Exercise Telemonitoring and Telerehabilitation Compared to Traditional Cardiac and Pulmonary Rehabilitation: A Systematic Review and Meta-analysis

Christen Chan, MSc*; Cristiane Yamabayashi, PT, PhD†; Nafeez Syed, PT‡; Ashley Kirkham, BCR*; Pat G. Camp, PT, PhD§

From the:

*Centre for Heart Lung Innovation, University of British Columbia, Vancouver;
† Alberta Health Services – Rockyview General Hospital, Calgary;
‡ School of Allied Health Sciences, Manipal University, Manipal, India;
§ Department of Physical Therapy, University of British Columbia, Vancouver.

Correspondence to: Pat G. Camp, UBC Department of Physical Therapy; Centre for Heart Lung Innovation, St Paul’s Hospital, 1081 Burrard Street, Burrard Building 454, V6Z 1Y6, Vancouver, BC; pat.camp@hli.ubc.ca.

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ABSTRACT

Background: Despite exercise capacity and quality of life benefits, pulmonary rehabilitation (PR) and cardiac rehabilitation (CR) programmes are not easily accessed due to a number of barriers. A solution may be telerehabilitation (TR) in which patients exercise in their communities while monitored via tele-technologies. However, the benefits of TR for PR and CR purposes have not been systematically reviewed. Objective: To determine if the benefits of the exercise component of PR and CR using TR are comparable to usual care (UC) programmes. Methods: A comprehensive literature search was performed on the Medline, Embase, and CINAHL databases up to July 13, 2015. Meta-analyses were performed for peak oxygen consumption, peak workload, exercise test duration, and 6-minute walk test (6MWT) distance using $I^2$ statistic and forest plots displaying standardized mean difference (SMD). Results: From 1431 citations found, nine CR studies met inclusion criteria. There were no differences in exercise outcomes between UC and TR groups for CR studies, except in exercise test duration, which slightly favoured UC (SMD 0.268, 95% confidence interval 0.002 to 0.534; $p < 0.05$). Only one PR study was included and it showed similar improvements in 6MWT between UC and TR groups. Conclusion: TR for patients with cardiac conditions provided similar benefits to usual care with no adverse effects reported. Similar studies on TR for patients with pulmonary conditions need to be conducted.
Cardiac rehabilitation (CR) and pulmonary rehabilitation (PR) are recommended for patients with cardiovascular disease (CVD) and chronic obstructive pulmonary disease (COPD), respectively, who have disabling symptoms, poor exercise capacity, reduced quality of life, and/or the need for chronic disease management skills.¹-⁴ The typical location for CR and PR programmes is within a hospital or health centre setting, with supervision from physiotherapists or other health care professionals and access to a variety of exercise and monitoring equipment. These programmes increase quality of life, exercise capacity and muscle strength.²,⁴-¹¹ The hallmark feature of CR and PR is aerobic training typically delivered in a group format; both types of rehabilitation also include education and behavioral modification.²-⁴,¹²

In Canada, less than 2% of COPD patients have access to PR.¹³,¹⁴ This low percentage is comparable to the United Kingdom, where less than 1.5% of patients with COPD have access to a PR programme in their community, with a total of only sixty-eight programmes nationwide in 2004.¹⁵,¹⁶ Similarly, as of 2009 fewer than 30% of cardiac patients who were qualified for CR in the United Kingdom attended a rehabilitation programme.¹⁷ This occurred despite all hospitals with an acute cardiac department providing access to a CR programme.¹⁷

Telerehabilitation (TR) has been proposed as a health service option to enable more patients to receive care regardless of where they live.¹⁸ TR programmes with exercise components that include telemonitoring may improve exercise-related outcomes, better ensure patient safety during exercise, and ultimately improve access to rehabilitation interventions; yet to date, the benefits of CR or PR with telemonitoring have not been thoroughly systematically reviewed. TR for cardiac or pulmonary patients has been evaluated in several trials.¹⁹-²⁴ Some of these studies have included telemonitored aerobic exercise which included the acquisition and transfer of data on the physiological responses to exercise, such as heart rate.¹⁹,²²,²⁵
Physiotherapists are key members of the cardiac and pulmonary rehabilitation teams and use a combination of clinical reasoning, knowledge of the pathophysiology of disease, objective measures of exercise response, and patient-reported outcomes to monitor and progress exercise programmes for individuals with heart or lung disease. In a TR setting, it is likely that physiotherapists would facilitate and adjust exercise programmes based on a variety of information, including data from telemonitoring devices.

A systematic review conducted by Hwang and colleagues on randomized controlled trials of TR home-based CR and PR compared to centre-based programmes, found that 6-minute walk test (6MWT), oxygen consumption, and quality of life improved similarly to centre-based programmes. Although promising, this review included only randomized controlled trials in which telephone calls were the form of telemonitoring used. This systematic review and meta-analysis seeks to add strength to the knowledge base about TR by exploring studies that used more sophisticated telemonitoring interventions. It is important to confirm the exercise benefits and safety aspects of TR in heart and lung disease patients compared to traditional CR and PR. This is particularly relevant to physiotherapists given that they are the primary health care professionals involved in CR and PR exercise monitoring and progression. Therefore, the purpose of this systematic review and meta-analysis was to determine and compare the exercise capacity changes from exercise programmes delivered via pulmonary or cardiac TR with telemonitoring compared to usual care rehabilitation.

METHODS

Literature Search

A systematic review of randomized and non-randomized controlled trials that compared TR to usual care (UC) rehabilitation for cardiac and lung disease patients was conducted.
Literature searches were performed on Medline, EMBASE, and CINAHL. The subject TR is termed “telemedicine” in Medline’s database. Databases were searched up to July 13, 2015. Citation index searches were conducted on related systematic reviews and included studies. Grey literature was searched through the University of British Columbia Library database. Only full-text studies written in English were included. The search terms used were: “pulmonary” or “airway” or “airflow” or “lung” or “bronch*” or “respire*” (terms were used adjacent to the derivative of “obstruct*”) or “chronic or pulmonary emphysema” or “hyperlucent lung”; or “heart” or “cardiac” or “myocardial” (terms were used adjacent to disease* or failure* or attack* or decompensation* or infarction*) or “arrhythmia”; AND “telemedicine” or “telehealth” or “ehealth” or “telerehabilitation” or “health mobile” or “home care services” or “rehabilitation” or “exercise” or “walking” or “exercise therapy” or “physical fitness” or “exercise movement techniques” or “exercise* (adjacent to) train*” or “strength* (adjacent to) train*” or “physiother* or physical therap*”.

**Study Selection and Eligibility**

Full text articles were retrieved and reviewed based on inclusion criteria. Included studies were randomized and non-randomized controlled trials that compared TR to UC rehabilitation for CR and PR populations. Included studies (1) enrolled adult participantss at least 18 years old with physician diagnosed COPD or CVD; (2) included people eligible for outpatient CR or PR; (3) delivered rehabilitation programmes that included exercise; (4) involved an experimental arm that provided TR with telemonitoring to assess signs, symptoms and/or exercise parameters; and (5) compared TR against UC, which was defined as a rehabilitation programme located in a hospital, clinic or community centre in which healthcare practitioner supervision was delivered in person. Real-time transmission of data to an off-site practitioner was not a requirement.
**Article Review and Data Abstraction**

Studies were screened for inclusion by two authors assessing titles and abstracts independently before a third reviewer completed a consensus. Reasons for exclusion were recorded. Two reviewers performed data extraction of the included studies using a data extraction form; they recorded inclusion criteria, intervention descriptions, patient characteristics, all outcome measures, and the study’s conclusion. The primary outcome of exercise capacity was evaluated by timed walk test distance, peak workload, exercise duration, and peak oxygen consumption (VO₂ peak). Secondary outcomes were health-related quality of life scores, adverse events, compliance rates, and complications with TR sessions. The two reviewers tested the data collection form on two included studies to ensure all desired data was recorded the same between different reviewers. Minor changes were made to the form before using it on all included studies.

**Risk of Bias within Studies**

Risk of bias within studies was assessed using the Physiotherapy Evidence Database (PEDro) Scale as it is a valid scale for measuring the quality of randomized and non-randomized clinical trial studies.²⁷ The scale mainly evaluates whether or not a study had randomization; used blinded participants, therapists and assessors; adequately collected data; and compared results between intervention groups. Scores of at least 8 out of 10 were considered good quality; studies that scored less than eight were considered weak to moderate quality.

**Meta-Analysis**

Meta-analysis was performed using Comprehensive Meta-Analysis (CMA) software. I² values < 50% were used to indicate sufficient homogeneity between studies for meta-analysis.²⁸ I² values < 30% resulted in a fixed effect model in the meta-analysis. Effect sizes for each
intervention group were calculated using standardized mean differences (SMD) for the main exercise outcomes of peak oxygen consumption, peak workload achieved on a maximal exercise test, exercise duration during a maximal exercise test, and 6MWT distance. SMD calculations incorporated TR and UC post-intervention sample size, and pre- and post-intervention means and standard deviations for each outcome measure. Forest plots displaying SMD and 95% confidence intervals (CI) were used to compare effects between intervention groups. SMDs less than ±0.2 are to be interpreted as a small effect, ±0.2 to ±0.8 as a medium effect, and SMDs greater than ±0.8 as a large effect. The study by Sparks and colleagues did not report numeric data and therefore was not included in meta-analysis.

RESULTS

Figure 1 diagrams the selection process. The literature search produced 1,431 citations leading to nine papers that were eligible for the systematic review. The main reasons for exclusion were lack of exercise monitoring using tele-technology in the TR group and the absence of a UC group for comparison.

A summary of study participant characteristics and exercise prescriptions is in Tables 1 and 2 respectively. Eight studies found were based on CR, with only one study that met all inclusion criteria being based on PR for people with COPD. Cardiovascular diagnoses or procedures in study participants were acute myocardial infarction, coronary artery bypass grafting, coronary angioplasty and other transcatheter procedures, cardiac transplantation, and post-valve surgery. The study on people with COPD included those who had previously completed a PR programme or were familiar with PR. Five studies were non-randomized controlled trials and four were randomized controlled trials. All studies were of outpatient
programmes and reported on patient demographics and health characteristics. However, each study reported different measures of exercise capacity and health-related quality of life.

All studies followed existing guidelines that are used in clinical rehabilitation programmes in prescribing aerobic exercise for the TR interventions. However, none of the CR exercise prescriptions included resistance exercise. Flexibility training was also not included and only two studies included details about warm-up and cool-down times. In addition, three studies used walking training in their TR group, but used cycle ergometers and other machines in their UC groups. Despite these differences in exercise intervention, there were no differences in changes to exercise capacity between groups, indicating no training specificity from these exercise prescription differences.

Risk of Bias

Studies scored between 4 and 6 out of 10 on the PEDro Scale (Table 3). This classified them as weak to moderate quality studies. Thus, results cannot be considered objectively valid and free of major biases within and across studies without further investigation into each paper. The major reason for low quality was a lack of randomization and blinding.

Technologies Used

Five studies utilized electrocardiography (ECG) to monitor TR participants (Table 2). The studies by Korzeniowska-Kubacka and colleagues and Piotrowicz and colleagues used the Pro Plus (Warsaw, Poland) EHO3 device. This device utilized 4 electrodes to record three-channel ECG. Data was sent to a mobile phone and then transmitted to a monitoring centre for assessment by a healthcare practitioner. ECGs and pre-exercise screening calls monitored for arrhythmias, ST segment changes, and other cardiac symptoms. The EHO3 also had pre-programmed training sessions for participants that outlined exercise duration, breaks, and ECG
recording. Studies led by Ades\textsuperscript{31} and Sparks\textsuperscript{23} used the ScottCare (Cleveland, U.S.A.) Tele-Rehab system, and the study by Giallauria and colleagues\textsuperscript{25} used a Sorin (Milan, Italy) Life Watch CG 6106. Both devices utilized an ECG to monitor exercise, while home telephone connections were used to communicate ECGs to practitioners. The study by Dalleck and colleagues\textsuperscript{32} utilized supervising staff along with video cameras at TR sites to monitor exercise, but off-site staff didn’t communicate with patients or TR-site staff during exercise. The study by Kraal and team members\textsuperscript{19} used the Garmin Forerunner 70 which recorded heart rate along with exercise data. These data were communicated to the rehab center and used for weekly progress calls via a web application called Garmin Connect. Varnfield and colleagues\textsuperscript{33} implemented a smartphone system called the Care Assessment Platform (CAP) which utilized a Nokia (Espoo, Finland) N96 smartphone equipped with applications to monitor exercise intensity and record daily health status measurements. Data transmission to a practitioner used a mobile network and was followed by weekly telephone calls. The study by Paneroni and colleagues\textsuperscript{34} implemented an interactive television monitor and remote control system called the IGEA-SAT (Milan, Italy) platform that monitored dyspnea, leg fatigue, and oxygen saturation before and after exercise sessions on a cycle ergometer.

**Exercise Outcomes**

Pre- and post-intervention outcome measures are summarized in Table 4. For VO\textsubscript{2} peak, studies headed by Ades\textsuperscript{31}, Kraal\textsuperscript{19}, Piotrowicz\textsuperscript{30}, and Sparks\textsuperscript{23} found significant improvements in both groups ranging from increases of 1.1 ml/kg/min to 4.9 ml/kg/min. Overall, the cumulative I\textsuperscript{2} statistic was 0\% and the SMD between the TR and UC care groups was 0.160 (95\% CI, -0.065 to 0.386; \(p = 0.16\)), indicating no difference between the groups (Figure 2).
Ades and colleagues\textsuperscript{31}, Sparks and colleagues\textsuperscript{23}, and Koreniowska-Kubacka and colleagues\textsuperscript{22} showed similar improvements in peak workload between TR and UC groups. Meanwhile, Giallauria and colleagues\textsuperscript{25} found greater improvements in peak workload among the TR group. Interestingly, this study included a third intervention group that performed unmonitored home exercise, which did not show an improvement (data not included in meta-analysis).\textsuperscript{25} The $I^2$ was 0\% over the three studies. Overall, there was no difference between TR and UC groups based on a SMD of 0.225 (95\% CI -0.043 to 0.493; $p = 0.10$) (Figure 2).

Three studies investigated exercise duration outcomes between groups.\textsuperscript{22,25,30} The $I^2$ value indicated low heterogeneity at 21.2\%. Figure 2 shows that the SMD was statistically significant at 0.268 in favour of UC (95\% CI 0.002 to 0.534; $p < 0.05$).

Studies led by Piotrowicz\textsuperscript{30} and Varnfield\textsuperscript{33} showed statistically significant improvements in 6MWT distance in both groups with no significant differences between intervention groups. The two studies produced an $I^2$ value of 0\% and the SMD was 0.169 (95\% CI -0.109 to 0.448; $p = 0.23$), suggesting no difference between groups (Figure 2).\textsuperscript{30,33} The lone PR study by Paneroni and colleagues\textsuperscript{34} found statistically significant improvements in both groups (UC: 397±57m to 430.6±39.2m; $p = 0.002$; TR: 380±86m to 414.2±50.8m; $p = 0.008$). There was no significant difference between groups ($p = 0.91$), indicating similar changes.

**Secondary Outcomes**

**Adverse Events and Compliance**

Adverse events were examined in seven of the eight CR studies and the PR study with no reported adverse events during any exercise sessions. Challenges related to using devices in the TR group were examined in only two studies.\textsuperscript{30,31} Ades and colleagues\textsuperscript{31} reported that seven out
of 3100 exercise sessions in the TR group were stopped due to abnormal symptoms recorded by the monitoring equipment. Piotrowicz and colleagues\textsuperscript{30} reported no complications or cancelled sessions. Intervention compliance rates were reported in six studies with each having good compliance throughout. The studies spearheaded by Kraal\textsuperscript{19} and Piotrowicz\textsuperscript{30} had perfect compliance in the TR group, while the UC group had 86\% and 80\% compliance respectively over the two studies. Sparks and colleagues\textsuperscript{23} had 93\% compliance in the TR group and 83\% compliance in the UC group. Paneroni and team\textsuperscript{34} reported TR group compliance at 82\% compared to 100\% for the UC group, while participants in the study by Varnfield and colleagues\textsuperscript{33} had 94\% compliance in the TR group and 68\% in the UC group. Dalleck and colleagues\textsuperscript{32} reported similar compliance rates between groups with rates at 81\% in the TR group and 83\% in the UC group.

\textit{Self-Reported Quality of Life/Health Status}

Five studies measured quality of life or psychological profile.\textsuperscript{19,25,31-33} Using the Health Status Questionnaire, Ades and colleagues\textsuperscript{31} reported significant improvements in all eight domains except health perception and mental health in both groups. Giallauria and team\textsuperscript{25} utilized four different questionnaires, the STAI-Y1 (state anxiety), the STAI-Y2 (trait scale of anxiety inventory), Beck Depression Inventory (BDI), and the Medical Outcomes Study 36-Item Short-Form Health Survey. Only the TR group improved their STAI-Y1 and BDI scores. Dalleck and colleagues\textsuperscript{32} reported reductions in stress scores in both groups. The study led by Varnfield\textsuperscript{33} found significant improvements in depression and anxiety scores in both groups using the Depression, Anxiety and Stress Scale, but only the TR group significantly improved on the Kessler 10 for psychological distress and EQ-5D tool. Kraal and colleagues\textsuperscript{19} utilized the MacNew Questionnaire and found significant improvements in all three domains in the UC
group, but only in the physical and social domains for the TR group, as emotional improvements were not significant. Lastly, Paneroni and colleagues\textsuperscript{34} found similar statistically significant improvements in both groups in the St. George’s Respiratory Questionnaire’s total score.

**DISCUSSION**

This systematic review reports on the impact of cardiac and pulmonary TR, versus traditional hospital-based/usual care rehabilitation, on exercise and quality of life-related outcomes. We found that in general, cardiac and pulmonary TR interventions resulted in similar outcomes to traditional CR and PR, except for exercise duration, which slightly favoured UC. There were no reported adverse events, hospitalizations, or mortality during telemonitored exercise. However, included studies were of poor to moderate quality and thus, findings should be taken with caution. In addition, only one PR study that met all inclusion criteria was found.

Many of the TR trials in this systematic review used sophisticated technology such as ECG to monitor their participants during the exercise sessions. This level of monitoring may have encouraged the participants to exercise at a higher intensity than they may have without the monitoring, as quantitative values could influence or moderate feelings of discomfort and risk from exercise. It is important to note that in other trials of unmonitored home-based PR and CR, the investigators developed exercise prescriptions that were lower intensity than would have been used in the traditional setting due to safety concerns.\textsuperscript{21,26,28} This review also demonstrated that health-related quality of life improvements were not different between TR and UC groups despite the lack of direct contact with health care providers and less interaction with other participants in the TR groups. In addition, three studies reported similar levels of adherence to exercise between groups. It is possible that despite the lack of in-person supervision to monitor symptoms (as would be found in a clinical environment), the inclusion of ECG monitoring in the
TR group may have had the same effects in increasing the participants’ self-efficacy for exercise, resulting in high adherence rates and improved quality of life.\textsuperscript{3,9} Future research should explore how telemonitoring versus in-person supervision affects exercise self-efficacy.

The main limitation of the review was a low number of papers that met the inclusion criteria, especially with only one on PR. There is a need for more TR research for PR, as the findings from CR cannot necessarily be generalized to the COPD population. In our clinical experience, the monitoring requirements, disease severity, and patient characteristics are often quite different between these two patient populations.

Another limitation of the review was the poor to moderate score in terms of bias (PEDro Scale) primarily from lack of blinding of therapists and participants. Although blinding of therapists and participants would be difficult for TR, studies utilized standardized tests to evaluate changes to exercise capacity as a way to minimize any potential biases. However, when reviewing findings in the TR groups, it should be noted that therapist expectations and data collection biases may have inflated results. Thus, there still remains a need for more randomized controlled trials or blinding of researchers to increase the quality of evidence and decrease potential outcome biases.

**CONCLUSION**

With an increasing need for better access to rehabilitation for CVD and COPD patients, TR interventions may offer a feasible, effective, and safe option. In this systematic review of nine studies, TR interventions in which a healthcare practitioner monitored patient symptoms prior to and during exercise appeared to offer similar benefits to the standard exercise components of CR and PR programmes. The findings from this systematic review and meta-analysis suggest that physiotherapists who are interested in developing TR interventions for their
CVD and COPD patients can expect similar exercise and quality of life outcomes for their patients, provided the technology and level of monitoring are similar to those used in the studies presented here. Researchers should also continue to explore the different barriers and factors at play in implementing TR interventions in CR and PR. This should include both quantitative and qualitative research to explore and identify solutions to barriers in TR program implementation and participant motivation.

**KEY MESSAGES**

**What Is Already Known on This Topic**

Cardiac and pulmonary rehabilitation programmes are effective in improving exercise capacity, quality of life, and chronic disease management, but home-based delivery of rehabilitation programmes may lack practitioner monitoring and safety. Telerehabilitation is a health service option that can potentially increase the capacity and reach of cardiac and pulmonary rehabilitation programmes to those without access.

**What This Study Adds**

This systematic review and meta-analysis found that telemonitored pulmonary and cardiac rehabilitation studies comparing telerehabilitation to usual care methods of delivery had similar exercise capacity benefits (6-minute walk test, peak workload, maximal exercise test duration, and peak oxygen consumption) between intervention groups, with no adverse events reported in the telerehabilitation groups. Only one study comparing telerehabilitation to usual care for pulmonary rehabilitation was included, with the study finding similar improvements in 6-minute walk test between intervention groups.
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Records identified from CINAHL
\[N = 489]\n
Records identified from EMBASE
\[N = 476]\n
Records identified from Medline
\[N = 430]\n
Records identified from hand searching
\[N = 36]\n
Records (titles and abstracts) from databases and hand searches identified
\[N = 1431]\n
Records excluded after de-duplication:
\[N = 615]\n
Records excluded after evaluation of titles and abstracts
\[N = 748]\n
Full text papers screened for eligibility in review
\[N = 68]\n
Records excluded after review of the full text
\[N = 59]\n
Studies included in the systematic review
\[N = 9]\n
**Figure 1.** PRISMA diagram of included studies for the systematic review and meta-analysis.
| Model   | Study Name | Comparison | Outcome           | Time Point | Statistics for each study |
|---------|------------|------------|-------------------|------------|---------------------------|
|         |            |            | Std diff in means | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
| Ades    | TR vs UC   | V̇O₂ peak  | 0.176             | 0.179       | 0.052      | -0.175      | 0.528      | 0.983   | 0.326   |
| Piotrowicz | TR vs UC | V̇O₂ peak  | 0.162             | 0.177       | 0.031      | -0.185      | 0.508      | 0.913   | 0.361   |
| Kraal   | TR vs UC   | V̇O₂ peak  | 0.118             | 0.283       | 0.080      | -0.437      | 0.672      | 0.415   | 0.678   |
| Fixed   |            |            | 0.160             | 0.115       | 0.013      | -0.065      | 0.386      | 1.304   | 0.163   |

Heterogeneity: Q = 0.031, df(Q) = 2; I² = 0% (p=0.985)

| Model   | Study Name | Comparison | Outcome           | Time Point | Statistics for each study |
|---------|------------|------------|-------------------|------------|---------------------------|
|         |            |            | Std diff in means | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
| Ades    | TR vs UC   | Workload   | 0.085             | 0.179       | 0.052      | -0.266      | 0.436      | 0.476   | 0.634   |
| Giallaura | TR vs UC | Workload   | 0.232             | 0.366       | 0.134      | -0.486      | 0.950      | 0.633   | 0.527   |
| Korniowska-Kubacka | TR vs UC | Workload   | 0.513             | 0.258       | 0.067      | 0.006       | 1.019      | 1.985   | 0.047   |
| Fixed   |            |            | 0.225             | 0.137       | 0.019      | -0.043      | 0.493      | 1.648   | 0.099   |

Heterogeneity: Q = 1.849, df(Q) = 2; I² = 0% (p=0.397)
### Table 1

| Model          | Study Name          | Comparison | Outcome               | Time Point | Statistics for each study |
|---------------|---------------------|------------|-----------------------|------------|---------------------------|
|               |                     |            |                       |            | Std diff in means | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
| Piotrowicz    | TR vs UC            | Exercise Duration (mins) | 8 weeks               |            | 0.099                     | 0.177         | 0.031     | -0.247      | 0.446       | 0.563    | 0.574    |
| Giullaria     | TR vs UC            | Exercise Duration (mins) | 8 weeks               |            | 0.349                     | 0.368         | 0.135     | -0.381      | 1.061       | 0.924    | 0.366    |
| Kereniowska-Kubacka | TR vs UC            | Exercise Duration (mins) | 8 weeks               |            | 0.595                     | 0.260         | 0.067     | 0.086       | 1.104       | 2.293    | 0.022    |
| Fixed         |                     |            |                       |            | 0.268                     | 0.136         | 0.018     | 0.002       | 0.534       | 1.972    | 0.049    |

Heterogeneity: $Q = 2.538$, df$(Q) = 2$; $I^2 = 21\%$ (p=0.281)

### Table 2

| Model          | Study Name          | Comparison | Outcome | Time Point | Statistics for each study |
|---------------|---------------------|------------|---------|------------|---------------------------|
|               |                     |            |         |            | Std diff in means | Standard error | Variance | Lower limit | Upper limit | Z-Value | p-Value |
| Piotrowicz    | TR vs UC            | 6MWT (m)   | 8 weeks |            | 0.219                     | 0.177         | 0.031     | -0.128      | 0.566       | 1.235    | 0.217    |
| Varnfield     | TR vs UC            | 6MWT (m)   | 6 weeks |            | 0.089                     | 0.238         | 0.057     | -0.385      | 0.546       | 0.337    | 0.736    |
| Fixed         |                     |            |         |            | 0.169                     | 0.142         | 0.020     | -0.109      | 0.448       | 1.192    | 0.233    |

Heterogeneity: $Q = 0.219$, df$(Q) = 1$; $I^2 = 0\%$ (p=0.640)
Figure 2. Meta-analysis and forest plot of peak oxygen consumption, peak workload, exercise test duration, and 6-minute walk test distance.
### Table 1. Study Participant Characteristics

| First Author | Study Year | N (TR/UC) | Group Age, mean (SD) | Total Males (%) |
|--------------|------------|-----------|----------------------|-----------------|
|              |            | TR        | UC                   | TR | UC |
| Sparks       | 1993       | 20 (10/10)| 50.0 (8.5)           | 53.3 (7.3)      | 100 | 100 |
| Ades         | 2000       | 133 (50/83)| 56 (9)               | 58 (12)         | 90  | 76  |
| Giallauria   | 2006       | 30 (15/15)| 60 (6)               | 54 (8)          | 100 | 100 |
| Dalleck      | 2010       | 226 (53/173)| 68 (9)             | 67 (11)         | 55  | 58  |
| Paneroni     | 2015       | 36 (18/18)| 65.7 (10.5)          | 66.3 (6)        | 89  | 83  |
| Piotrowicz   | 2010       | 131 (75/56)| 56.4 (10.9)         | 60.5 (8.8)      | 85  | 95  |
| Koreniowska-Kubacka | 2011 | 62 (30/32) | 55.5 (8.1) | 55.2 (7.7) | 100 | 100 |
| Kraal        | 2014       | 50 (25/25)| 60.6 (7.5)           | 56.1 (8.7)      | 88  | 84  |
| Varnfield    | 2014       | 94 (53/41)| 56.2 (10.1)          | 54.9 (9.6)      | 90  | 83  |
| TOTAL        |            | 782 (329/453) |                 | 84        | 75  |

TR = telerehabilitation; UC = usual care.
| First Author (Publication year) | TR Intervention Description/Monitoring                                                                 | TR Exercise Prescription                                                                 | UC Exercise Prescription |
|--------------------------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|----------------------------|
| Sparks (1993)                  | -Scott Care Tele-Rehab transtelephonic system monitored ECGs during exercise.                        | -Cycle ergometer 3 days/week for 12 weeks for a maximum of 35 mins/session at 60-75% max HR reserve achieved during a cardiopulmonary exercise test. | -Same as TR group. |
|                                | -Patients in direct telephone contact with the practitioner and other patient participants during exercise. |                                                                                         |                            |
| Ades (2000)                    | -Scott Care Tele-Rehab transtelephonic system monitored ECGs during exercise.                        | -Cycle ergometer continuous or intermittent for 15-25 mins/session at 65% maximal measured HR. | -Treadmill exercise for 36 sessions over 3 months at 25-30 mins/session. |
|                                | -Patients in direct telephone contact with the practitioner and other patient participants during exercise. |                                                                                         | -5-10 mins of another apparatus. |

Table 2. Study Exercise Prescriptions
| Study          | Description                                                                 | Details                                                                 | Details                                                                 |
|---------------|-----------------------------------------------------------------------------|-------------------------------------------------------------------------|-------------------------------------------------------------------------|
| Giallauria (2006) | - Sorin Life Watch CG 6106 used to record and transmit ECG, at baseline and during exercise. | - 8 week home based CR with teledcardiology monitoring.                 | - Standard in-hospital 8 week CR monitored by a cardiologist.            |
|               | - ECG transmitted to a Call Centre by home telephone, then sent to clinic centre by email within minutes. | - 3 sessions/ week, 30 mins of cycling at 75% peak HR.                  | - 3 sessions/week, 30 mins cycling at 75% peak HR in baseline exercise stress test. |
| Dalleck (2010) | - Rural patients travelled to a setting closer to them where on-site junior exercise physiologist monitored pulse oximetry, blood pressure, and RPE via portable telemetry. | - 4-7 days/week, RPE of 11-13 on a scale of 6-20, and 20-60 mins/day.     | - Same as TR group.                                                     |
|               | - Telemetry was also monitored by an exercise physiologist at the conventional site. | - Exercises designed to patient preferences, included: stepper, arm ergometer, cycle ergometer, elliptical cross-trainer, and treadmill. |                                                                         |
|               | - Site had 2 large video displays, 2                                         |                                                                         |                                                                         |
videoconferencing units and one video visualizer camera.

| Paneroni (2015) | -IGEA-SAT platform involved a remote control with interactive television monitor that screened participants for dyspnea, leg fatigue, and oxygen saturation (portable pulse oximeter used) before and after exercise sessions.  
-Practitioner periodically called or videoconferenced to collect clinical data, supervise, support, and reinforce the rehabilitation programme. Practitioner contacts were gradually tapered off.  
-Exercise prescription was updated every 2 days based on symptoms and outcomes | -28 exercise sessions over 40 days, 100 mins/session.  
-40 min incremental cycle ergometer, 40 min muscle strength exercises, 20 min stretching and relaxation. | -Same as TR group. |
| Piotrowicz (2010) | -EHO 3 device to record ECG data from 3 pre-cordial leads and transmit the data to a monitoring centre via a mobile phone.  
-Before training: answered questions on phone about condition (fatigue, dyspnoea, BP, body mass, and medications).  
-Exercise programs were adjusted based on exercise results and symptoms. | -5-10 mins warm-up, 10-30 continuous walking training, 5 mins cool down.  
-Same intensity prescription as UC.  
-Started at 10 or 15 min/session, twice daily, or 20 mins/session/day, depending on baseline VO$_2$ peak. | -8-week endurance training was interval training on a cycle ergometer.  
-Target training HR was 40-70% of the HR reserve and/or max of 11 on the Borg Scale (6-20).  
-Started at 10-15 mins/session/day (1-3 mins exercise followed by 1-2 mins active recovery). |
|---|---|---|
| Koreniowska-Kubacka (2011) | -EHO 3 device to record ECG data from 3 pre-cordial leads and transmit the data to a monitoring centre via a mobile phone.  
-ECG assessed for HR, arrhythmias,  
-Walking training: 3 10-mins walk exercises with 2 mins rest in between. | -Walking training: 3 10-mins walk exercises with 2 mins rest in between. | -Cycle ergometer 3 times/week, 8 weeks, 40 mins/session.  
-4 min warm-up, 6 4-mins bouts of exercise with 2 mins |
changes in ST segment, and other cardiac disturbances.

rest in between, 10 mins cool down.

-ECG, HR, and BP were measured at baseline, at the end of each interval and at recovery.

| Kraal (2014) | -Garmin Forerunner 70 HR monitor recorded HR and exercise data.  
Data uploaded to a web application called Garmin Connect for review by practitioners during weekly telephone calls. | -3 exercise sessions at main site, followed by individualized walking or jogging for 12 weeks. | -Treadmill or cycle ergometry 2 times/week for 12 weeks at 70-85% max HR for 45-60 mins/session. |
| Varnfield (2014) | -CAP-CR utilized a Nokia N96 smartphone with WellnessDiary and StepCounter applications. | -Moderate walking (Borg scale 11-13) for 6 weeks on most days of the week for at least 30 | -Light to moderate intensity (Borg scale 6-13) cardiovascular and |
| WellnessDiary tracked daily blood pressure, weight, and other lifestyle habits. | mins/time. | strengthening routine consisting of a mixture of treadmill, rower, resistance bands, weights, squats, and modified push-ups 2 times/week for 6 weeks. |
|---|---|---|
| StepCounter monitored steps, duration, and intensity during exercise. | - Data sent using a mobile 3G network to a mentor whom provided feedback during weekly telephone consultations. | - TR = telerehabilitation; UC = usual care; BP = blood pressure; CAP = -care assessment platform; CR = -cardiac rehabilitation; ECG = electrocardiogram; HR = -heart rate; RPE = rating of perceived exertion. |
Table 3. PEDro Scale

A The first item refers to external validity, but is not included in the total PEDro score

B Each item is given 1 point for a yes answer. Maximum total score is 10

| First Author (Publication year) | PEDro Ratings |
|----------------------------------|---------------|
|                                  | 1A 2 3 4 5 6 7 8 9 10 11 TotalB |
| Ades (2000) Yes                  | 0 0 1 0 0 0 1 1 1 1 5 |
| Dalleck (2010) Yes               | 0 0 1 0 0 0 1 1 1 0 4 |
| Giallauria (2006) Yes            | 0 0 1 0 0 0 1 1 1 1 5 |
| Koreniowska-Kubacka (2011) Yes  | 0 0 1 0 0 0 1 1 1 1 5 |
| Kraal (2014) Yes                 | 1 0 1 0 0 0 1 1 1 1 6 |
| Paneroni (2015) Yes              | 1 1 1 1 1 1 5 |
| Piotriwicz (2009) Yes            | 1 0 1 0 0 0 0 1 1 1 5 |
| Sparks (1993) Yes                | 1 0 1 0 0 0 1 1 1 0 5 |
| Varnfield (2014) Yes             | 1 1 1 0 0 0 0 1 1 1 6 |
| **Total, mean (SD)**             |               | **5.1(0.6)** |
| Outcome/First Author (Publication year) | TR Pre mean (SD) | TR Post mean (SD) | UC Pre mean (SD) | UC Post mean (SD) | p-value between groups |
|-----------------------------------------|------------------|------------------|------------------|------------------|-----------------------|
| VO₂ peak (ml/kg/min)                    |                  |                  |                  |                  |                       |
| Ades (2000)                             | 19.2 (±5.5)      | 22.7 (±7.3*)     | 21.2 (±5.6)      | 26.1 (±8.3*)     | NS                    |
| Piotrowicz (2010)                       | 17.8 (±4.1)      | 19.7 (±5.2*)     | 17.9 (±4.4)      | 19.0 (±4.6*)     | NS                    |
| Kraal (2014)                            | 22.8 (±4.2)      | 26.0 (±5.9*)     | 23.7 (±6.4)      | 26.1 (±7.6*)     | NS                    |
| Peak workload (W or MET)                |                  |                  |                  |                  |                       |
| Ades (2000)                             | 106 (±36)W       | 131 (±40)W*      | 131 (±34)W       | 159 (±32)W*      | NS                    |
| Giallauria (2006)                       | 100 (±24.5)W     | 123 (±20.7)W*    | 94 (±16.4)W      | 112 (±22.4)W*    | 0.01                  |
| Koreniowska-Kubacka (2011)              | 8.5 (±1.8)METs   | 9.9 (±2.2)METs*  | 7.3 (±1.4)METs   | 7.8 (±1.2)METs*  | NS                    |
| Kraal (2014)                            | 181.1 (±49)W     | 200.2 (±53.3)W*  | 179.6 (±53.9)W   | 202.4 (±68.2)W*  | NS                    |
| Energy expenditure (kcal/week)          |                  |                  |                  |                  |                       |
| Dalleck (2010)                          | 307 (±359)       | 1225 (±664)      | 209 (±307)       | 1181 (±676)*     | Not reported          |
| 6MWT distance (m)                       |                  |                  |                  |                  |                       |
| Study                  | VO$_2$ peak (±SD) | VO$_2$ peak (±W) | Work (±SD) | Work (±W) | p-value |
|------------------------|-------------------|------------------|------------|-----------|---------|
| Paneroni (2015)        | 380 (±86)         | 414.2 (±50.8)    | 397 (±57)  | 430.6 (±39.2) | NS      |
| Piotrowicz (2010)      | 418 (±92)         | 462 (±91)*       | 398 (±91)  | 462 (±92)* | 0.05    |
| Varnfield (2014)       | 520 (±78)         | 570 (±80)*       | 527 (±86)  | 584 (±99)* | NS      |
| *statistically significant difference between pre- and post-intervention (p < 0.05) |

Exercise duration (min)

| Study                  | Duration (±SD) | Duration (±MET) | Duration (±W) | Duration (±W) | p-value |
|------------------------|----------------|-----------------|---------------|---------------|---------|
| Giallauria (2006)      | 5.8 (±2.1)     | 7.6 (±2.5)*     | 3.6 (±1.2)    | 4.6 (±2.2)*   | 0.01    |
| Piotrowicz (2010)      | 6.8 (±2.3)     | 8.0 (±2.7)*     | 7.1 (±2.3)    | 8.0 (±2.3)*   | NS      |
| Koreniowska-Kubacka (2011) | 10.9 (±3.6) | 12.5 (±4.1)*    | 10.1 (±2.0)   | 13.5 (±1.4)*  | NS      |

TR = -telerehabilitation; UC = -usual care; VO$_2$ peak = peak oxygen consumption; ml = milliliter; kg = kilogram; min = minute; SD = standard deviation; NS = -not statistically significant; W = watts; MET = metabolic equivalent of task; kcal = kilocalorie; 6MWT = six-minute walk test; m = metres.