

Home-based exercise increases exercise capacity but not quality of life in people with chronic heart failure: a systematic review

Chen-Lin Chien, Chii-Ming Lee, Yen-Wen Wu, Tzu-An Chen and Ying-Tai Wu

National Taiwan University
Taiwan

Questions: Does home-based exercise improve exercise capacity and quality of life in people with chronic heart failure? Is it safe? **Design:** Systematic review with meta-analysis. **Participants:** Adults with heart failure > 3 months duration. **Intervention:** Home-based aerobic exercise with or without resistance exercise. **Outcome measures:** Exercise capacity (measured at the impairment level by peak VO_2 and at the activity level by 6-min Walk Test), quality of life (measured by disease-specific scales), and adverse events (measured as death, hospitalisation). **Results:** 10 randomised controlled trials with 648 participants of New York Heart Association Class II or III were included. Most participants were male ≥ 50 years old with an ejection fraction $\leq 40\%$. The exercise programs ranged from 6 weeks to 9 months at low to moderate intensity (40–70% of maximum heart rate or heart rate at 70% peak VO_2). Home-based exercise increased 6-min walking distance by 41 m (WMD, 95% CI 19 to 63) and peak VO_2 by 2.71 ml/kg/min (WMD, 95% CI 0.67 to 4.74) more than usual activity. It did not improve scores on the Minnesota Heart Failure Questionnaire (WMD 0.5 points out of 105, 95% CI –4.4 to 5.4) or increase the odds of hospitalisation (OR 0.75, 95% CI 0.19 to 2.92) more than usual activity. **Conclusions:** Home-based exercise increased exercise capacity safely but did not improve quality of life in patients with chronic heart failure. It could therefore be used to improve the management of people with chronic heart failure who do not have access to hospital-based exercise. [Chien CL, Lee CM, Wu YW, Chen TA, Wu YT (2008) Home-based exercise increases exercise capacity but not quality of life in people with chronic heart failure: a systematic review. *Australian Journal of Physiotherapy* 54: 87–93]

Key words: Exercise, Chronic Heart Failure, Quality of Life

Introduction

Heart failure is the final common stage of various heart diseases and has a significant impact on quality of life and prognosis. With improved short- and long-term survival after myocardial infarction, the prevalence of chronic heart failure has increased (Bleumink et al 2004, Davies et al 2001). Clinical features of heart failure include dyspnoea, fatigue, and reduced exercise tolerance. The severity of symptoms and exercise capacity is commonly defined by New York Heart Association classification, from mild to severe (I to IV). Heart failure is also associated with increased morbidity, mortality, significantly decreased quality of life, and high health care costs (Bennett et al 2003, Gwady-Sridhar et al 2004).

Exercise is safe and effective in improving exercise capacity and quality of life in people with heart failure (Piepoli et al 2004, Rees et al 2004, Smart and Marwick 2004, van Tol et al 2006). Recent studies have demonstrated that exercise for people with heart failure is associated with improved left ventricular function, reverse left ventricular remodeling (Giannuzzi et al 2003, Haykowsky et al 2004, Klecha et al 2007, Myers et al 2007a), and blunting of neurohumoral activation (de Mello Franco et al 2006, Gao et al 2007, Myers et al 2007b, Passino et al 2006, Wisloff et al 2007).

Most of the studies that have established exercise as an effective part of heart failure management have investigated hospital-based exercise (van Tol et al 2006). With more individuals surviving an initial acute event, heart failure management has switched from crisis to chronic care on an out-patient basis (Riegel et al 2002a, Shah et al 1998, Wheeler and Waterhouse 2006). However, only a small proportion of people with heart failure participate, with one factor underpinning non-participation being lack of access to hospital-based exercise (Cooper et al 2000, Cottin et al 2004, Evenson et al 1998, Johnson et al 2004).

Home-based exercise could be made accessible to most people with chronic heart failure, because of its relatively low cost and feasibility. It has been shown to be effective for other cardiac conditions and in older adults (Arthur et al 2002, Ashworth et al 2005, Marchionni et al 2003). However, its effect in people with chronic heart failure is unclear. Therefore, the research questions for this systematic review were:

1. Is home-based exercise effective at improving exercise capacity and quality of life in people with chronic heart failure?
2. Is it safe?

Method

Identification and selection of studies

Searches were conducted of PubMed, MEDLINE, EMBASE, CINAHL, Cochrane Library Register of Controlled Trials, PEDro, Chinese Electronic Periodical Service (CEPS), and MD Consult for studies published between January 1980 and July 2006 using the following keywords and MESH terms: *heart failure, chronic heart failure, congestive heart failure, ischaemic cardiomyopathy, cardiac failure, left ventricle failure, cardiac rehabilitation, exercise (training), physical training, aerobic training, activity, physical fitness, exercise tolerance, exercise, quality of life*. Searches were limited to full studies in English. (See Appendix 1 on the eAddenda for complete search strategy.) We also hand-searched reference lists of all identified studies and previous systematic reviews from 1980 to 2006, and sought expert advice.

Reviewers (TC and YW) reviewed the trials independently using predetermined criteria. There was no blinding to author, place of publication, or results. To be included, studies had to be randomised controlled trials. Participants were required to be adults with chronic heart failure (ie, duration ≥ 3 months) based on clinical presentation or left ventricular ejection fraction. The home-based exercise could be aerobic exercise with or without resistance exercise of peripheral muscles. Studies of simultaneous supervised exercise and home-based exercise, respiratory muscle training, or training of a single muscle were excluded but studies of home-based followed by supervised hospital-based exercise were included. Studies were required to have at least one of the following outcome measures: exercise capacity (measured at the impairment level by peak VO_2 and at the activity level by a graded exercise test or the 6-min Walk Test), health-related quality of life (measured by disease-specific scales such as the Chronic Heart Failure Questionnaire or Minnesota Heart Failure Questionnaire), and adverse events (measured by all-cause mortality, cardiac death, hospitalisation for heart failure).

Assessment of methodological quality of studies

Quality was assessed with the PEDro Scale (Maher et al 2003). Quality was assessed by reviewers (CC and YW) independently. Disagreements regarding methodological quality were resolved by consensus.

Data analysis

Study outcome data were extracted by one reviewer (TC) and checked by a second reviewer (CC). Authors were contacted to provide additional information when necessary.

For continuous outcomes (peak VO_2 , 6-min Walk Test, Chronic or Minnesota Heart Failure Questionnaires), the WMD (95% CI) or SMD (95% CI) of the post-intervention scores were calculated. For dichotomous outcomes (deaths, hospitalisations), OR (95% CI) were calculated.

For each outcome, a test of heterogeneity was carried out. In case of significant heterogeneity, a random effect meta-analysis without aggregating the studies was applied. Fixed effect meta-analysis was used if no significant heterogeneity was detected. All p values < 0.05 were considered significant. The analyses were performed using RevMeta.

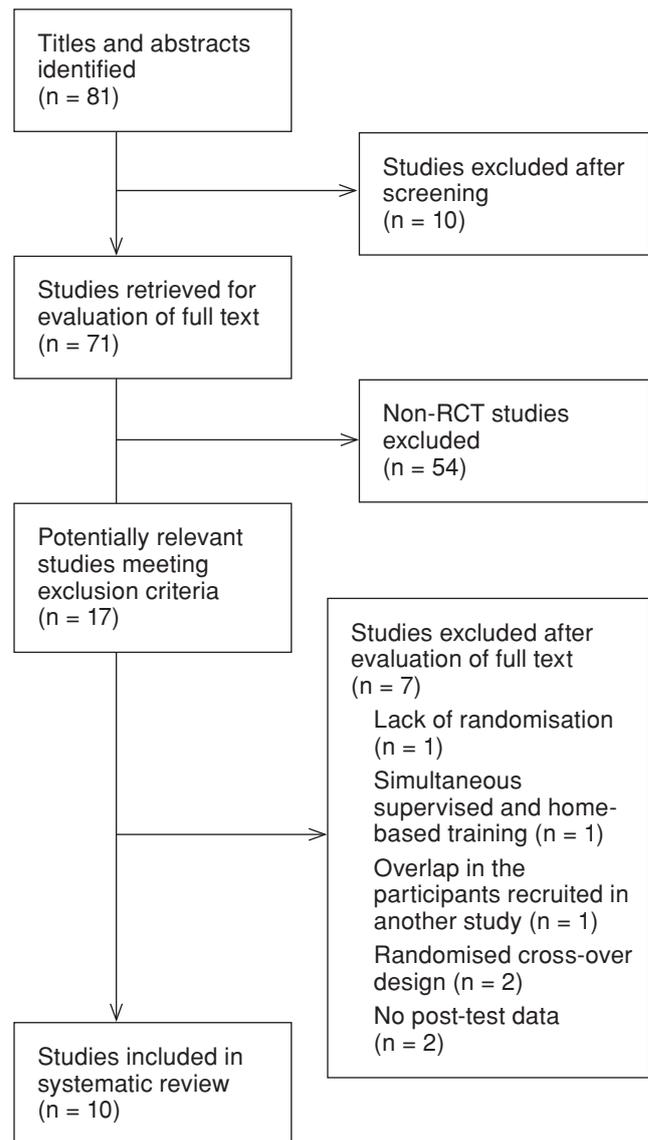


Figure 1. Flow of studies through the review.

Results

Identification and selection of studies

We identified 81 studies from the search strategy. After initial screening, 71 potentially-relevant articles met the inclusion criteria. After exclusion of non-RCT studies, 17 articles met the inclusion criteria (Adamopoulos et al 2001, Corvera-Tindel et al 2004, de Mello Franco et al 2006, Evangelista et al 2006, Gary et al 2004, Gielen et al 2005, Hambrecht et al 2000, Harris et al 2003, Kiilavuori et al 2000, Linke et al 2005, McKelvie et al 2002, Niebauer et al 2005, Oka et al 2000, Oka et al 2005, Sabelis et al 2004, Smart et al 2005, Witham et al 2005). Three studies were excluded due to: lack of randomisation (Smart et al 2005), simultaneous supervised and home-based exercise (Sabelis et al 2004), or participant overlap with another study (Oka et al 2005). Also, two studies with randomised cross-over design with incomplete data (Adamopoulos et al 2001, Niebauer et al 2005) and two studies without post-test data (de Mello Franco et al 2006, Kiilavuori et al 2000) were unable to be included in the analysis. Therefore, 10 studies with 648 participants were subsequently analysed (Figure 1). Among them, three studies (Gielen et al 2005, Hambrecht et

Table 1. Summary of included studies.

Study	Participants	Intervention	Home visit	Outcome measures
Corvera-Tindel et al (2004)	Incl = HF secondary to IHD and non-IHD, NYHA II–IV, EF 24.7–29.1% n = Exp 42 (42 male), Con 37 (36 male) Age = 61–63 yr	Exp = 12-week home walking exercise with intensity at 40–65% max HR, 60 min/day, 5 days/week Con = usual activity	Yes First 6-week: once per week Last 6-week: biweekly	Peak VO ₂ 6-min Walk Test
Evangelista et al (2006)	Incl = Advanced HF, BMI ≥ 27 kg/m ² , NYHA II–IV, EF ≤ 40% n = Exp 48 (37 male), Con 51 (34 male) Age = 53–55 yr	Exp = 6-month home walking program with intensity at 60% max HR, 45 min, combined with resistance exercise, ≥ 4 times/week Con = usual activity	Yes Once per month	Peak VO ₂ 6-min Walk Test
Gary et al (2004)	Incl = HF secondary to IHD and non-IHD, NYHA II–III, EF 54–57% n = Exp 15 (0 male), Con 13 (0 male) Age = 67–69 yr	Exp = 12-week home walking program with intensity at 40–60% max HR, 40 min/day, 3 days/week, 12 weekly home visit with education program Con = 12 weekly home visits with education program only	Yes 12 weekly home visit	6-min Walk Test QOL (MHFQ)
Gielen et al (2005)	Incl = HF secondary to DCM and IHD, NYHA II–III, EF 24.7–26.1% n = Exp 10 (10 male), Con 10 (10 male) Age = 53–55 yr	Exp = 2-week in-patient exercise first and then 6-month home exercise with bicycle ergometer (HR at 70% VO ₂), and at least one group training session of 60 min/week Con = usual activity	No	Peak VO ₂
Hambrecht et al (2000)	Incl = HF secondary to DCM and IHD, NYHA I–III, EF 27% n = Exp 31 (31 male), Con 33 (33 male) Age = 54 yr	Exp = 2-week in-hospital first and then 6-month home-based bicycle ergometer exercise with intensity at 70% VO ₂ , 20 min/day for 6 months, and at least one group training session of 60 min/week Con = usual activity	No	Peak VO ₂
Harris et al (2003)	Incl = HF secondary to DCM and IHD, NYHA II–III, EF 28.3–32% n = Exp 24 (21 male), Con 22 (17 male) Age = 61–63 yr	Exp = 6-week home bicycle exercise with intensity at 70% max HR, 30 minutes/day, 5 days/week Con = functional electrical stimulator, no specific exercise	No	Peak VO ₂ 6-min Walk Test QOL (MHFQ)
Linke et al (2005)	Incl = HF secondary to DCM and IHD, NYHA II–III, EF 26–27% n = Exp 12 (12 male), Con 11 (11 male) Age = 52–55 yr	Exp = 2-week in-hospital first and then 6-month home bicycle exercise with intensity at HR at 70% VO ₂ , 20 min/day and at least one group session of 60 min/week Con = usual activity	No	Peak VO ₂
McKevie et al (2002)	Incl = Mixed HF, NYHA I–III, EF < 40% n = Exp 90 (82% male), Con 91 (80% male) Age = 64–68 yr	Exp = 3-month supervised first and then 9-month home-based exercise (aerobic ergometer + free weight weights strengthening) with intensity at 60–70% peak HR, 3 times/week Con = usual activity	Yes All participants reviewed monthly throughout the study	Peak VO ₂ 6-min Walk Test QOL (MHFQ)
Oka et al (2000)	Incl = Mixed HF, NYHA II–III, EF 22.3–24.9% n = Exp 20 (17 male), Con 20 (14 male) Age = unknown	Exp = 12-week aerobic walking (70% max HR), 40–60 min/day, 3 days/week Resistance training = 75% 1RM, 30–40 min/day, 2 days/week Con = usual care	Weekly phone call	Peak VO ₂ QOL (CHFQ)
Witham et al (2005)	Incl = Mixed HF, NYHA II–III, EF 12–15% n = Exp 36 (26 male), Con 32 (19 male) Age = 80–81 yr	Exp = 3-month supervised exercise first and then 3-month home exercise, 2–3 times/week with video or audio aid Con = usual care	Weekly phone call	6-min Walk Test QOL (CHFQ)

HF = heart failure, IHD = ischaemic heart disease, NYHA = New York Heart Association (Functional Class I–IV), EF = ejection fraction, n = number of participants randomised, Exp = exercise group, Con = control group, BMI = body mass index, DCM = dilated cardiomyopathy, RM = repetition maximum, QOL = quality of life, MHFQ = Minnesota Heart Failure Questionnaire, CHFQ = Chronic Heart Failure Questionnaire

Table 2. PEDro scores for included studies (n = 10).

Study	Random allocation	Concealed allocation	Groups similar at baseline	Participant blinding	Therapist blinding	Assessor blinding	< 15% dropouts	Intention-to-treat analysis	Between-group difference reported	Point estimate and variability reported	PEDro score (0 to 10)
Corvera-Tindel et al (2004)	Y	N	Y	N	N	Y	N	Y	Y	Y	6
Evangelista et al (2006)	Y	N	Y	N	N	N	Y	N	Y	Y	5
Gary et al (2004)	Y	N	Y	N	N	N	Y	N	Y	Y	5
Gielen et al (2005)	Y	N	Y	N	N	N	N	N	Y	Y	4
Hambrecht (2000)	Y	N	Y	N	N	Y	Y	N	Y	Y	6
Harris et al (2003)	Y	N	Y	N	N	N	Y	Y	Y	Y	6
Linke et al (2005)	Y	N	N	N	N	N	Y	N	Y	Y	4
McKelvie et al (2002)	Y	Y	Y	N	N	Y	Y	N	Y	Y	7
Oka et al (2000)	Y	N	Y	N	N	N	Y	N	Y	Y	5
Witham et al (2005)	Y	Y	Y	N	N	Y	Y	N	Y	Y	7

al 2000, Linke et al 2005) examined two weeks of hospital-based exercise before home-based exercise, and two studies (McKelvie et al 2002, Witham et al 2005) examined three months of supervised exercise before home-based exercise.

Description of studies

The studies included adults ≥ 50 years with ischaemic heart disease or dilated cardiomyopathy of either primary or secondary origin, with clinically-stable heart failure symptoms, a New York Heart Association functional class II or III, and an ejection fraction ≤ 40%. Participants were predominantly men with the exception of one study that recruited only women (Gary et al 2004). The duration of home-based exercise ranged from 6 weeks to 9 months. All programs included aerobic exercise (walking or cycling), some in combination with resistance exercise. Most studies were of exercise at a low to moderate intensity: 40–70% of maximum heart rate (HR) or 70% peak VO₂. The control groups maintained usual activity or usual care during the study period with one exception (Harris et al 2003) where the control group carried out home-based electrical stimulation (Table 1). The 10 studies used in the analysis had a mean adherence to exercise of over 60% although Oka et al (2000) reported that adherence slowly declined over the intervention period. All included studies scored over 4 (out of 10) on the PEDro scale (Table 2).

Effect of home-based exercise

The effect of home-based exercise on peak VO₂ was examined by pooling post-intervention data from 7 studies with 355 participants using a random effects model. Home-based exercise increased peak VO₂ by 2.7 ml/kg/min (95% CI 0.7 to 4.7) more than usual activity (Figure 2, see also Figure 3 on the eAddenda for detailed forest plot).

The effect of home-based exercise on 6-min Walk Test was examined by pooling post-intervention data from 5 studies with 320 participants using a fixed effects model. Home-based exercise increased 6-min Walk Test distance by 41 m (95% CI 19 to 63) more than usual activity (Figure 4, see also Figure 5 on the eAddenda for detailed forest plot).

The effect of home-based exercise on quality of life was examined by pooling post-intervention data from three studies using the Minnesota Heart Failure Questionnaire with 198 participants. Home-based exercise did not improve quality of life (WMD 0.5 points out of 105, 95% CI -4.4 to 5.4) more than usual activity (Figure 6, see also Figure 7 on the eAddenda for detailed forest plot). Another two studies that measured quality of life with Chronic Heart Failure Questionnaire were not included in the analysis due to the variability in domains studied (Oka et al 2000, Witham et al 2005). Only one of these studies reported significant improvement in quality of life after training.

Safety of home-based exercise

Adverse events were examined by pooling hospitalisation due to cardiac events from two studies with 143 participants. Home-based exercise did not increase the odds of hospitalisation (OR 0.75, 95% CI 0.19 to 2.92) more than usual activity (Figure 8, see also Figure 9 on the eAddenda for detailed forest plot). Some studies indicated that death caused some dropouts (Corvera-Tindel et al 2004, Hambrecht et al 2000, Witham et al 2005), however, none of them reported that the cardiac events were directly related to exercise.

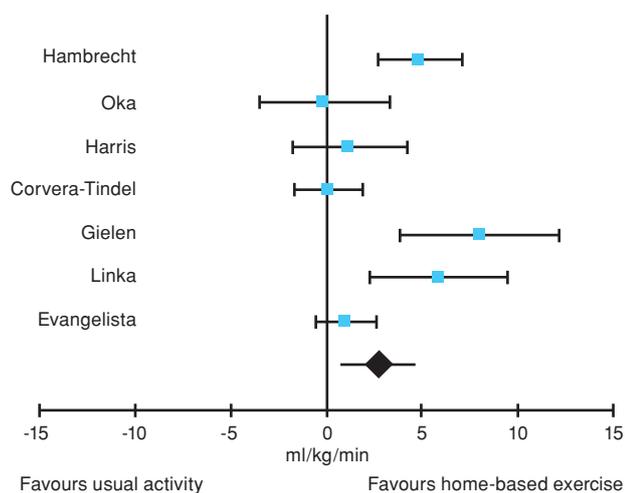


Figure 2. WMD (95% CI) of effect of home-based exercise on peak VO₂ by pooling post-intervention data from 7 studies (n = 355).

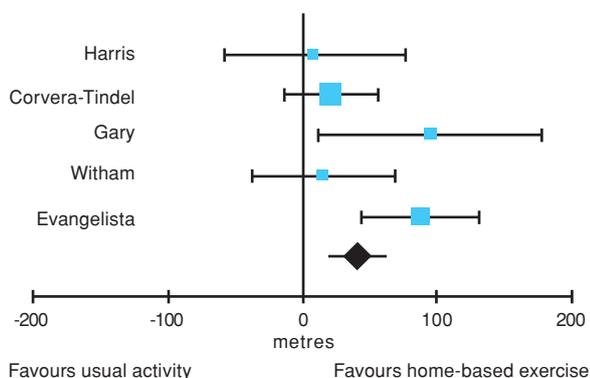


Figure 4. WMD (95% CI) of effect of home-based exercise on 6-min Walk Test by pooling post-intervention data from 5 studies (n = 320).

Discussion

Meta-analysis of the data in this systematic review has confirmed that home-based exercise has significant benefits in chronic heart failure in terms of exercise capacity at both the impairment and the activity level. The effect on quality of life was based on only three studies and no significant effect was demonstrated. Of note, home-based exercise has no direct and deleterious effect and can therefore be used safely in people with chronic heart failure.

The increase of 2.71 ml/kg/min in peak oxygen consumption after home-based exercise compared with usual activity was comparable to hospital-based exercise previously reported by Rees and colleagues (2004) (WMD 2.16 ml/kg/min, 95% CI 1.49 to 2.82) and by van Tol and colleagues (2006) (WMD 2.06 ml/kg/min, 95% CI 0.42 to 0.79). The increase of 41 m in the 6-min Walk Test after home-based exercise compared with usual activity is clinically significant since it is more than the minimum clinically-worthwhile difference of 30 m proposed by Guyatt et al (1984). Also, the magnitude of the effect was comparable to hospital-based exercise previously reported by Rees et al (2004) (WMD 41 m, 95% CI 17 to 65), and by van Tol et al (2006) (WMD 46 m, 95% CI 0.36 to 0.69).

van Tol et al (2006) reported that the Minnesota Heart

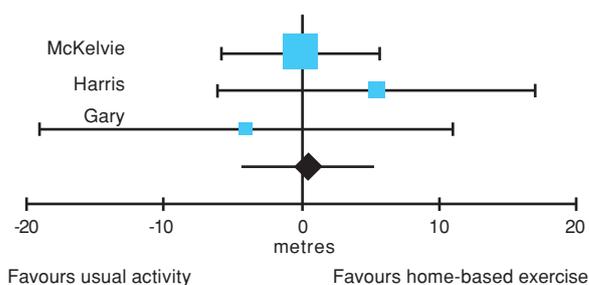


Figure 6. WMD (95% CI) of effect of home-based exercise on quality of life (measured by Minnesota Heart Failure Questionnaire) by change data from one study and post-intervention data from 2 studies (n = 198).

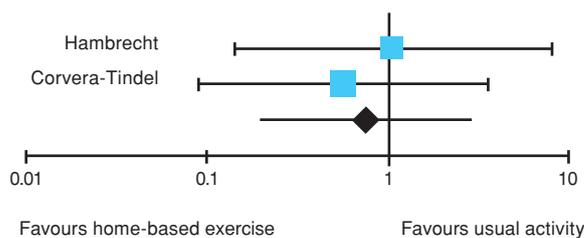


Figure 8. OR (95% CI) of effect of home-based exercise on adverse events by pooling number of hospitalisations due to cardiac events from 2 studies (n = 143).

Failure Questionnaire score improved by 10 points out of 105 after exercise which is more than the minimum clinically-worthwhile difference of 5 points proposed by Riegel et al (2002b). Westlake et al (2002) reported that quality of life was correlated with New York Heart Association class and 6-min Walk Test in people with heart failure. It was therefore unexpected that no benefit in terms of quality of life was observed in our meta-analysis even though 6-min Walk Test and peak oxygen consumption improved significantly. However, only one study (Gary et al 2004) contributed meta-analysable data to both exercise capacity and quality of life.

It has been reported that quality of life is better maintained in adherent compared to non-adherent people with heart failure (Smart et al 2005). Previous investigations found that adherence to home-based exercise by people with heart failure was not comparable to supervised exercise and thus may not induce an equivalent training effect (de Mello Franco et al 2006, McKelvie et al 2002). Three of the studies included in our meta-analysis (Corvera-Tindel et al 2004, Hambrecht et al 2000, Oka et al 2000) reported that initial adherence of 60–70% declined progressively during the home-based exercise. Non-adherence could therefore be the cause of less improvement in quality of life with home-based program. Development of strategies to improve exercise adherence and to reduce barriers to home exercise in people with heart failure should be investigated as a possible means to increase the effectiveness of home-based exercise on quality of life.

People with heart failure are at higher risk of cardiac events (Corvera-Tindel et al 2004, Hambrecht et al 2000). Our systematic review found no increase in hospitalisation due to cardiac events. However, most studies included in the meta-analysis were not principally designed to assess safety and data were scarce. Not enough information exists to identify high-risk people who were more likely to

experience cardiac events (Nishi et al 2007). Further studies on safety are needed.

Our conclusions are constrained by the low to moderate exercise intensity adopted in these studies, by the vast majority of participants in these trials being clinically stable (NYHA class II or III), and by people with severe co-morbidities often being excluded. Such features are not typical of the demographic profile in population-based studies of people with heart failure. Most studies did not report systolic function of the left ventricle or quality of life as outcomes. Where quality of life was measured, several tools were used. It is difficult to compare the results of different quality of life evaluation tools, thus we limited the meta-analysis to Minnesota Heart Failure Questionnaire. Other possible confounders were variability in number of home visits and prior experience of hospital-based exercise that might have influenced adherence to home-based exercise.

In conclusion, home-based exercise had a significant benefit on exercise capacity (6-min Walk Test and peak VO_2) but did not affect on quality of life in people with chronic heart failure. It did not adversely affect hospitalisations due to cardiac events suggesting it is safe. Home-based exercise may improve management for people with heart failure especially for those have limited access to hospital-based programs.

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

Footnote: ^aReview Manager Version 4.2, The Nordic Cochrane Centre, Copenhagen.

Acknowledgements: We thank Dr Jau-Yih Tsauo for her statistical consultation and assistance.

Correspondence: Ying-Tai Wu, School and Graduate of Physical Therapy, College of Medicine, National Taiwan University, Floor 3, No.17, Xuzhou Rd, Zhongzheng District, Taipei City 10020, Taipei, Taiwan. Email: ytw@ntu.edu.tw

References

- Adamopoulos S, Parissis J, Kroupis C, Georgiadis M, Karatzas D, Karavolias G, Koniavitou K, Coats AJ, Kremastinos DT (2001) Physical training reduces peripheral markers of inflammation in patients with chronic heart failure. *European Heart Journal* 22: 791–797.
- Arthur HM, Smith KM, Kodis J, McKelvie R (2002) A controlled trial of hospital versus home-based exercise in cardiac patients. *Medicine and Science in Sports and Exercise* 34: 1544–1550.
- Ashworth NL, Chad KE, Harrison EL, Reeder BA, Marshall SC (2005) Home versus center based physical activity programs in older adults. *Cochrane Database of Systematic Reviews*: CD004017.
- Bennett SJ, Oldridge NB, Eckert GJ, Embree JL, Browning S, Hou N, Chui M, Deer M, Murray MD (2003) Comparison of quality of life measures in heart failure. *Nursing Research* 52: 207–216.
- Bleumink GS, Knetsch AM, Sturkenboom MC, Straus SM, Hofman A, Deckers JW, Wittman JC, Stricker BH (2004) Quantifying the heart failure epidemic: prevalence, incidence rate, lifetime risk and prognosis of heart failure. The Rotterdam Study. *European Heart Journal* 25: 1614–1619.
- Cooper R, Cutler J, Desvigne-Nickens P, Fortmann SP, Friedman L, Havlik R, Hogelin G, Marler J, McGovern P, Morosco G, Mosca L, Pearson T, Stamler J, Stryer D, Thom T (2000) Trends and disparities in coronary heart disease, stroke, and other cardiovascular diseases in the United States: findings of the national conference on cardiovascular disease prevention. *Circulation* 102: 3137–3147.
- Corvera-Tindel T, Doering LV, Woo MA, Khan S, Dracup K (2004) Effects of a home walking exercise program on functional status and symptoms in heart failure. *American Heart Journal* 147: 339–346.
- Cottin Y, Cambou JP, Casillas JM, Ferrieres J, Cantet C, Danchin N (2004) Specific profile and referral bias of rehabilitated patients after an acute coronary syndrome. *Journal of Cardiopulmonary Rehabilitation* 24: 38–44.
- Davies M, Hobbs F, Davis R, Kenkre J, Roalfe AK, Hare R, Wosornu D, Lancashire RJ (2001) Prevalence of left-ventricular systolic dysfunction and heart failure in the Echocardiographic Heart of England Screening study: a population based study. *Lancet* 358: 439–444.
- de Mello Franco FG, Santos AC, Rondon MU, Trombetta IC, Strunz C, Braga AM, Middlekauff H, Negrão CE, Pereira Barretto AC (2006) Effects of home-based exercise training on neurovascular control in patients with heart failure. *European Journal of Heart Failure* 8: 851–855.
- Evangelista LS, Doering LV, Lennie T, Moser DK, Hamilton MA, Fonarow GC, Dracup K (2006) Usefulness of a home-based exercise program for overweight and obese patients with advanced heart failure. *American Journal of Cardiology* 97: 886–890.
- Evenson KR, Rosamond WD, Luepker RV (1998) Predictors of outpatient cardiac rehabilitation utilization: the Minnesota Heart Surgery Registry. *Journal of Cardiopulmonary Rehabilitation* 18: 192–198.
- Gao L, Wang W, Liu D, Zucker IH (2007) Exercise training normalizes sympathetic outflow by central antioxidant mechanisms in rabbits with pacing-induced chronic heart failure. *Circulation* 115: 3095–3102.
- Gary RA, Sueta CA, Dougherty M, Rosenberg B, Cheek D, Preisser J, Neelon V, McMurray R (2004) Home-based exercise improves functional performance and quality of life in women with diastolic heart failure. *Heart and Lung* 33: 210–218.
- Giannuzzi P, Temporelli PL, Corra U, Tavazzi L (2003) Antiremodeling effect of long-term exercise training in patients with stable chronic heart failure: results of the Exercise in Left Ventricular Dysfunction and Chronic Heart Failure (ELVD-CHF) Trial. *Circulation* 108: 554–559.
- Gielen S, Adams V, Linke A, Erbs S, Mobius-Winkler S, Schubert A, Schuler G, Hambrecht R (2005) Exercise training in chronic heart failure: correlation between reduced local inflammation and improved oxidative capacity in the skeletal muscle. *European Journal of Cardiovascular Preventive Rehabilitation* 12: 393–400.
- Guyatt GH, Pugsley SO, Sullivan MJ, Thompson PJ, Berman L, Jones NL, Fallen EL, Taylor DW (1984) Effect of encouragement on walking test performance. *Thorax* 39: 818–822.
- Gwadyr-Sridhar FH, Flintoft V, Lee DS, Lee H, Guyatt GH (2004) A systematic review and meta-analysis of studies comparing readmission rates and mortality rates in patients with heart failure. *Archives of Internal Medicine* 164: 2315–2320.
- Hambrecht R, Gielen S, Linke A, Fiehn E, Yu J, Walther C, Schoene N, Schuler G (2000) Effects of exercise training on left ventricular function and peripheral resistance in patients with chronic heart failure: A randomized trial. *Journal of American Medical Association* 283: 3095–3101.
- Harris S, LeMaitre JP, Mackenzie G, Fox KA, Denvir MA (2003) A randomised study of home-based electrical stimulation of the legs and conventional bicycle exercise training for patients with chronic heart failure. *European Heart Journal* 24: 871–878.
- Haykowsky MJ, Ezekowitz JA, Armstrong PW (2004) Therapeutic exercise for individuals with heart failure:

- special attention to older women with heart failure. *Journal of Cardiac Failure* 10: 165–173.
- Johnson N, Fisher J, Nagle A, Inder K, Wiggers J (2004) Factors associated with referral to outpatient cardiac rehabilitation services. *Journal of Cardiopulmonary Rehabilitation* 24: 165–170.
- Kiilavuori K, Naveri H, Salmi T, Harkonen M (2000) The effect of physical training on skeletal muscle in patients with chronic heart failure. *European Journal of Heart Failure* 2: 53–63.
- Klecha A, Kawecka-Jaszcz K, Bacior B, Kubinyi A, Pasowicz M, Klimeczek P, Banys R (2007) Physical training in patients with chronic heart failure of ischaemic origin: effect on exercise capacity and left ventricular remodeling. *European Journal of Cardiovascular Preventive Rehabilitation* 14: 85–91.
- Linke A, Adams V, Schulze PC, Erbs S, Gielen S, Fiehn E, Mobius-Winkler S, Schubert A, Schuler G, Hambrecht R (2005) Antioxidative effects of exercise training in patients with chronic heart failure: increase in radical scavenger enzyme activity in skeletal muscle. *Circulation* 111: 1763–1770.
- Maher CG, Sherrington C, Herbert RD, Moseley AM, Elkins M (2003) Reliability of the PEDro scale for rating quality of randomized controlled trials. *Physical Therapy* 83: 713–721.
- Marchionni N, Fattiroli F, Fumagalli S, Oldridge N, Del Lungo F, Morosi L, Burgisser C, Masotti G (2003) Improved exercise tolerance and quality of life with cardiac rehabilitation of older patients after myocardial infarction: results of a randomized, controlled trial. *Circulation* 107: 2201–2206.
- McKelvie RS, Teo KK, Roberts R, McCartney N, Humen D, Montague T, Hendrican K, Yusuf S (2002) Effects of exercise training in patients with heart failure: the Exercise Rehabilitation Trial (EXERT). *American Heart Journal* 144: 23–30.
- Myers J, Gujja P, Neelagaru S, Burkhoof D (2007a) Cardiac output and cardiopulmonary responses to exercise in heart failure: application of a new bio-reactance device. *Journal of Cardiac Failure* 13: 629–636.
- Myers J, Hadley D, Oswald U, Bruner K, Kottman W, Hsu L, Dubach P (2007b) Effects of exercise training on heart rate recovery in patients with chronic heart failure. *American Heart Journal* 153: 1056–1063.
- Niebauer J, Clark AL, Webb-Peploe KM, Boger R, Coats AJ (2005) Home-based exercise training modulates pro-oxidant substrates in patients with chronic heart failure. *European Journal of Heart Failure* 7: 183–188.
- Nishi I, Noguchi T, Furuichi S, Iwanaga Y, Kim J, Ohya H, Aihara N, Takaki H, Goto Y (2007) Are cardiac events during exercise therapy for heart failure predictable from the baseline variables? *Circulation Journal* 71: 1035–1039.
- Oka RK, De Marco T, Haskell WL, Botvinick E, Dae MW, Bolen K, Chatterjee K (2000) Impact of a home-based walking and resistance training program on quality of life in patients with heart failure. *American Journal of Cardiology* 85: 365–369.
- Oka RK, DeMarco T, Haskell WL (2005) Effect of treadmill testing and exercise training on self-efficacy in patients with heart failure. *European Journal of Cardiovascular Nursing* 4: 215–219.
- Passino C, Severino S, Poletti R, Piepoli MF, Mammini C, Clerico A, Gabutti A, Nassi G, Emdin M (2006) Aerobic training decreases B-type natriuretic peptide expression and adrenergic activation in patients with heart failure. *Journal of the American College of Cardiology* 47: 1835–1839.
- Piepoli MF, Davos C, Francis DP, Coats AJS, ExTraMATCH Collaborative (2004) Exercise training meta-analysis of trials in patients with chronic heart failure (ExTraMATCH). *British Medical Journal* 328: 189–192.
- Rees K, Taylor RS, Singh S, Coats AJS, Ebrahim S (2004) Exercise based rehabilitation for heart failure. *Cochrane Database of Systematic Reviews*: CD003331.
- Riegel B, Carlson B, Kopp Z, LePetri B, Glaser D, Unger A (2002a) Effect of a standardized nurse case-management telephone intervention on resource use in patients with chronic heart failure. *Archives of Internal Medicine* 162: 705–712.
- Riegel B, Moser DK, Glaser D, Carlson B, Deaton C, Armola R, Sethares K, Shively M, Evangelista L, Albert N (2002b) The Minnesota Living With Heart Failure Questionnaire: sensitivity to differences and responsiveness to intervention intensity in a clinical population. *Nursing Research* 51: 209–218.
- Sabelis LW, Senden PJ, Fijnheer R, de Groot PG, Huisveld IA, Mosterd WL, Zonderland ML (2004) Endothelial markers in chronic heart failure: training normalizes exercise-induced vWF release. *European Journal of Clinical Investigation* 34: 583–589.
- Shah NB, Der E, Ruggerio C, Heidenreich PA, Massie BM (1998) Prevention of hospitalizations for heart failure with an interactive home monitoring program. *American Heart Journal* 135: 373–378.
- Smart N, Haluska B, Jeffriess L, Marwick TH (2005) Predictors of a sustained response to exercise training in patients with chronic heart failure: a telemonitoring study. *American Heart Journal* 150: 1240–1247.
- Smart N, Marwick TH (2004) Exercise training for patients with heart failure: a systematic review of factors that improve mortality and morbidity. *American Journal of Medicine* 116: 693–706.
- van Tol BA, Huijsmans RJ, Kroon DW, Schothorst M, Kwakkel G (2006) Effects of exercise training on cardiac performance, exercise capacity and quality of life in patients with heart failure: A meta-analysis. *European Journal of Heart Failure* 8: 841–850.
- Westlake C, Dracup K, Creaser J, Livingston N, Heywood JT, Huiskes BL, Fonarow G, Hamilton M (2002) Correlates of health-related quality of life in patients with heart failure. *Heart and Lung* 31: 85–93.
- Wheeler EC, Waterhouse JK (2006) Telephone interventions by nursing students: improving outcomes for heart failure patients in the community. *Journal of Community Health Nursing* 23: 137–146.
- Wisloff U, Stoylen A, Loennechen JP, Bruvold M, Rognum O, Haram PM, Tjonna AE, Helgerud J, Slordahl SA, Lee SJ, Videm V, Bye A, Smith GL, Najjar SM, Ellingsen O, Skjaerpe T (2007) Superior cardiovascular effect of aerobic interval training versus moderate continuous training in heart failure patients: a randomized study. *Circulation* 115: 3086–3094.
- Witham MD, Gray JM, Argo IS, Johnston DW, Struthers AD, McMurdo ME (2005) Effect of a seated exercise program to improve physical function and health status in frail patients > or = 70 years of age with heart failure. *American Journal of Cardiology* 95: 1120–1124.