gaspar et al, 2019; Eitivipart et al, 2019).

6. Quality of life

There is minimal and inconsistent evidence regarding the effect of ACE on quality of life for people with SCI. Three of the systematic reviews included in this paper found evidence relating to improvements in quality of life (Wilig et al, 2022; Chiou et al, 2022; Selph et al, 2021). Selph et al (2021) found one moderate quality RCT showing no significant improvement in quality of life after ACE. More recently, Gee et al (2022) found no significant improvement in quality of life after ACE intervention.

Wilig et al (2022) and Chiou et al (2022) found low quality evidence supporting a possible improvement in quality of life after ACE. Both reviews support this with reference to a single RCT, Nightingale et al (2018). In this study, the authors investigate the effects of a 6-week program involving 45-minute moderate-intensity ACE sessions, 4 times per week. They find

moderate to large effect sizes for improvement in health-related quality of life as measured by the physical component of the Short Form 36 Health Survey.

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