Resistance training increases 6-minute walk distance in people with chronic heart failure: a systematic review

Chueh-Lung Hwang, Chen-Lin Chien and Ying-Tai Wu
National Taiwan University, Taiwan

Question: Does resistance training, either alone or as an adjunct to aerobic training, improve cardiac function, exercise capacity and quality of life in people with chronic heart failure? Design: Systematic review with meta-analysis of randomised trials. Participants: Adults with stable chronic heart failure. Intervention: Progressive resistance exercise training, alone or as an adjunct to aerobic training. Outcome measures: Cardiac function, exercise capacity and quality of life. Results: 241 participants from eight trials performed 2 to 6 months of moderate-intensity resistance training (50–75% of 1RM). Most programs consisted of 5 to 6 exercises for large limb and trunk muscles with two sets of 8 to 12 repetitions, three times a week. Resistance training significantly increased 6-minute walk distance (WMD 52 m, 95% CI 19 to 85) but not peak oxygen consumption (WMD 0.7 ml/kg/min, 95% CI –0.3 to 3.1). When used as an adjunct to aerobic training, resistance training did not significantly alter left ventricular ejection fraction (WMD –0.5%, 95% CI –4.3 to 3.3), peak oxygen consumption (WMD –0.7 ml/kg/min, 95% CI –2.3 to 1.0), or Minnesota Living with Heart Failure Questionnaire scores (WMD –0.9, 95% CI –5.4 to 3.7), compared with aerobic training alone. Conclusion: Resistance training increased 6-minute walk distance compared to no training, but had no other benefits on cardiac function, exercise capacity, or quality of life if used alone or as an adjunct to aerobic training in people with chronic heart failure. However, further high quality, large scale, randomised trials are needed.

Key words: Resistance training, Exercise capacity, Quality of life, Chronic heart failure

Introduction

Both the prevalence and incidence of chronic heart failure have increased due to the improved survival of coronary heart disease patients and to the aging of populations worldwide (Bleumink et al 2004). The major symptoms of chronic heart failure include exertional dyspnoea, fatigue, exercise intolerance, and functional limitations, which may result in poor quality of life. Previous studies suggested that both central and peripheral impairments limit exercise capacity in chronic heart failure patients (Mueller et al 2007, van Tol et al 2006, Volaklis and Tokmakidis 2005). Aerobic exercise training has been considered a safe and effective strategy to improve clinical symptoms (Flynn et al 2009, Mueller et al 2007, O’Connor et al 2009). Consistent results in meta-analyses provide further evidence that aerobic training is an effective treatment strategy (Chien et al 2008, Rees et al 2004, van Tol et al 2006).

Chronic heart failure is characterised by skeletal myopathy with reduced muscle mass, decreased vascular density and conductance, and impaired muscle oxidative capacity. This results in a shift toward type-II muscle fibres (Duscha et al 1999, Harrington and Coats 1997, Hulsmann et al 2004, Sunnerhagen et al 1998). These abnormalities may lead to disuse atrophy, further inactivity, and even cachexia. This progressive weakness has been noted in people with chronic heart failure and correlated with the severity of disease and exercise capacity (Hulsmann et al 2004, Toth et al 1997), suggesting that resistance training may help to ameliorate peripheral muscle weakness in chronic heart failure. Moreover, muscular strength is reported as a predictor of long-term survival in chronic heart failure (Hulsmann et al 2004).

Resistance training has been considered in people with chronic heart failure recently because it imposes less cardiac demand than aerobic exercise (King et al 2000, McKeilvie et al 1995, Meyer et al 1999). Several studies have established the safety of resistance exercise (Braith and Beck 2008, Braith et al 2005, Cheetham et al 2002, Jennings and Esler 1990, Magnusson et al 1996, Meyer 2006, Volaklis and Tokmakidis 2005, Williams et al 2007a, Williams et al 2007b). The American College of Sports Medicine has recommended that people with cardiac disease should add resistance training to their exercise program (Thompson et al 2010). However, the use of resistance training by people with chronic heart failure is controversial and its use in clinics remains limited because of uncertainty about its benefits and risks (Elkayam et al 1985). In the past decade, resistance training has been proven to improve both muscle strength and functional capacity in individuals with chronic heart failure. It can improve static as well as dynamic muscular strength by increasing the cross-sectional area of local muscle (Magnusson et al 1996). Furthermore, skeletal muscle adapts metabolically to resistance training in people with chronic heart failure (Minotti et al 1990). Some studies showed definite improvement in muscle strength, peak oxygen consumption...
and quality of life after resistance training, although there were no beneficial effects on left ventricular function (Levinger et al 2005a, Levinger et al 2005b). One study of 14 high-risk chronic heart failure patients demonstrated an average of 26% improvement in muscle strength after adding an 8-week resistance training regimen to aerobic training (Barnard et al 2000). There is even some evidence in chronic heart failure patients that resistance training added to aerobic training can improve heart function, exercise tolerance and quality of life more than aerobic training alone (Degache et al 2007, Maiorana et al 2000a). A recent systematic review of the effect of resistance training on these outcomes included non-randomised trials (Spruit et al 2009), introducing important potential for bias in the results. Therefore, the effects of resistance training, either alone or in combination with aerobic training, in people with chronic heart failure remain unclear. Therefore the following research questions for this study focused on people with heart failure:

- Does resistance training improve heart function, exercise capacity and quality of life in people with chronic heart failure more than no intervention or usual care?
- If combined with aerobic training, does it show a greater improvement in these measures than aerobic training alone?

### Methods

#### Identification and selection of studies

Six electronic databases (PubMed, MEDLINE, EMBASE, Chinese Electronic Periodical Service [CEPS], CINAHL, and Cochrane Library Register of Controlled Trials) were searched from the earliest available date until September 2009. We hand-searched reference lists of all identified original articles, previous meta-analyses and reviews. Experts were asked to identify any other relevant trials known to them. The following keywords and Medical Subject Heading (MeSH) terms were used in our searches: heart failure, heart dysfunction, ventricular dysfunction, resistance training, strength exercise, strength training, weight-lifting, and weight training (see Appendix 1 on the eAddenda for the full search strategy).

#### Box 1 Inclusion criteria.

<table>
<thead>
<tr>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomised trial</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults with chronic heart failure</td>
</tr>
<tr>
<td>Diagnosis based on clinical signs or left ventricular ejection fraction &lt;40%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progressive resistance exercise training, with training defined as a structured, hospital- or home-based program with a target exercise type, intensity, duration and frequency, and with regular measurement of whether these were achieved</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outcome measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cardiac function</td>
</tr>
<tr>
<td>Exercise capacity</td>
</tr>
<tr>
<td>Quality of life</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Comparisons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Progressive resistance exercise training versus no training or usual care or sham exercise</td>
</tr>
<tr>
<td>Progressive resistance exercise training plus aerobic exercise training versus aerobic exercise training only</td>
</tr>
</tbody>
</table>

Published randomised trials limited to human subjects were considered. Articles written in languages other than English or Chinese were excluded. Two reviewers (CLH and CLC) reviewed the trials using predetermined criteria independently (Box 1). Reviewers were not blinded to authors, place of publication, or results.

#### Assessment of characteristics of studies

**Quality:** All trials were critically appraised for methodological quality using the PEDro Scale (0 to 10, Maher et al 2003, de Morton 2009) by two reviewers (CLH and CLC). Any disagreements were resolved by discussion with another reviewer (YTW).

**Participants:** Age, gender, and cause and severity of chronic heart failure were recorded to determine the similarity of participants between groups and between trials.

**Intervention:** The target intensity, duration, and frequency of exercise and the length of the intervention period were recorded. For the study question assessing the effect of resistance training alone, the control was categorised as no intervention, usual activity or sham exercise. For the study question assessing the effect of combined training versus aerobic training alone, the target intensity, duration, and frequency of aerobic exercise were also recorded.

**Outcome measures:** We recorded cardiac function (measured by the left ventricular ejection fraction), exercise capacity (measured at the impairment level by peak oxygen consumption and at the activity level by the 6-min walk test), and quality of life (measured by disease-specific scales).

#### Data analysis

The reviewers extracted post-intervention sample sizes, means, and standard deviations (SD) for the experimental and control groups. The authors were contacted to provide additional information if necessary.

The analyses were performed using RevMan 5. In each study, the effect size for the intervention was calculated by the difference between the means of the experimental and control groups at the end of the intervention. If the outcome was measured on the same scale, the weighted mean difference (WMD) and 95% confidence interval (CI) were calculated. Otherwise, the standardised mean difference (SMD) and 95% CI were calculated. Data were pooled using a fixed effect model unless heterogeneity was calculated using a random effect model. A random effect model was used to re-analyse data when significant heterogeneity was noted. Publication bias was investigated by using the funnel plot (Leandro 2005).

#### Results

**Flow of studies through the review**

consisted of resistance training and control groups that were excluded due to lack of control group randomisation (Feiereisen et al 2007). We included one study (Barnard et al 2000) through searching reference lists of one review article (Volaklis and Tokmakidis 2005) (Figure 1).

### Characteristics of included studies

Tables 1 and 2 summarise the characteristics of the included studies.

#### Quality

The methodological quality of the eight included trials ranged from 4 (Barnard et al 2000) to 7 (Beckers et al 2008, Mandic et al 2009, Pu et al 2001) on the PEDro scale (Table 1), with a mean of 5.7 out of 10 (SD 1.2). No trials blinded participants or therapists, while four trials blinded assessors, seven had 85% or greater retention rates, and all reported between-group differences with point estimates and measures of variability.

#### Participants

Most of the included studies had predominantly male participants with stable chronic heart failure and mean ages ranging from 55 to 65 years. Only one study recruited only women (Pu et al 2001), with participants aged a mean of 77 years. New York Heart Association classifications ranged from I to III and left ventricular ejection fraction was approximately 40% in most studies. One study included participants with left ventricular

---

**Table 1. Quality (PEDro scores) for included studies.**

<table>
<thead>
<tr>
<th>Study</th>
<th>Random allocation</th>
<th>Concealed allocation</th>
<th>Groups similar at baseline</th>
<th>Therapist blinding</th>
<th>Assessor blinding</th>
<th>Intention-to-treat analysis</th>
<th>&lt; 15% dropouts</th>
<th>Participant blinding</th>
<th>Comparison of groups similar at baseline</th>
<th>Between-group difference reported</th>
<th>Point estimate and variability reported</th>
<th>PEDro score (0 to 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnard et al (2000)</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>4</td>
</tr>
<tr>
<td>Beckers et al (2008)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>5</td>
</tr>
<tr>
<td>Cedra et al (1997)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>5</td>
</tr>
<tr>
<td>Feiereisen et al (2007)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>5</td>
</tr>
<tr>
<td>Mandic et al (2009)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>5</td>
</tr>
<tr>
<td>Pu et al (2001)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>5</td>
</tr>
<tr>
<td>Tyni-Lenné et al (2001)</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
<td>5</td>
</tr>
</tbody>
</table>

---

**Figure 1.** Flow of papers through the study.
### Table 2. Summary of included studies (n = 8).

<table>
<thead>
<tr>
<th>Study</th>
<th>Participants</th>
<th>Interventions</th>
<th>Outcome measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Resistance exercise versus control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cider et al (1997)</td>
<td>HF (21 IHD, 1 CMP, 2 VD)</td>
<td>Exp = PRE at 60% of 1RM, 1 min/set × 2 sets × 6 exercises, 60 min × 2 × 5 mo</td>
<td>Peak VO2, QOL (QOL-HF), QOL (NHP), Adverse events</td>
</tr>
<tr>
<td></td>
<td>NYHA II–III, n = 12 Exp (9 males, aged 62 yrs), 12 Con (7 males, aged 65 yrs)</td>
<td>Con = usual activity</td>
<td></td>
</tr>
<tr>
<td>Pu et al (2001)</td>
<td>HF (12 IHD, 1 VD, 3 idiopathic)</td>
<td>Exp = Supervised PRE at 80% of 1RM, 8 reps × 3 sets × 5 exercises, 60 min × 3/wk × 10 wk</td>
<td>Peak VO2, 6-min walk test, LVEF, Adverse events</td>
</tr>
<tr>
<td></td>
<td>NYHA I–III, n = 9 Exp (all females, aged 77 yrs, LVEF 36%), 7 Con (all females, aged 77 yrs, LVEF 36%)</td>
<td>Con = sham (low-intensity stretching exercise, 2/wk)</td>
<td></td>
</tr>
<tr>
<td>Selig et al (2004)</td>
<td>HF (23 IHD, 16 DCM)</td>
<td>Exp = PRE at moderate intensity, 30-120 sec × 1 set × 6 exercises, 3/wk × 3 mo</td>
<td>Peak VO2, Adverse events</td>
</tr>
<tr>
<td></td>
<td>NYHA II–III, n = 19 Exp (15 males, aged 65 yrs, LVEF 27%), 20 Con (18 males, aged 64 yrs, LVEF 28%)</td>
<td>Con = usual care</td>
<td></td>
</tr>
<tr>
<td>Tyni-Lenné et al (2001)</td>
<td>HF (15 CAD, 9 IDCM)</td>
<td>Exp = Supervised PRE at 13-16/20 on Borg scale, 25 reps × 2 sets/exercise, 60 min × 3/wk × 8 wk</td>
<td>Peak VO2, 6-min walk test, QOL (MLHF-Q), Adverse events</td>
</tr>
<tr>
<td></td>
<td>NYHA II–III, n = 16 Exp (8 males, aged 63 yrs, LVEF 30%), 8 Con (5 males, aged 62 yrs, LVEF 30%)</td>
<td>Con = usual activity</td>
<td></td>
</tr>
<tr>
<td><strong>Combined resistance and aerobic exercise versus aerobic exercise</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barnard et al (2000)</td>
<td>HF (14 CAD, 6 CMP, 1 VD)</td>
<td>Exp = Aerobic exercise training at 60 to 80% of peak HR, 30 min × 3/wk</td>
<td>Adverse events</td>
</tr>
<tr>
<td></td>
<td>NYHA II–III, n = 14 Exp (all males, aged 55 yrs), 7 Con (all males, aged 60 yrs)</td>
<td>PRE with intensity at 60 to 80% of 1RM, 8 to 12 reps × 2 sets/exercise × 2/wk</td>
<td></td>
</tr>
<tr>
<td>Beckers et al (2008)</td>
<td>HF (34 IHD, 24 DCM)</td>
<td>Exp = Interval aerobic exercise training at 90% of maxHR, 8 to 15 min/exercise × 10 to 45 min</td>
<td>Peak VO2, LVEF, QOL (HCS), Adverse events</td>
</tr>
<tr>
<td></td>
<td>NYHA II–III, n = 28 Exp (18 males, aged 58 yrs, LVEF 26%), 30 Con (24 males, aged 59 yrs, LVEF 23%)</td>
<td>PRE at 50 to 60% of 1RM, 10 to 15 reps × 1 to 2 sets × 9 exercises (including respiratory muscle)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Con = Interval aerobic exercise training at 90% of maxHR, 8 to 15 min/exercise × 60 min</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Both groups = Supervised, 60 min × 3/wk × 6 mo (70 sessions)</td>
<td></td>
</tr>
</tbody>
</table>
Hwang et al: Resistance training for heart failure

Feiereisen et al (2007) HF (14 CAD, 16 IDCM) NYHA II–III
Exp = 15 (13 males, aged 61 yrs, LVEF 23%)
Con = 15 (1 male, aged 59 yrs, LVEF 25%)
Exp = Aerobic exercise training at 60 to 75% of peakVO2 × 20 min
PRE at 60 to 70% of 1RM, 10 reps × 4 sets × 5 exercises, 20 min/session
Con = Aerobic exercise training at 60 to 70% of peakVO2 × 45 min
Both groups = Supervised, 40 sessions

Peak VO2 LVEF QOL (MLHF-Q) Adverse events

Mandic et al (2009) HF (15 IHD, 14 non-IHD) NYHA I–II
Exp = 15 (11 males, aged 59 yrs, LVEF 33%)
Con = 14 (11 males, aged 63 yrs, LVEF 30%)
Exp = Aerobic exercise training at 50 to 70% of HRR or Borg Scale 11 to 14 / 20, 30 min/session
PRE at 50 to 70% of 1RM, 10 to 15 reps × 1 to 2 sets × 6 exercises
Con = Aerobic exercise training at 50 to 70% of HRR or Borg Scale 11 to 14 / 20, 30 min/session
Both groups = Supervised, 3/wk × 12 wk

Peak VO2 LVEF QOL (MLHF-Q) Adverse events


All the training programs were supervised. The length of training ranged from 2 to 6 months. The intensity for resistance training was moderate or about 50–75% of one repetition maximum (1RM), while aerobic training on a treadmill or cycle ergometer was moderate to vigorous intensity. Two studies used high intensity exercise at 80% of 1RM, with no exercise-induced cardiac events reported (Barnard et al 2000, Pu et al 2001). The resistance training usually consisted of 2 sets of 8–12 repetitions for 5–6 exercises targeting the large muscle groups of upper limbs, trunk, and lower limbs. The exercise duration was around 30–60 minutes and exercise frequency was 2–3 times per week. One study included respiratory muscle training as one of the nine exercises (Beckers et al 2008). This was the largest number of exercises among the eight studies.

Effect of resistance training

We examined by separate analyses the effect of resistance training alone or in combination with aerobic training. Four studies reported cardiac function, seven reported exercise capacity, and five reported quality of life. All reported whether there were adverse events.

Cardiac function: The effect of resistance training alone on cardiac function was examined in one trial (Pu et al 2001), with no significant difference in left ventricular ejection fraction compared to control (MD 1.8%, 95% CI –5.7 to 9.3). Three studies with 115 participants provided post-intervention data for pooling with a fixed model to examine the effect of resistance training as an adjunct to aerobic training on cardiac function. The overall improvement in left ventricular ejection fraction was comparable to that obtained with aerobic training only (WMD –0.5%, 95% CI –4.3 to 3.3) (Figure 2, see also Figure 3 on the eAddenda for detailed forest plot).

Exercise capacity: The effect of resistance training alone on peak oxygen consumption was calculated using the pooled post-intervention data of four studies with 96 participants.
Resistance training alone showed a favourable trend only on peak oxygen consumption (WMD 1.4 ml/kg/min, 95% CI –0.3 to 3.1) (Figure 4a, see also Figure 5a on the eAddenda for detailed forest plot). The effect of resistance training as an adjunct to aerobic training was derived from three studies with 115 participants. The addition of resistance training to aerobic training resulted in an increase in peak oxygen consumption that ranged from 1.1 to 3.0 ml/kg/min (WMD 2.1 ml/kg/min, 95% CI 0.8 to 3.4). Figure 5a shows the forest plot for the studies included in the meta-analysis. Table 3 provides a summary of the cardiac-related adverse events during or drop-outs related to exercise with resistance training in people with heart failure (n = 8).

### Table 3. Cardiac-related adverse events during or drop-outs related to exercise with resistance training in people with heart failure (n = 8).

<table>
<thead>
<tr>
<th>Study</th>
<th>n</th>
<th>Age (y)</th>
<th>NYHA</th>
<th>LVEF (%)</th>
<th>Intensity of resistance training</th>
<th>Adverse events (N)</th>
<th>Drop-outs (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnard et al (2000)</td>
<td>14</td>
<td>60</td>
<td>–</td>
<td>25</td>
<td>60-80% of 1RM, 2 × (8 to 12) reps/min</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Beckers et al (2008)</td>
<td>28</td>
<td>58</td>
<td>II–III</td>
<td>26</td>
<td>50-60% of 1RM, (1 to 2) × (10 to 15) reps/min and 1 min rest</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cider et al (1997)</td>
<td>12</td>
<td>62</td>
<td>II–III</td>
<td>–</td>
<td>60% of 1RM, 2 × 30 reps/min</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Feiereisen et al (2007)</td>
<td>15</td>
<td>61</td>
<td>II–III</td>
<td>23</td>
<td>60–70% of 1RM, 10 reps/min and 2 min rest</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mandic et al (2009)</td>
<td>15</td>
<td>59</td>
<td>I–III</td>
<td>30</td>
<td>50–70% of 1RM, (1 to 2) × (10 to 15) reps/min</td>
<td>1 (AF)</td>
<td>0</td>
</tr>
<tr>
<td>Pu et al (2001)</td>
<td>9</td>
<td>77</td>
<td>I–III</td>
<td>36</td>
<td>80% of 1RM, 3 × 8 reps/min</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Selig et al (2004)</td>
<td>19</td>
<td>65</td>
<td>2.4</td>
<td>27</td>
<td>cycling/climbing (0.5 to 2 min) and 2 × 30 sec of strength training at moderate intensity</td>
<td>1 (sudden death)</td>
<td>1</td>
</tr>
<tr>
<td>Tyni-Lenné et al (2001)</td>
<td>16</td>
<td>63</td>
<td>II–III</td>
<td>30</td>
<td>2 × 25 reps until 13 on Borg scale</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

NYHA = New York Heart Association (Functional Class I–IV), LVEF = left ventricular ejection fraction, RM = repetition maximum, AF = atrial fibrillation
Two studies with 57 participants examined the effect of resistance exercise as an adjunct to aerobic training. Both used the Minnesota Living with Heart Failure Questionnaire. Their data were pooled using a fixed effect model. Adding resistance training to aerobic training programs did not significantly change Minnesota Living with Heart Failure Questionnaire scores compared to those obtained with aerobic exercise alone, WMD 0.9 (95% CI –5.4 to 3.7) (Figure 8, see also Figure 9 on the eAddenda for detailed forest plot). A third study (Beckers et al 2008) used the Health Complaints Scale, which primarily measures somatic symptoms. Combined resistance and aerobic training was significantly more beneficial than aerobic training, with 12 (60%) of the 20 combined-training participants reporting a marked decrease in cardiac symptoms, compared with 7 (28%) of the 25 aerobic-training participants (OR 3.86, 95% CI 1.11 to 12.46).

Funnel plots were constructed for the five meta-analyses performed. Although they demonstrated no evidence of publication bias, each plot contained four data points or fewer. This makes the power of the tests too low to distinguish change from real asymmetry (Higgins and Green 2008). Therefore, the funnel plots are not presented.

Discussion

This systematic review provides some firm evidence about the effects of resistance training on cardiac function, exercise capacity, and quality of life in people with chronic heart failure. The search for evidence was systematic and thorough. The included studies had PEDro scores of 4 to 7 (out of 10). Meta-analysis of the results was performed where possible. When compared to usual or low-intensity activity, a significant beneficial effect of resistance training on 6-minute walk distance was demonstrated based on the results of two studies. However, further research is required to determine whether this is considered clinically worthwhile by people with chronic heart failure.

The results did not indicate a beneficial effect of resistance training on cardiac function. People with chronic heart failure have reduced cardiac output because of impaired ventricular systolic or diastolic function, or both. Chronic heart failure patients primarily have elevated heart rates rather than stroke volume. This allows them to meet metabolic demands accompanied by possible high work load on the heart resulting from increased exercise intensity (Cheetham et al 2002). A study of one bout of isotonic exercise with different intensities found minimal changes in central haemodynamics, which were well tolerated by the chronic heart failure patients (King et al 2000). Significant improvements in muscular strength as well as reduction in peripheral resistance, resulting in improved afterload to the heart, were demonstrated after long-term resistance training (Maiorana et al 2000b, Selig et al 2004, Tyni-Lenné et al 2001). Two studies found that exercise training did not alter left ventricular function regardless of exercise mode (Mandic et al 2009, Pu et al 2001), while other studies reported favourable but non-significant effects on left ventricular function (Beckers et al 2008, Feiereisen et al 2007). Notably, the participants in the former two studies had a slightly higher left ventricular ejection fraction (at 30% and 36%) at baseline than in the latter two studies (at 23% and 26%). Further study is required to examine if there was a ceiling effect or if cardiac function could adapt after exercise training.
This review partially supports the belief that resistance training could elevate maximally tolerable exercise workload without changing peak oxygen consumption (Magnusson et al 1996), given the effect on 6-minute walk distance. The mechanisms that may contribute to the peripheral adaptation of the muscle, such as the increased cross-sectional area, capillarisation, and oxidative capacity, were proposed by Magnusson (1996). Previous studies found that skeletal myopathy, including impaired muscle metabolic capacity and muscle fibre transformation, may be the primary limiting factors of exercise capacity (Okita et al 1998, Vescovo et al 1998). Other studies correlated the improvement of muscle strength, aerobic, and anaerobic performance with increases in muscle fibre cross-sectional area as well as in citrate synthase activity, and lactate dehydrogenase and muscle mitochondrial ATP production rates (Pu et al 2001, Williams et al 2007a). In addition to the muscular level, an improvement of neurovascular level could also contribute to the improvement in 6-minute walk distance. Chronic heart failure in patients with skeletal myopathy may induce sympathetic nerve activation with resultant peripheral vasoconstriction (Clark et al 1996). Plasma norepinephrine levels at rest and submaximal exercise may decrease after high repetitions and moderate resistance training (Tyni-Lenné et al 2001) and thus increase blood flow in response to submaximal activity, such as the 6-minute walk test (Selig et al 2004).

The results of this review suggest that resistance training alone does not significantly improve peak oxygen consumption. Two studies we reviewed (Selig et al 2004, Tyni-Lenné et al 2001) reported increments of 8% and 10%, respectively. Combining resistance with aerobic training failed to demonstrate a greater increase in peak oxygen consumption than aerobic training alone. Similar effects on peak oxygen consumption among three types of exercise training were noted by Feiereisen and colleagues (2007), with gains of 17%, 11%, and 14% for groups undertaking resistance, aerobic, and combined exercise training respectively. Resistance training can have a direct effect on blood flow and metabolism of skeletal muscles independent of any central adaptation due to the specificity of exercise training (Pu et al 2001, Selig et al 2004). If peripheral muscle weakness plays a role in exercise limitation, resistance training may be helpful to improve exercise capacity even though the peak oxygen consumption may not change after training (Delagardelle et al 2002, Feiereisen et al 2007, Hulsmann et al 2004). Delagardelle and colleagues (2002) found combined training was superior to endurance training alone in terms of left ventricular function, peak oxygen consumption, and strength. The inconsistent finding may result from differences in training mode, intensity, or volume of exercise. Further investigation is needed.

Two meta-analyses have reported that exercise training significantly improves quality of life in people with chronic heart failure (Flynn et al 2009, van Tol et al 2006). Nevertheless, there remain disagreements about the effect of resistance exercise alone on quality of life (Cider et al 1997, Tyni-Lenné et al 2001). In this review, quality of life as measured by the Minnesota Living with Heart Failure Questionnaire showed a favourable but non-significant trend with resistance training. A study demonstrated that the improvement in muscle strength after training correlated with the improvement of quality of life (Jankowska et al 2008). Since resistance training ameliorates muscle strength more effectively than aerobic training alone, adding resistance exercise may strengthen the effect of exercise on quality of life. Beckers and colleagues reported that resistance exercise combined with aerobic training had a significant greater benefit on quality of life, as measured by the Health Complaints Scale, than aerobic training alone (Beckers et al 2008). Furthermore, low compliance was noted in the study that reported no improvement in QOL (Cider et al 1997). There is a need for further studies on resistance training on quality of life, especially with strategies to optimise adherence to the training regimen (Mandic et al 2009).

This review had some limitations. The numbers of included studies and sample sizes were relatively small. The outcome variable measures were often different between studies, limiting the potential for meta-analysis. The likelihood of publication bias can not be assessed. Data for females were very limited. A previous study indicated that female patients had less improvement in cardiopulmonary function than males after combined resistance and aerobic training (Miche et al 2008). Thus the conclusion of this review may not be applicable to female populations. The gender differences in aetiology and pathophysiology of chronic heart failure (Regitz-Zagrosek et al 2004) and responses to resistance training deserve further investigation.

In conclusion, resistance training alone increases 6-minute walking distance but has no additional benefits on heart function, maximal exercise capacity, or quality of life. Furthermore, it does not improve any of these outcomes in people with chronic heart failure who already perform aerobic exercise training. However, further prospective controlled trials of high-quality and large scale are needed to confirm the conclusion of this systematic review.

**eAddenda:** Appendix 1, Figures 3, 5, 7, 9 available at jop.physiotherapy.asn.au

**Competing interests:** None declared.

**Correspondence:** Assoc Prof Ying-Tai Wu, School and Graduate Institute of Physical Therapy, Floor 3, No.17, Xuzhou Rd., Zhongzheng District, Taipei City 100, Taiwan. Email: ytw@ntu.edu.tw

**References**


Pu CT, Johnson MT, Forman DE, Hausdorf JM, Roubenoff R, Foldvari M, et al (2001) Randomized trial of progressive resistance training to counteract the myopathy of chronic...


