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ORIGINAL ARTICLE

Cost-Utility Analysis of Home-Based Telerehabilitation Compared With Centre-Based Rehabilitation in Patients With Heart Failure

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Background Whilst home-based telerehabilitation has been shown non-inferior to traditional centre-based rehabilitation in patients with chronic heart failure, its economic sustainability remains unknown. This study aimed to investigate the cost-utility of a home-based telerehabilitation program.

Methods A comparative, trial-based, incremental cost-utility analysis was conducted from a health care provider's perspective. We collected data as part of a multi-centre, two-arm, non-inferiority, randomised controlled trial with 6 months follow-up. There were 53 participants randomised to either a telerehabilitation program (consisting of 12 weeks of group-based exercise and education delivered into the home via online video-conferencing) or a traditional centre-based program. Health care costs (including personnel, equipment and hospital readmissions due to heart failure) were extracted from health system records, and calculated in Australian dollars using 2013 as the base year. Health utilities were measured using the EuroQol five-dimensional (EQ-5D) questionnaire. Estimates were presented as means and 95% confidence intervals (CIs) based on bootstrapping. Costs and utility differences were plotted on a cost-effectiveness plane.

Results Total health care costs per participant were significantly lower in the telerehabilitation group (-$1,590, 95% CI: −2,822, −359) during the 6 months. No significant differences in quality-adjusted life years (0, 95% CI: −0.06, 0.05) were seen between the two groups.

Conclusions Heart failure telerehabilitation appears to be less costly and as effective for the health care provider as traditional centre-based rehabilitation.

Keywords Cardiac failure • Cost-effectiveness • Economic evaluation • Exercise • Telemedicine • Telerehabilitation

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Introduction

Patients with chronic heart failure (CHF) are ranked as one of the largest and most expensive groups of health care consumers in Australia [1]. It has been estimated that over 23 million people worldwide [2] and 511,000 (2%) people in Australia have CHF, contributing $3.1 billion to the annual Australian health care cost [3]. Exercise has been shown to increase exercise capacity, improve quality of life and lower heart failure hospital readmissions [4]. Despite compelling evidence for its benefits, many patients are unable to access traditional centre-based rehabilitation programs. The reasons for poor access to centre-based rehabilitation programs are complex, however transport and program availability are two of the most commonly cited barriers [5,6].

In an effort to overcome some of these barriers and widen access to exercise programs for patients with CHF and other chronic diseases, alternative models such as home-based telerehabilitation have been developed and tested. Telerehabilitation is defined as the delivery of rehabilitation services at a distance via telecommunication technologies [7], such as telephone, internet and video-based communications between the patient and health care provider [8]. Evidence suggests that the implementation of telerehabilitation can be successful. For example, a systematic review reported a 71% success rate with telerehabilitation (where telerehabilitation was at least as effective as the control group) in patients with physical disabilities [8]. In cardiac and pulmonary rehabilitation programs, telerehabilitation has been found to be non-inferior to traditional rehabilitation programs [9]. Moreover, in cardiac patients telerehabilitation demonstrated a lower risk of adverse events and cardiovascular readmissions and a higher adherence to physical activity guidelines compared with usual care [10].

This alternative model of delivery may alleviate transport barrier, facilitate peer support through group-based activities and promote program attendance through real-time supervision [11]. However, the economic sustainability of implementing and delivering group-based telerehabilitation remains unknown. We recently reported that a group-based telerehabilitation program was not inferior to a traditional centre-based rehabilitation program in patients with CHF, on the primary measure of the 6-minute walk test distance change from baseline to the end of the rehabilitation program [12]. We also found that participants in this telerehabilitation program liked the health benefits, access to care and social support [13]. As a follow-up to these studies, we performed an economic analysis of these interventions, to inform the future uptake of this new delivery model. The aim of this study was, therefore, to investigate the cost-utility of a home-based telerehabilitation program versus a traditional centre-based rehabilitation program in patients with CHF.

Methods

Design

This economic evaluation was a comparative, trial-based, incremental cost-utility analysis conducted from a health care perspective. It used data collected as part of a multi-centre, two-arm, non-inferiority, randomised controlled trial, with 6 months follow-up. Assessments were undertaken at baseline (Week 0), immediately after completion of the rehabilitation program (Week 12); and at follow-up 3 months later (Week 24). The trial was approved by the Human Research Ethics Committees of participating hospitals and was included in the Australian Clinical Trials Registry (ACTRN12613000390785).

Participants and Settings

This was part of a trial investigating the effects of a heart failure telerehabilitation program conducted across two tertiary hospitals in Queensland, Australia [12]. In brief, the trial recruited patients with stable CHF, and a comprehensive heart failure disease management program was delivered between July 2013 and February 2016. Patients were excluded if they did not meet safety screening criteria as outlined by the Australian exercise guidelines for patients with CHF [14] or lived more than an hour driving distance from the treating hospital.

Participants were randomised either to a home-based telerehabilitation program (intervention group), or a traditional centre-based heart failure rehabilitation program (control group). Of the 53 participants enrolled in the study, 24 were randomised to the telerehabilitation group and 29 in the control group (see study flowchart in Figure 1). The mean age of participants was 67 years, 75% were male, and 55% had ischaemic cardiomyopathy. Table 1 summarises participant characteristics. No significant baseline differences were seen between the two groups. There were 255 sessions conducted for the telerehabilitation group and 215 sessions in the control group, across both hospitals.

Intervention

The telerehabilitation program consisted of a 12-week exercise and education intervention delivered into the patient's home twice-weekly. Each exercise session was supervised by a physiotherapist and the education discussion was facilitated by a physiotherapist and a nurse. The physiotherapist guided participants through a supervised exercise program similar to the control group, such that both groups received similar contact time with the health professionals and comparable exercise dose. A commercially available online videoconferencing platform was used for synchronous audio-visual communication with groups of up to four participants. Educational topics were delivered as PowerPoint presentations with voice narrations and viewed by participants in their own time in preparation for a 15-minute online group discussion held at the start of each telerehabilitation session. Telerehabilitation equipment was loaned to the participants as required, including a laptop computer, a mobile broadband device connected to the 3G wireless broadband internet, automatic sphygmomanometer, finger pulse oximeter, free weights and resistance bands. Participants received a demonstration session, either at the hospital or during a home visit, to become familiar with the equipment.

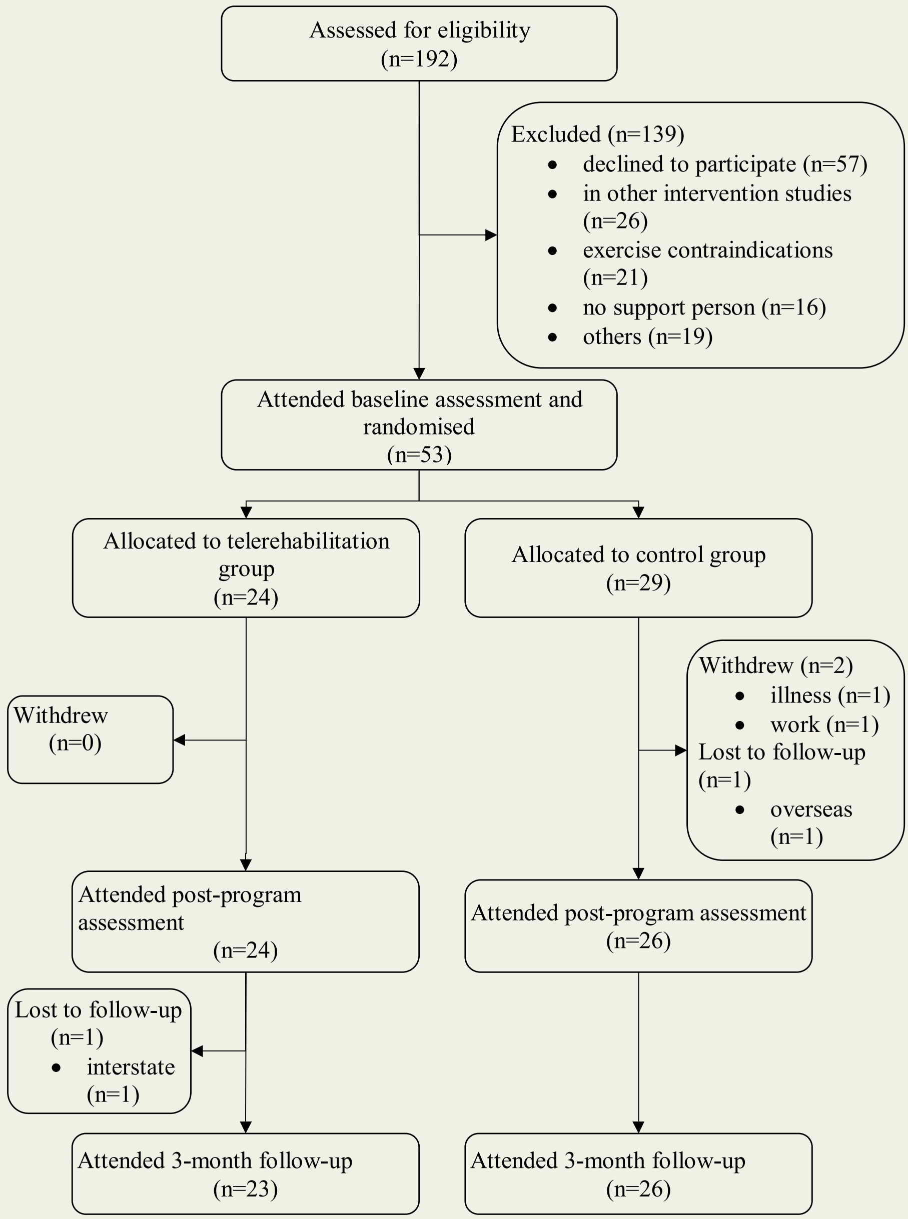

Figure 1 Study flowchart.

The control group received a centre-based rehabilitation program based on current recommended guidelines encompassing education, aerobic and strength training exercise [14]. The program was delivered to groups of up to eight participants in hospitals and was of the same duration and frequency as the telerehabilitation program. Each exercise session was facilitated by a physiotherapist and a nurse, and the duration was approximately 60 minutes. The control group attended education sessions at the hospital on the same day as the exercise sessions and each education session was approximately 60 minutes. These education sessions were delivered by a multidisciplinary team including the nurse, dietitian, physiotherapist, occupational therapist, social worker and pharmacist.

Outcome Measures

The primary outcome of the cost-utility analysis was quality-adjusted life years (QALY) lived, derived from the health-related quality of life using the EuroQol five-dimensional (EQ-5D) questionnaire [15], undertaken at baseline, after completion of the rehabilitation program and at follow-up 3 months later. 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 [16]. A United Kingdom valuation was used as previous studies reported relatively comparable valuations for Australians [17,18].

Secondary outcomes include costs incurred by the health care providers. All costs (health care resource usage and

Table 1 Baseline characteristics.

Characteristic	*Telerehabilitation (n = 24)*	*Control (n = 29)*	*Total (n = 53)*
Age (*year*), 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)
BMI (kg/m^2), mean (SD)	31 (8)	32 (6)	31 (7)
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)
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)
Social situation, n (%)			
lives alone	0 (0)	5 (17)	5 (9)
lives with others	24 (100)	24 (83)	48 (91)

Abbreviations: ACE-I, angiotensin-converting enzyme inhibitor; ARB, angiotensin receptor blocker; BMI, body mass index; LVEF, left ventricular ejection fraction; n, number, NYHA, New York Heart Association.

program costs) were calculated in Australian dollars using 2013 as the base year. Labour costs for the assessments and delivery of programs by allied health and nurses were calculated based on local award rates (allied health professionals at HP 3.7 and nurses at CN 6.2) multiplied by 1.3 for on-costs. Equipment costs were based on actual costs incurred and capital costs were discounted using the diminishing value methods for depreciating assets in line with the national taxation guidelines [19]. For instance, the rowing machine cost was calculated by annuitising the initial capital outlay of $3,000 over the effective life of the asset (of 5 years), which equates to $1,200 in the first year, $720 in the second year and $432 in the third year (totalling to $2,352 across the 3-year study period). Similarly, travel costs associated with the home visits were calculated using 74 cents per kilometre travelled, in line with national taxation guidelines for car transportation [19]. During the 6 months, the number and type of hospital readmissions were extracted from health system records. The costs of acute day and overnight hospitalisation (aggregated costs of emergency visits, hospital readmissions and day procedures) during the 6 months were valued using the national hospital cost data at 2013 [20].

Data Analysis

A comparative, incremental cost-utility analysis was conducted. Statistical analysis was performed using IBM SPSS Statistics 25 (SPSS Inc., Armonk, NY, USA). Descriptive analyses of clinical variables were undertaken. Data were presented as means (standard deviations, SD) and counts (percentages) as appropriate. Data were also checked for missing values, distribution and outliers. Missing data were not imputed and p-values of less than 0.05 were considered significant. This economic evaluation was developed following the consolidated health economic evaluation reporting standards guidelines [21].

Health care costs over the 6 months were summed within individual participants. Costs were categorised into personnel, equipment and heart failure readmissions. Total costs were compared between the two intervention groups using the non-parametric Mann–Whitney U test. Health effects were initially analysed using a linear mixed-effects model, which is recommended for its ability to account for repeated measures and missing data [22]. 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 represents the difference between the EQ-5D slopes. We used this coefficient and its 95% confidence intervals (CI) to estimate the between-group difference. Health effects were also converted to QALYs using an area under the curve approach (where the EQ-5D scores were multiplied by duration spent in those health states) [23]. This translated to a maximum QALY score of 0.5 over the 6 months. This approach accounts for baseline utility scores as these are predictive of follow-up scores [24] and patients with low scores at baseline generally show more gains than those with high scores. Health effects with the QALYs were compared between the two intervention groups using the independent t-test.

In addition to the cost-utility analysis, an incremental cost-effectiveness ratio (ICER) was calculated as a between-group difference in costs over a between-group difference in QALY. The ICER can be interpreted as the extra cost of obtaining one extra QALY. A willingness-to-pay threshold of between $50,000 and $60,000 per QALY is commonly used to determine cost-effectiveness in Australia [25]. Uncertainty in this ICER analysis was investigated using bootstrap resampling; 1,000 replications was used to estimate the 95% CI for the ICER. These bootstrap replications were plotted on a cost-effectiveness plane.

Two sensitivity analyses were undertaken. First, health care costs (including personnel, equipment and hospital readmissions due to heart failure) were estimated based on the number of exercise programs required (rather than the actual number of programs delivered) if there were full attendances (all participants attending all 24 sessions). Second, health care costs were expanded from hospital readmissions related to heart failure to all-causes (aggregated costs of all-cause emergency visits, hospital readmissions and day procedures).

Results

Costs

The mean cost per group is presented in Table 2. The program costs per participant for delivering the 12-week telerehabilitation and centre-based programs (inclusive of equipment and personnel costs) were $1,778 and $2,906 respectively (refer to Appendix A for details on program costs). Total health care costs per participant over the 6 months (inclusive of program and heart failure readmission costs) were $2,325 in the telerehabilitation group and $3,916 in the control group, leading to a significant difference ($p < 0.001$) of -1,590 (95% CI: -2,822, -359) in favour of the telerehabilitation group.

Effects

The EQ-5D results at each assessment time and the between-group differences are presented in Table 3. Mixed-model analyses showed no significant overall between-group differences on the EQ-5D index ($F_{(1,6)} = 0.002$, $p = 0.965$), with an estimated between-group difference of -0.06 (95% CI: -0.17, 0.05) at Week 12. At Week 24, this difference was also non-significant at -0.06 (95% CI: -0.16, 0.03). Similarly, there was no significant between-group difference in the QALY, with a mean difference of 0 (95% CI: -0.06, 0.05) over the 6 months.

Incremental Cost-Effectiveness Ratio

Comparing the telerehabilitation with the control group, the ICER adopting the health care provider's perspective was -$4,157 per QALY gained. Figure 2 illustrates a cost-

Table 2 Health care costs over 6 months.

Average cost per participant	Telerehabilitation	Control	Between-group difference (Telerehabilitation − Control)
Exercise equipment[a]	17.52	765.23	
Monitoring equipment[a]	36.02	160.03	
Videoconferencing equipment[a]	353.67	0	
Physiotherapist	844.34	681.18	
Nurse	278.69	674.49	
Other personnel		454.12	
Home visit	87.92		
Assessment	160.17	171.09	
Heart failure readmissions	546.77	1,009.42	
Total health care cost/participant, means (95% CI)	**$2,325.09**	**$3,915.55**	**$-1,590.45 (-2,821.69, -359.21)**

[a]Equipment costs were calculated using the diminishing value methods for depreciating assets.

Table 3 Health effects over 6 months.

	Telerehabilitation, means (SD)	Control, means (SD)	Between-group difference (Telerehabilitation − Control), means (95% CI)
EQ-5D index scores			
Week 0	0.73 (0.13)	0.69 (0.26)	
Week 12	0.73 (0.21)	0.74 (0.21)	
Week 24	0.73 (0.22)	0.74 (0.25)	
Week 12 minus Week 0[a]			-0.06 (-0.17, 0.05)
Week 24 minus Week 0[a]			-0.06 (-0.16, 0.03)
Quality adjusted life years[b]	**0.36** **(0.09)**	**0.36** **(0.1)**	**0** **(-0.06, 0.05)**

[a]Using a linear mixed-effects model.
[b]Values calculated using the area under the curve approach.

effectiveness plane scatter plot of the incremental cost (actual program and heart failure readmission costs) and incremental QALY gained. This was generated by bootstrapping the point estimates of the costs and utilities. The majority of the bootstrapped ICERs fall in the lower quadrants, indicating no difference in utilities between the two programs, but the telerehabilitation group has a high probability of being cost-saving compared with the control group.

Sensitivity Analysis

Similar trends were reflected in the sensitivity analyses, where costs for the telerehabilitation group were lower than

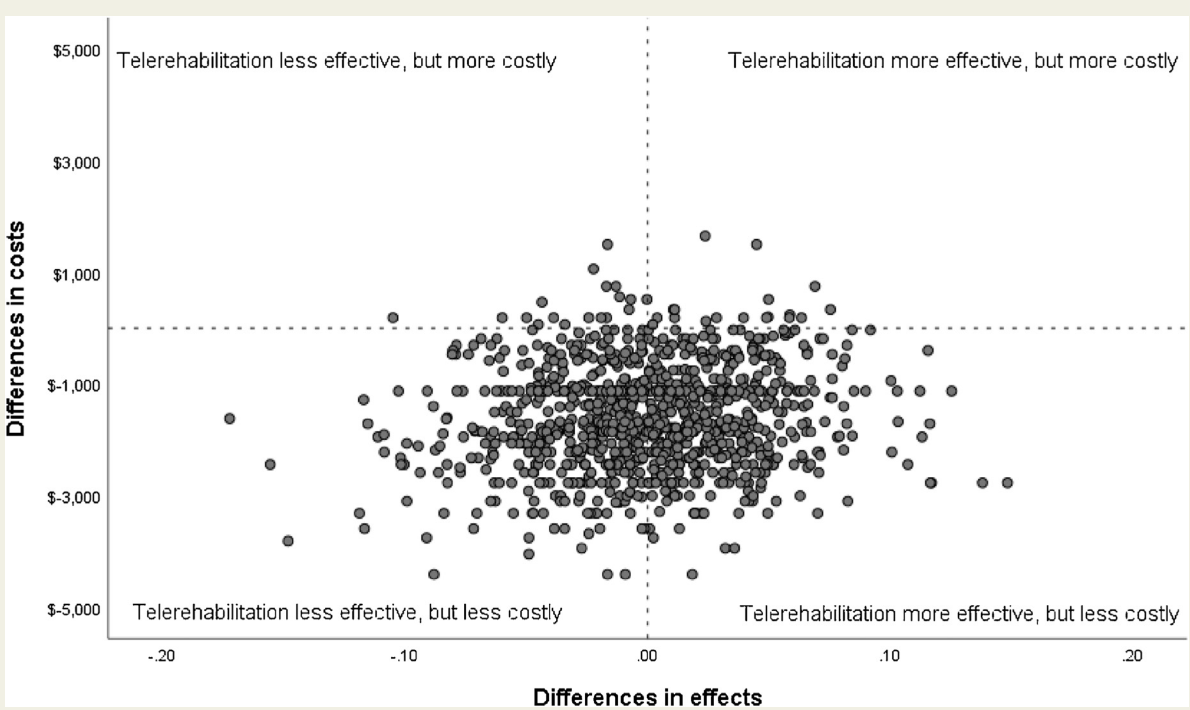

Figure 2 The cost-utility plot of a home-based telerehabilitation program versus a centre-based heart failure rehabilitation program (actual costs).
Based on actual health care costs (including actual program costs and heart failure readmission costs).

the control group. First, the estimated health care costs (including estimated program costs based on full attendance and heart failure readmission costs) were $1,478 in the telerehabilitation group and $2,243 in the control group, leading to a non-significant difference of -$765 (95% CI: -1,996, 466). Second, all-cause health care costs (including actual program costs, and aggregated costs of all-cause emergency visits, hospital readmissions and day procedures) were $6,625 in the telerehabilitation group and $11,077 in the control group, leading to a non-significant difference of -$4,452 (95% CI: -9,994, 1,091).

Second, a majority of the bootstrapped ICERs were located in the lower quadrants of the cost-effectiveness plots (see Figure 3 and Figure 4). The ICER for estimated health care costs (including estimated program costs based on full attendances and heart failure readmission costs) was -$5,408 per QALY gained. The ICER for all-cause health care costs (including actual program costs, and aggregated costs of all-cause emergency visits, hospital readmissions and day procedures) was -$82,536 per QALY gained.

Discussion

A heart failure telerehabilitation program appears to be a cost-saving intervention from the health care provider's perspective, compared with a traditional centre-based rehabilitation program. Specifically, the total costs in our telerehabilitation group were $1,590 less than the control group, and there were no differences between the two intervention groups in the QALY during the 6 months. This cost difference appears partly attributable to the higher equipment costs, higher personnel costs (in the delivery of education sessions) and a higher number of heart failure readmissions in the control group. Interestingly this between-group difference was narrowed when estimating costs based on full program attendance, as it was possible to accommodate up to eight participants per session in the control compared with four in the telerehabilitation group. It should be noted, however, that the cost-saving may be under-represented, as our cost-utility analyses were based on the health care provider rather than the societal perspective, and thereby disregarded the patient transportation cost and time incurred by the control group.

Our results demonstrated that given a willingness-to-pay threshold of $50,000 per QALY, a heart failure telerehabilitation program was cost-effective. This is in agreement with a systematic review in cardiac patients which estimated the cost-effectiveness of cardiac rehabilitation compared to no cardiac rehabilitation of $1,398 to $94,204 per QALY gained [26], as well as a cardiac telerehabilitation study where the ICER was estimated to be -$5,510 [27]. Similarly, other studies of patients with coronary heart disease also demonstrated that secondary prevention programs delivered by mobile phone text messages [28], web portals [29] and smartphones with wearable sensors [30] were cost-saving. However, our results are inconsistent with another cardiac telerehabilitation study where the intervention group accessed tablet

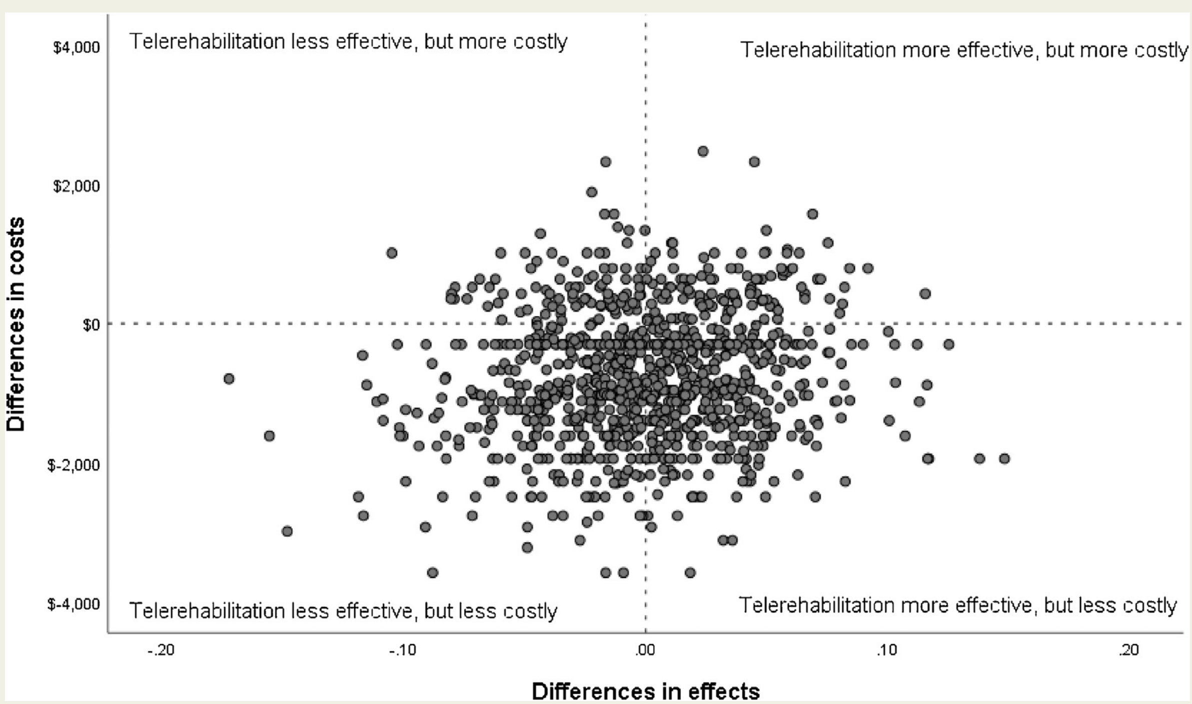

Figure 3 The cost-utility plot of a home-based telerehabilitation program versus a centre-based heart failure rehabilitation program (estimated costs).
Based on the estimated health care costs (including estimated program costs based on full attendances and heart failure readmission costs).

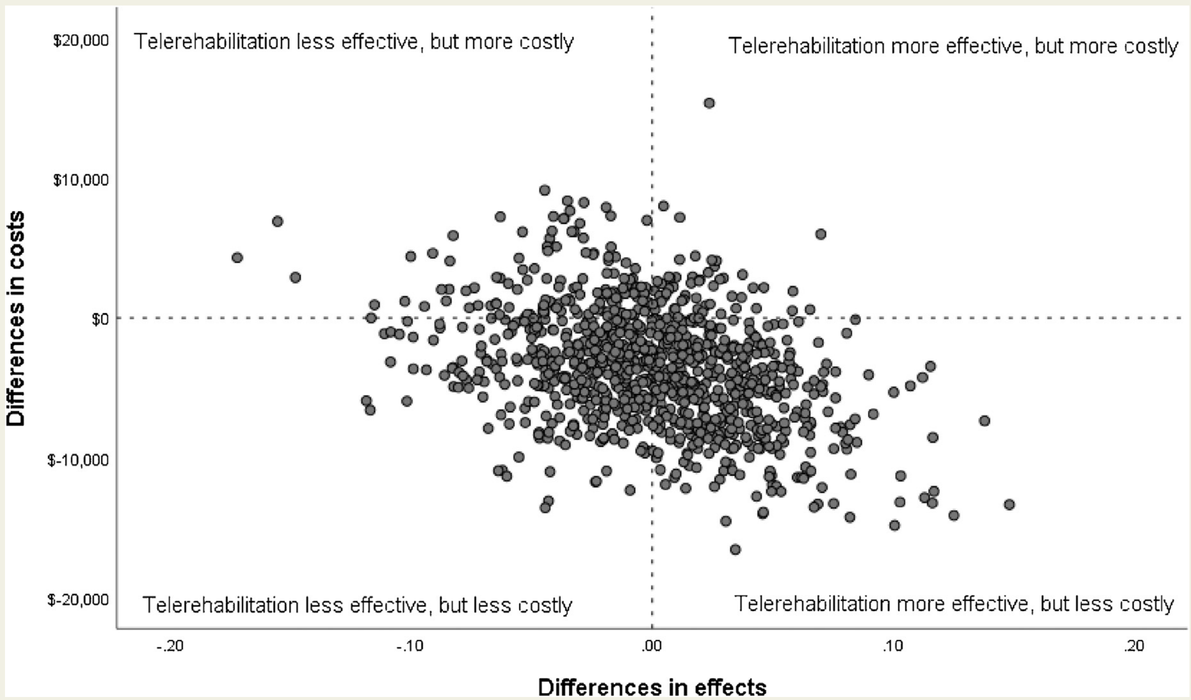

Figure 4 The cost-utility plot of a home-based telerehabilitation program versus a centre-based heart failure rehabilitation program (all-cause hospital readmissions).
Based on all-cause health care costs (including actual program costs, and aggregate costs of all-cause emergency visits, hospital readmissions and day procedures).

devices with an online portal for vital signs monitoring, activity tracking via pedometers and education videos [31]. These authors of this study reported that with this equipment outlay, telerehabilitation program was not cost-effective with an ICER of $754,081 per QALY gained [31]. This difference may be related to a higher average cost in the telerehabilitation group compared with the control group, and a wider health care perspective (with costs related to primary and secondary care costs) [31].

Strengths and Limitations

Our study is strengthened by the use of relatively low-cost technologies (such as resistance bands and laptop computers) available in most clinical settings and thereby increases the likelihood of translation into usual practice. There are, however, some limitations associated with our study. This economic evaluation was embedded within the randomised controlled trial and thus the sample size calculation was not powered for a cost-utility analysis. However, given the between-group difference in effects is small, a larger study will likely reach similar results. Another limitation was the inclusion of hospital costs only and the exclusion of other health system costs such as costs related to general practitioner visits or medications. However, this information is still vital as a high proportion of health care funding is spent on the hospital system. Research with the inclusion of all health system costs will provide further insight into the economic impact of this new program. As our study was relatively short-term, further research will be required to determine the long-term cost-effectiveness of heart failure telerehabilitation.

Conclusions

Heart failure telerehabilitation appears to be a cost-saving intervention for the health care provider, compared with traditional centre-based rehabilitation. Specifically, a 12-week group-based video telerehabilitation program was less costly and as effective as a centre-based rehabilitation program, over 6 months. Given an expansion of alternative models such as telerehabilitation, information from this economic analysis may help inform uptake of this innovative service delivery model.

Ethics Approval

This project received ethics approval (HREC/12/QPCH/86 and The University of Queensland 2013000796), with site-specific approvals at the Princess Alexandra Hospital (AU/3/FDD1118) and The Prince Charles Hospital (AU/3/3501113). All participants gave written informed consent before data collection began.

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Guarantor and Statement of Contributorship

RH and JB conceived and designed the study and collected the data. RH analysed the data and drafted the manuscript. AM, NM and TR were consulted on study design and statistical analysis and edited the draft manuscript. All authors reviewed and approved the manuscript.

Competing Interests

The authors declare that there is no conflict of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.hlc.2018.11.010.

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