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Research

Home-based telerehabilitation is not inferior to a centre-based program in patients with chronic heart failure: a randomised trial

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KEY WORDS

Cardiac failure
Exercise
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ABSTRACT

Question: Is a 12-week, home-based telerehabilitation program conducted in small groups non-inferior to a traditional centre-based program in terms of the change in 6-minute walk distance? Is the telerehabilitation program also non-inferior to a centre-based program in terms of functional capacity, muscle strength, quality of life, urinary incontinence, patient satisfaction, attendance rates, and adverse events? **Design**: Randomised, parallel, non-inferiority trial with concealed allocation, intention-to-treat analysis and assessor blinding. **Participants**: Patients with stable chronic heart failure (including heart failure with reduced or preserved ejection fraction) were recruited from two tertiary hospitals in Brisbane, Australia. **Intervention**: The experimental group received a 12-week, real-time exercise and education intervention delivered into the participant's home twice weekly, using online videoconferencing software. The control group received a traditional hospital outpatient-based program of the same duration and frequency. Both groups received similar exercise prescription. **Outcome measures**: Participants were assessed by independent assessors at baseline (Week 0), at the end of the intervention (Week 12) and at follow-up (Week 24). The primary outcome was a between-group comparison of the change in 6-minute walk distance, with a non-inferiority margin of 28 m. Secondary outcomes included other functional measures, quality of life, patient satisfaction, program attendance rates and adverse events. **Results**: In 53 participants (mean age 67 years, 75% males), there were no significant between-group differences on 6-minute walk distance gains, with a mean difference of 15 m (95% CI −28 to 59) at Week 12. The confidence intervals were within the predetermined non-inferiority range. The secondary outcomes indicated that the experimental intervention was at least as effective as traditional rehabilitation. Significantly higher attendance rates were observed in the telerehabilitation group. **Conclusion**: Telerehabilitation was not inferior to a hospital outpatient-based rehabilitation program in patients with chronic heart failure. Telerehabilitation appears to be an appropriate alternative because it promotes greater attendance at the rehabilitation sessions. **Trial registration**: ACTRN12613000390785. **[Hwang R, Bruning J, Morris NR, Mandrusiak A, Russell T (2017) Home-based telerehabilitation is not inferior to a centre-based program in patients with chronic heart failure: a randomised trial. *Journal of Physiotherapy* 63: 101–107]**

Introduction

Exercise-based rehabilitation has emerged as a safe and effective intervention for patients with chronic heart failure and is now recommended as standard practice.[1,2] Specifically, exercise-based rehabilitation increases physical function, improves quality of life, and lowers hospital admission rates.[3] Despite this, participation in rehabilitation remains low.[4] Reported barriers to participation include transport difficulties, financial cost, embarrassment about participation, and program availability.[4,5] Telerehabilitation may be an alternative approach that could alleviate some of these barriers.

Telerehabilitation is the delivery of rehabilitation services at a distance via telecommunication technologies, such as telephone, internet and videoconference.[6] This delivery model has been successfully trialled in patients with various cardiopulmonary diseases.[6–9] In a pilot study of home-based rehabilitation delivered via a tablet computer, all participants with chronic obstructive pulmonary disease (COPD) remained actively participating in the program after 1 year, and (although statistically non-significant) COPD-related hospital costs were reduced by an average of 27%.[7] In people with chronic heart failure, a home-based telerehabilitation program was delivered individually three times per week for 8 weeks, using mobile phones for voice communication and electrocardiogram transmission.[8] This program produced equivalent increases in peak oxygen consumption and quality of life as a centre-based program of the same duration and frequency.[8] Home-based telerehabilitation could also have similar benefits

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in other outcomes (such as functional exercise capacity and balance) for patients with chronic heart failure.

International experience shows that rehabilitation programs for people with heart failure can be delivered using various models, including centre-based, home-based or a hybrid of these approaches. For example, home-based and centre-based cardiac rehabilitation programs have been shown to be equally effective in improving health-related quality of life and reducing mortality rates in patients with heart disease.[9] A flexible or remote model has also been proposed to improve attendance.[4] However, the feasibility of a group-based, video-linked telerehabilitation program delivered into the home has not yet been investigated in patients with chronic heart failure.

The aim of the present study was to determine the efficacy and safety of a short-term, real-time, group-based heart failure rehabilitation program delivered into each participant's home via an online telerehabilitation system.

Therefore, the research questions for this randomised trial were:

1. Is a 12-week, home-based telerehabilitation program conducted in small groups non-inferior to a traditional centre-based program in terms of the change in 6-minute walk distance?
2. Is the telerehabilitation program also non-inferior to a centre-based program in terms of functional capacity, muscle strength, quality of life, urinary incontinence, patient satisfaction, attendance rates, and adverse events?

Method

Design

A two-group, parallel, non-inferiority trial with blinded outcome assessors was undertaken. Participants were randomised to either: an experimental group, who were provided with a 12-week home-based telerehabilitation program delivered twice-weekly; or a control group, who were provided with a traditional centre-based program of the same duration and frequency. Consenting participants were allocated 1:1 using a non-blocked random allocation sequence. Allocation was concealed through the use of opaque, sealed and numbered envelopes, and administered by an experienced, independent researcher at a central location. While the treating healthcare professionals could not be blinded to group allocation, participants were asked not to disclose their group allocation to the blinded assessors. All assessments were undertaken at the hospitals using a standardised protocol at baseline (Week 0), immediately after completion of the rehabilitation program (Week 12) and at follow-up 12 weeks later (Week 24). The assessors were 19 hospital physiotherapists with an average of 9 years of work experience in physiotherapy.

Participants, therapists and centres

Patients were recruited from cardiology and general medical wards of two tertiary hospitals in Brisbane, Australia, between July 2013 and February 2016. The patients who were recruited had a recent hospital admission for heart failure and were referred to heart failure services. Patients were eligible if they: had a diagnosis of chronic heart failure confirmed by an echocardiogram (heart failure with reduced or preserved ejection fraction), presented with clinical heart failure symptoms, and were aged over 18 years. Patients were excluded if they: did not meet safety screening criteria as outlined by the Australian exercise guidelines for patients with chronic heart failure,[1] such as symptomatic severe aortic stenosis and significant ischaemia at low exercise intensity; lived in an institution such as a nursing home; lived more than an hour driving distance from the treating hospital; or had no support person at home, which was important for those recruited to the home-based telerehabilitation program for safety reasons. Healthcare professionals at each site were physiotherapists who were highly experienced in prescribing exercise for patients with chronic heart failure.

Intervention

The control group received a centre-based rehabilitation program based on current recommended guidelines encompassing education, aerobic and strength training exercise.[1] This traditional heart failure rehabilitation program was led by physiotherapists over a 12-week period; it consisted of 60 minutes of exercise per session, two sessions per week, at the treating hospital. Each session consisted of a 10-minute warm-up, 40-minutes of aerobic and strength exercises, and a 10-minute cool-down. Exercise intensity commenced at 9 (very light) and gradually progressed towards 13 (somewhat hard) on the rate of perceived exertion scale.[10] Exercise prescription was tailored to the participant's goal and the treating physiotherapist continuously reviewed it to ensure appropriate progression. The control group attended education sessions at the hospital on the same day as the exercise sessions. These sessions were delivered by a multidisciplinary team including the nurse, dietitian, physiotherapist, occupational therapist, social worker and pharmacist. The topics that were covered included self-management, nutritional counselling, physical activity counselling, psychological interventions, medications and risk factor management, where appropriate. Participants were provided with additional home exercises to be undertaken three times per week, at a similar intensity as prescribed for the supervised exercise sessions.

The telerehabilitation program was delivered via a synchronous videoconferencing platform[a] across the internet to groups of up to four participants within the home. Two-way audiovisual communication enabled interaction of all parties, and the physiotherapist guided participants through an exercise program similar to the control group. This approach enabled the physiotherapist to watch participants performing the exercises and provide real-time feedback and modification, as required, as well as facilitating peer support from other participants. A group-based program was selected because many people undertaking cardiac rehabilitation value the guidance from healthcare professionals and enjoy the group interaction and social support.[4] Participants were provided with additional home exercises similar to the control group. Educational topics were delivered as electronic slide presentations with embedded audio files,[b] which were recorded from the education sessions delivered for a centre-based program. Participants were encouraged to watch the designated presentation individually or with their support person, in their own time in preparation for subsequent online group discussions. A 15-minute interaction period was held at the start of each telerehabilitation session to facilitate these discussions. A range of resources were accessed through the videoconferencing platform to facilitate these discussions, such as screen and document sharing, collaborative drawing and chat functions.

Telerehabilitation equipment was loaned to participants as required, including a laptop computer,[c] a mobile broadband device[d] connected to 3G wireless broadband internet,[e] an automatic sphygmomanometer,[f] a finger pulse oximeter,[g] free weights and resistance bands. Participants received an equipment familiarisation session either in-person at the hospital or during a home visit, which covered operating the laptop, accessing the online videoconferencing software[a] and using the monitoring equipment. An equipment manual with written and pictorial instructions was also supplied. Telephone contact details to access technical support were included in the event that participants needed additional assistance or encountered technical difficulties. Participants were guided to self-monitor and verbally report their blood pressure, heart rate and oxygen saturation levels at the start of each rehabilitation session. Other measurements such as

weight, blood sugar level, extent of peripheral oedema and general wellbeing were also undertaken, where relevant.

Outcome measures

Primary outcome

Participants performed the 6-minute walk test in accordance with recommended guidelines, including standardised encouragements,[11] on a 30-m walk track in hospital at a face-to-face appointment. The 6-minute walk distance (6MWD) was recorded to the nearest metre. The test was performed twice, as recommended, to account for a learning effect,[11] and the longer distance was used in the analysis.

Secondary outcomes

Other outcomes included balance tests, a 10-m walk test, grip strength, quadriceps strength, urinary incontinence, quality of life, patient satisfaction, program attendance and adverse events. Balance was measured by the Balance Outcome Measure for Elder Rehabilitation (BOOMER),[12] which consisted of four components: the timed up and go test (TUGT), functional reach, static standing with the eyes closed and feet together, and step test. Each BOOMER component was converted into a 5-point ordinal scale, and then combined to provide a total score out of 16, with higher scores representing better balance.[12] The 10-m walk test (at both comfortable and fast pace) was undertaken on a straight walking track from a static start.[13] The time taken to walk 10 m was recorded in seconds, with two decimal places. Each test was measured twice, with the average of the two tests recorded. Maximum grip strength for each hand was measured in kilograms three times with a hand-held dynamometer,[h] as described previously,[14] and the best measurement was used in the analysis as the maximum voluntary contraction. Quadriceps strength was also measured in kilograms three times with a hand-held dynamometer,[h] as per previous methodology,[15] with an adjustable strap, and the best measurement was used in the analysis.

Validated surveys were used to measure health-related quality of life and patient satisfaction. The Minnesota Living with Heart Failure Questionnaire (MLWHFQ) is a disease-specific questionnaire that contains 21 questions determining the key physical, emotional, social and mental dimensions of quality of life.[16] Scores range from 0 to 105, with higher scores representing worse quality of life. The Revised Urinary Incontinence Scale (RUIS) consists of five questions that rate aspects of incontinence severity.[17] The scores are summed to give a total from 0 to 16, with higher scores indicating worse severity. Quality of life was also measured using a generic tool, the EuroQol five-dimensional (EQ-5D) questionnaire.[18] This questionnaire has two sections: the EQ-5D descriptive system (which measures mobility, self care, usual activities, pain/discomfort, and anxiety/depression) and the visual analogue scale (which measures self-rated health status from 0 to 100).[18] Responses on the EQ-5D were converted to a utility score of 0 (worst) to 1 (best) using a scoring algorithm based on the United Kingdom general population.[19] Patient satisfaction was measured by the Client Satisfaction Questionnaire (CSQ-8).[20] This eight-item questionnaire measures the participant's perspective of the value of services received, and has a total score ranging from 8 to 32, with high scores indicating greater satisfaction.[20]

Additional outcomes included program attendance rates and the number of adverse events. Attendance rates were presented as the number of sessions attended by each participant, also categorised into adherent (>80%), partly adherent (20 to 80%) and non-adherent (<20%) based on the proportion of sessions attended.[5] Serious adverse events were defined as death, cardiac arrest and syncope, and minor adverse events included angina, diaphoresis, palpitations and falls. Healthcare professionals who delivered the rehabilitation programs recorded any adverse events after each exercise session. A list of potential adverse events was attached to the exercise recording form. At completion of the 12-week rehabilitation program, the assessors tallied the number of adverse events and recorded them in a database. The research team also reviewed the number and type of adverse events.

Demographic and clinical information were obtained from participant interview and the medical records. These included the New York Heart Association (NYHA) functional classification; self-reported falls in the previous 12 months; and left ventricular ejection fraction reported from echocardiography performed in the previous 6 months.

Data analysis

The study was powered to detect non-inferiority of the slope of 6MWD change from Week 0 to Week 12 between the two intervention groups. An a priori, non-inferiority margin of –28 m (which corresponds to 20% less than the minimum clinically important difference reported for the 6MWD)[21] was adopted as per recommendations.[22,23] Using a standard deviation (SD) of 31 m, based on previous data,[24] a one-sided significance level of 2.5% and allowing for a 10% drop-out rate, a sample of 48 participants was required in order for the study to have 80% power to detect the non-inferiority margin.

Statistical analysis was performed using commercial software.[i] Data were checked for missing values, distribution and outliers; and descriptively summarised as means (SD) or counts (%), as appropriate. A strong positive skew in the TUGT and 10-m walk test data was successfully resolved using logarithmic transformations, and the data were back-transformed. The analyses for the primary and secondary outcomes were on an intention-to-treat basis, supplemented by a per-protocol analysis of the primary outcome similar to a previous research approach.[25] Participants were considered as per-protocol if they were in the adherent and partly adherent groups. The primary outcome was analysed using a linear mixed-effects model, which is recommended for its ability to account for repeated measures and missing data.[26] The model (using maximum likelihood method, unstructured covariance type and controlling for baseline variables) included group, time and group-by-time interaction as fixed-effect covariates, and intercepts and participants as random-effects. In this model, the coefficient associated with the interaction represented the difference between the 6MWD slopes. This coefficient and its 95% CI were used to estimate the between-group difference. Telerehabilitation was considered non-inferior if the lower limit of this 95% CI was below the pre-determined margin.[22,23] Similar analyses were applied to secondary outcome measures collected at three time points. Between-group comparisons for continuous data collected at the end of the intervention period were analysed using independent t-tests. Ordinal data were analysed with a non-parametric equivalent. *P*-values less than 0.05 were considered to be significant in all analyses.

Results

Flow of participants through the study

As shown by the flowchart in Figure 1, 53 participants were enrolled. Slight over-enrolment in the study was required to achieve the 24 participants in each group, as per the sample size calculation, given the non-block randomisation design. Fifty-five percent had ischaemic cardiomyopathy and 57% were NYHA II. Table 1 summarises participant characteristics and shows that the groups were well matched.

Compliance with the study protocol

As illustrated in Figure 1, 50 and 49 participants attended post-program and follow-up assessments, respectively. Of the 51 participants who attended the rehabilitation programs, 49 were categorised as adherent (>80% of sessions attended) or partly adherent (20 to 80% of sessions attended). Compared to the control

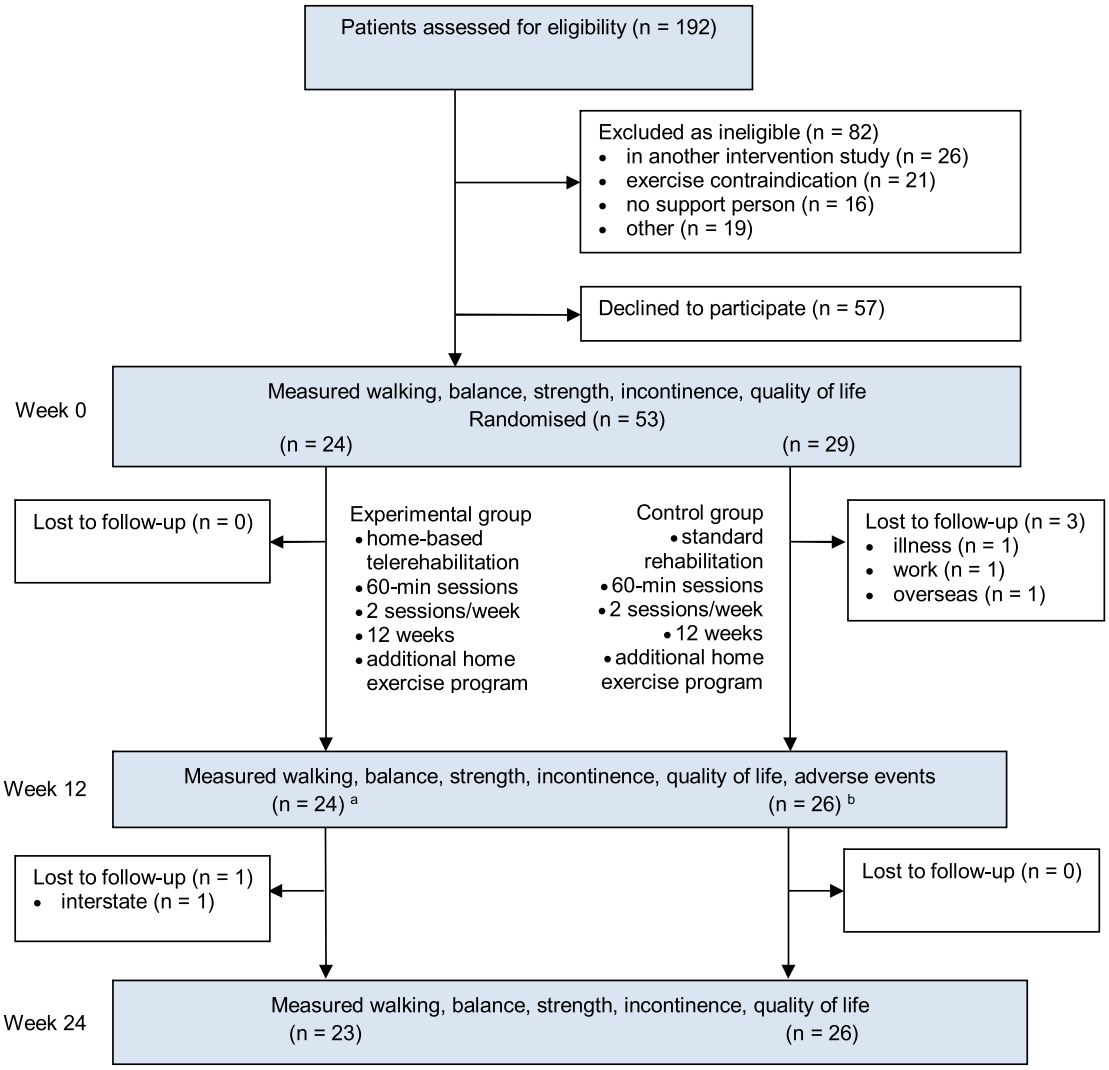

Figure 1. Design and flow of participants through the trial.
[a] None attended < 20% of available exercise sessions.
[b] Two attended < 20% of available exercise sessions.

group, participants in the experimental group were significantly more likely to be categorised as adherent (RR 2.39, 95% CI 1.27 to 4.51) and significantly less likely to be categorised as partly adherent (RR 0.46, 95% CI 0.23 to 0.92). The only participants categorised as non-adherent (<20% of sessions attended) were in the control group. Further data are presented in Table 2.

In the registered version of the protocol, falls were the only adverse event. For completeness, other unregistered adverse events will also be reported in this paper.

Effect of the intervention

Primary outcome

The 6MWD results at each assessment time and the between-group differences are presented in Table 3. Individual participant data are presented in Table 4 (see eAddenda for Table 4). There was no significant overall between-group difference in the 6MWD ($F_{(1,6)} = 1.39$; $p = 0.24$), with an estimated between-group difference in favour of the experimental group of 15 m (95% CI –28 to 59) at Week 12. At Week 24, this difference was non-significant at 2 m (95% CI –36 to 41), again in favour of the telerehabilitation group. As illustrated in Figure 2, the lower limit of the 95% CI was within the non-inferiority margin at Week 12, but slightly outside of the margin at Week 24. There was no significant overall group-by-time interaction effect.

Table 5 (see eAddenda for Table 5) shows the within-group differences from baseline to Week 12 and to Week 24 assessments, for both groups combined. There was a significant overall improvement in the 6MWD over time ($F_{(2,6)} = 3.23$; $p = 0.048$). Specifically, there was a non-significant post-program improvement over baseline of 14 m for both groups combined and a significant follow-up improvement over baseline of 24 m ($p = 0.046$). The per-protocol analysis performed for the partly adherent to adherent participants demonstrated similar results, with an estimated between-group difference of 11 m (95% CI –31 to 54) at Week 12 and 3 m (95% CI –36 to 43) at follow-up, both in favour of the telerehabilitation group.

Secondary outcomes

As presented in Table 3, the between-group differences in the other functional, balance and muscle strength measures did not substantially differ. Similarly, no between-group differences were found in quality of life and urinary incontinence.

Mixed-model analyses showed that both intervention groups experienced significant improvements in their quality of life from pre-program to post-program, and improvements were sustained at follow-up (Table 5, see eAddenda for Table 5). However, no significant time effects were observed for most other outcome measures.

Table 6 outlines other outcome measures, including patient satisfaction and adverse events. Both intervention groups reported

Table 1
Baseline characteristics of participants.

Characteristic	Exp (n = 24)	Con (n = 29)	Total (n = 53)
Age (*yr*), mean (SD)	68 (14)	67 (11)	67 (12)
Gender, n male (%)	19 (79)	21 (72)	40 (75)
Ethnicity, n Caucasian (%)	22 (92)	27 (93)	49 (92)
Aetiology, n (%)			
ischaemic cardiomyopathy	14 (58)	15 (52)	29 (55)
valvular	1 (4)	1 (3)	2 (4)
idiopathic dilated cardiomyopathy	4 (17)	6 (21)	10 (19)
heart failure with preserved ejection fraction	3 (13)	2 (7)	5 (9)
LVEF (%), mean (SD)	36 (16)	35 (17)	35 (17)
Atrial arrhythmia, n (%)	9 (38)	12 (41)	21 (40)
Co-morbidities, n (%)			
diabetes mellitus	13 (54)	10 (35)	23 (43)
chronic respiratory conditions	5 (21)	13 (45)	18 (34)
depression	5 (21)	3 (10)	8 (15)
stroke	6 (25)	1 (3)	7 (13)
arthritis	7 (29)	10 (35)	17 (32)
NYHA functional class, n (%)			
I	3 (13)	2 (7)	5 (9)
II	9 (37)	21 (72)	30 (57)
III	12 (50)	6 (21)	18 (34)
IV	0 (0)	0 (0)	0 (0)
Medications, n (%)			
ACE-I or ARB	23 (96)	25 (86)	48 (91)
beta-blockers	22 (92)	23 (79)	45 (85)
diuretics	21 (88)	26 (90)	47 (89)
Walking aid, n (%)			
none	18 (75)	22 (76)	40 (76)
stick	5 (21)	3 (10)	8 (15)
walker	1 (4)	4 (14)	5 (9)
Social situation, n (%)			
lives alone	0 (0)	5 (17)	5 (9)
lives with others	24 (100)	24 (83)	48 (91)
Home oxygen, n (%)	3 (13)	0 (0)	3 (6)
BMI (kg/m^2), mean (SD)	31 (8)	32 (6)	31 (7)
Resting SBP (*mmHg*), mean (SD)	124 (21)	123 (19)	123 (20)
Resting DBP (*mmHg*), mean (SD)	70 (14)	73 (11)	71 (12)
Resting HR (*beats/min*), mean (SD)	66 (13)	73 (12)	69 (13)
Fallers, n (%)	5 (21)	11 (38)	16 (30)

ACE-I = angiotensin-converting enzyme inhibitor, ARB = angiotensin receptor blocker, BMI = body mass index, Con = control group, DBP = diastolic blood pressure, Exp = experimental group, HR = heart rate, LVEF = left ventricular ejection fraction, NYHA = New York Heart Association, SBP = systolic blood pressure.

high levels of satisfaction with the program, with no significant between-group difference. The telerehabilitation group had significantly higher attendance rates than the control group, with a mean difference of 6 (95% CI 2 to 9) sessions. No significant difference was found in the number of adverse events between the two groups. There were no occurrences of death, cardiac arrest, syncope or fall in either group during the exercise session. There were some minor adverse events in both groups, including three incidences of angina, three of diaphoresis and two of palpitations.

Table 2
Attendance data for the participants who participated in any rehabilitation sessions (n = 51). Mean (SD) sessions attended in each group, mean difference (95% CI) between groups, and number (%) in each attendance category in each group and the relative risk (95% CI) between groups.

Adherence measure	Exp (n = 24)	Con (n = 27)	MD (95% CI)	Relative Risk (95% CI)
Sessions attended (*n*), mean (SD)	20 (6)	14 (7)	6 (2 to 9)	
Category, n (%)				
adherent [a]	17 (71)	8 (30)		2.39 (1.27 to 4.51)
partly adherent [b]	7 (29)	17 (63)		0.46 (0.23 to 0.92)
non-adherent [c]	0 (0)	2 (7)		not estimable

Con = control group, Exp = experimental group.
[a] > 80% of sessions attended.
[b] 20 to 80% of sessions attended.
[c] < 20% of sessions attended.

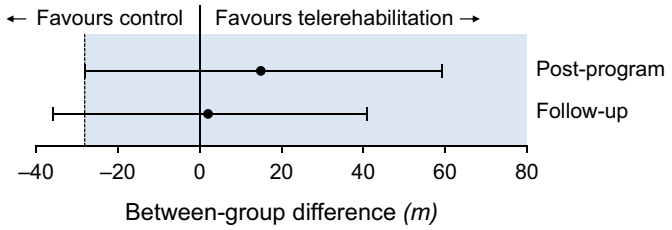

Figure 2. Non-inferiority plot of 6-minute walk test distance. Difference between the experimental and control groups in the change in 6-minute walk distance from Week 0 to 12 and from Week 0 to 24. Error bars indicate the 95% confidence intervals and the shaded area indicates the non-inferiority zone.

Discussion

This innovative study is the first to test a group-based video telerehabilitation program delivered in the home against a traditional centre-based rehabilitation program for people with chronic heart failure. Results verified the primary research hypothesis that the 6MWD change from baseline to Week 12 in the experimental group was not inferior compared with that in the control group. However, non-inferiority of telerehabilitation compared with traditional rehabilitation could not be proven for the 6MWD change from baseline to follow-up. This may have been influenced by the small improvements observed in both groups during this unsupervised exercise phase at follow-up, which is in line with a previous study[27] that reported difficulty in maintaining benefits gained from a supervised exercise program after program cessation. There were also no differences between the two intervention groups in most other functional capacity measures, muscle strength, quality of life, urinary incontinence, patient satisfaction and adverse events. The only significant differences were relatively minor, but they did favour the telerehabilitation group. The telerehabilitation group had higher attendance rates compared with the control group.

These results resonate with previous research on telerehabilitation. For instance, home-based telemonitored Nordic walking training has been demonstrated to be safe, effective and well-accepted in patients with chronic heart failure.[28] In telecoaching studies, the use of text messaging was reported to be as effective as a centre-based cardiac rehabilitation program in terms of 6MWD change,[29] as well as lower costs and fewer days lost to cardiovascular readmissions.[30] Higher attendance rates were found in the telemonitored exercise programs,[8,28] which is also in agreement with our results. The low number of adverse events experienced in our study is also consistent with the results of those same studies,[8,28] suggesting that telerehabilitation is safe in patients with chronic heart failure who meet the recommended exercise screening criteria.[1] These minor adverse events are not uncommon in an exercise program, and the healthcare professionals adequately addressed the events in our study.

Few studies have been performed on cardiac 'telerehabilitation', and 65% of these predominantly focused on phone-based interventions.[6] Our study has added to this evidence by using a video-based intervention and a range of core cardiac rehabilitation components.[31] Video-based telerehabilitation is a new approach that enables patients to exercise in the comfort of their home, whilst maintaining real-time communication with healthcare professionals. For example, the patient can demonstrate how they have been performing the exercises and the physiotherapist can monitor the accuracy of the exercises performed, modifying and progressing them accordingly through a practical demonstration. It is also possible to generate discussions through online tools such as video sharing and collaborative drawing. This modality may help to improve access to those with travel or cost barriers, whilst exercising under supervision. Furthermore, with a rapid expansion of internet usage in health, this mode of healthcare delivery should be further explored. Telerehabilitation has been suggested to allow

Table 3
Mean (SD) of groups, mean (95% CI) difference between groups, and non-inferiority range.

Outcome	Groups [a]						Between-group difference [b]		Non-inferiority range
	Week 0		Week 12		Week 24		Week 12 minus Week 0	Week 24 minus Week 0	
	Exp (n = 24)	Con (n = 29)	Exp (n = 24)	Con (n = 26)	Exp (n = 23)	Con (n = 26)	Exp minus Con	Exp minus Con	
6MWD *(m)*	346 (104)	382 (106)	364 (96)	394 (119)	374 (89)	410 (103)	15 (−28 to 59)	2 (−36 to 41)	−28 to positive
TUGT *(s)*	9.4 (2.8)	9.6 (3.7)	8.9 (3.0)	9.7 (5.4)	8.5 (2.2)	9.7 (6.6)	1.0 (0.8 to 1.1)	1.0 (0.9 to 1.1)	negative to 1.2
10-m walk test *(s)*									
comfortable	10.2 (2.6)	11.0 (5.4)	9.3 (2.1)	10.2 (4.5)	9.4 (2.2)	9.7 (3.1)	1.0 (0.8 to 1.2)	1.0 (0.9 to 1.2)	negative to 1.5
fast	7.2 (1.8)	7.4 (2.5)	7.1 (2.4)	7.4 (3.0)	6.9 (1.6)	7.5 (3.0)	1.0 (0.9 to 1.1)	1.0 (0.9 to 1.1)	negative to 1.5
Strength *(kg)* [c]									
grip	27 (11)	31 (10)	30 (9)	32 (9)	30 (7)	32 (9)	0 (−3 to 4)	1 (−2 to 4)	−5 to positive
quadriceps	24 (10)	26 (11)	25 (11)	25 (11)	25 (10)	25 (11)	1 (−4 to 6)	1 (−3 to 5)	−6 to positive
BOOMER *(0 to 16)*	13 (2)	13 (3)	13 (2)	13 (2)	13 (2)	13 (3)	0 (−1 to 1)	−1 (−2 to 0)	−2 to positive
RUIS *(0 to 16)*	4 (5)	4 (4)	4 (5)	4 (4)	4 (5)	4 (4)	1 (−1 to 2)	0 (−1 to 2)	negative to 2
EQ-5D									
VAS *(0 to 100)*	62 (19)	69 (18)	70 (17)	70 (18)	69 (17)	75 (14)	7 (−3 to 17)	−1 (−9 to 8)	−6 to positive
Utility *(0 to 1)*	0.73 (0.13)	0.69 (0.26)	0.73 (0.21)	0.74 (0.21)	0.73 (0.22)	0.74 (0.25)	−0.06 (−0.17 to 0.05)	−0.06 (−0.16 to 0.03)	−0.02 to positive
MLWHFQ *(0 to 105)*	47 (19)	41 (22)	32 (19)	35 (24)	34 (23)	33 (21)	−7 (−20 to 6)	−4 (−17 to 10)	negative to 4

BOOMER = balance outcome measure for elder rehabilitation, Con = control group, EQ-5D = EuroQoL, Exp = experimental group, MLWHFQ = Minnesota Living With Heart Failure questionnaire, RUIS = Revised Urinary Incontinence Scale, TUGT = Timed Up and Go test, VAS = visual analogue scale, 6MWD = 6-minute walk distance.
Shaded cell = primary outcome.
[a] Descriptive statistics using non-transformed data.
[b] Using a linear mixed-effects model.
[c] Right side.

early advice, detection and intervention in a similar approach as telemonitoring.[8] For people with chronic heart failure, structured telephone support and non-invasive home telemonitoring have been shown to reduce the risk of all-cause mortality and heart failure-related hospitalisations, with concomitant improvements in quality of life.[32] Telerehabilitation has the potential to monitor clinical symptoms, as well as improve the equity of access to high-quality heart failure rehabilitation programs, and thereby narrow the gap between recommended clinical practice and current feasibility.

Our study was strengthened by the direct comparison of two different delivery models for heart failure rehabilitation programs and the same staff contact frequency for both groups. The generalisability of the results to the typical heart failure population is boosted by the recruitment of participants who were older, female, and with a broad range of aetiology and computer experience. Relatively low-cost technologies that are available in most clinical settings were chosen, which increases the likelihood of translation into usual practice. However, there were some limitations: there may have been recruitment bias, as patients enrolled in a rehabilitation trial may have been more motivated than the general heart failure population. As the study was conducted in a metropolitan area with reliable internet coverage, further research will be required to determine the applicability of telerehabilitation in rural and remote areas with variable internet coverage. A non-block randomisation design was used for the study, which resulted in uneven group allocation. Small improvements from baseline were noted in many outcome measurements, which may have been related to a low training volume; however, these results represent everyday clinical practice and are not uncommon in the literature. The extent to which participants carried out independent home exercises beyond the formal program sessions was not objectively evaluated; therefore, the exact training volume could not be ascertained. No formal cost evaluation was performed in this study and this should be the focus of future work; however, anecdotally, the cost for the delivery of both programs in this study was similar.

In conclusion, telerehabilitation was not inferior to centre-based rehabilitation program in patients with chronic heart failure on the primary measure of 6MWD change from baseline to the end of the rehabilitation program. The between-group differences for the other outcomes suggest that telerehabilitation is at least similarly effective to traditional rehabilitation. Telerehabilitation appears an effective and safe option for the delivery of heart failure exercise-based rehabilitation program.

Table 6
Outcomes finalised at the end of the intervention period, by group and statistical significance of the between-group comparison.

Outcome	Exp (n = 24)	Con (n = 26)	*p*-value
CSQ-8 *(8 to 32)*, median (IQR)	32 (31 to 32)	32 (30 to 32)	0.17 [a]
Adverse events, n (%)	6	2	0.89 [b]
angina	3	0	
cardiac arrest	0	0	
death	0	0	
diaphoresis	1	2	
fall	0	0	
palpitations	2	0	
syncope	0	0	

CSQ-8 = client satisfaction questionnaire, Con = control group, Exp = experimental group.
[a] Mann–Whitney U test.
[b] Independent samples median test.

What is already known on this topic: For people with chronic heart failure, exercise rehabilitation increases physical function, improves quality of life, and lowers hospital admission rates. Telerehabilitation with monitoring via telephone-based technologies is an effective way to provide rehabilitation in the home for this population.

What this study adds: Telerehabilitation can be provided for people with chronic heart failure using internet-based video links and a group format. Such rehabilitation appears to be at least as effective as traditional hospital outpatient-based rehabilitation, with the added advantage of making participants significantly more likely to attend the majority of the scheduled sessions.

Footnotes: [a]Adobe Connect 9.2, Adobe Systems Inc, San Jose, USA; [b]Microsoft PowerPoint, Microsoft, Redmond, USA; [c]Inspiron 15, Dell Inc, Round Rock, USA; [d]E3131 modem, Huawei Technologies Co Ltd, Shenzhen, China; [e]Optus, Australia; [f]ri-champion N, Rudolf Riester GmbH, Jungingen, Germany; [g]Digit 3420 BCI, Smiths Medical PM Inc, Waukesha, USA; [h]Jamar dynamometer, Jamar, Lafayette, USA; [i]SPSS Statistics 22, SPSS Inc, Chicago, USA.

eAddenda: Tables 4 and 5 can be found online at http://dx.doi.org/10.1016/j.jphys.2017.02.017

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