

Northumbria Research Link

Citation: Okwose, Nduka, Avery, Leah, O'Brien, Nicola, Cassidy, Sophie, Charman, Sarah J., Bailey, Kristian, Velicki, Lazar, Olivotto, Iacopo, Brenna, Paul, MacGowan, Guy and Jakovljevic, Djordje (2019) Acceptability, Feasibility and Preliminary Evaluation of a Novel, Personalised, Home-based Physical Activity Intervention for Chronic Heart Failure (Active-at-Home-HF): a Pilot Study. *Sports Medicine - Open*, 5 (1). p. 45. ISSN 2199-1170

Published by: Springer

URL: <https://doi.org/10.1186/s40798-019-0216-x> <<https://doi.org/10.1186/s40798-019-0216-x>>

This version was downloaded from Northumbria Research Link:
<http://nrl.northumbria.ac.uk/id/eprint/41277/>

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: <http://nrl.northumbria.ac.uk/policies.html>

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher's website (a subscription may be required.)

[Click here to view linked References](#)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

Acceptability, Feasibility and Preliminary Evaluation of a Novel, Personalised, Home-based Physical Activity Intervention for Chronic Heart Failure (Active-at-Home-HF): A Pilot Study

50
51
52
53
54
55
56
57

Nduka C. Okwose¹ PhD, Leah Avery² PhD, Nicola O'Brien³ PhD, Sophie Cassidy¹ PhD, Sarah J. Charman¹ PhD, Kristian Bailey⁵ MD, Lazar Velicki⁶ MD, Iacopo Olivotto⁷ MD, Paul Brennan⁴ MD, Guy A MacGowan^{1,5} MD, Djordje G Jakovljevic^{1,5,7} PhD

58
59
60
61
62
63
64
65

¹Cardiovascular Research Centre, Institute of Cellular Medicine, Faculty of Medical Sciences

²Centre for Rehabilitation, Exercise and Sports Science, School of Health & Social Care, Teesside University, Tees Valley, UK

³Department of Psychology, Northumbria University, Newcastle upon Tyne, UK

⁴Institute of Genetic Medicine, Faculty of Medical Sciences, Newcastle University, Newcastle upon Tyne, UK

⁵Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle upon Tyne, UK

⁶Faculty of Medicine, University of Novi Sad, Novi Sad, Serbia and Department of Cardiovascular Surgery, Institute of Cardiovascular Diseases Vojvodina, Sremska Kamenica, Serbia

⁶Cardiomyopathy Unit and Genetic Unit, Careggi University Hospital, Florence, Italy.

⁷RCUK Centre for Ageing and Vitality, Newcastle University, Newcastle upon Tyne, UK

Corresponding author: Dr Djordje Jakovljevic, Institute of Cellular Medicine, Newcastle University, Newcastle upon Tyne, NE2 4HH, United Kingdom. Email: djordje.jakovljevic@newcastle.ac.uk. Tel: +441912088257

Word count: 2992; Tables: 3; figures: 2; References: 30

1 Nduka C Okwose: Nduka.okwose@ncl.ac.uk

2
3 Leah Avery: Leah.avery@tees.ac.uk

4
5
6 Nicola O'Brien: nicki.obrien@northumbria.ac.uk

7
8
9 Sophie Cassidy: Sophie.cassidy@newcastle.ac.uk

10
11
12 Sarah Charman: sarah.charman@newcastle.ac.uk

13
14
15 Kristian Bailey: Kristian.bailey@nuth.nhs.uk

16
17
18 Lazar Velicki: lvelicki@gmail.com

19
20
21 Iacopo Olivotto: Iacopo.olivotto@gmail.com

22
23
24 Paul Brennan: paul.brennan@nuth.nhs.uk

25
26
27 Guy A Macgowan: Guy.MacGowan@nuth.nhs.uk

28
29
30 Djordje G. Jakovljevic: Djordje.jakovljevic@newcastle.ac.uk

Abstract

Purpose: Less than 10% of heart failure patients in the UK participate in cardiac rehabilitation programmes. The present pilot study evaluated feasibility, acceptability and physiological effects of a novel, personalised, home-based physical activity intervention in chronic heart failure.

Methods: Twenty patients (68 ± 7 years old, 20% females) with stable chronic heart failure due to reduced left ventricular ejection fraction (31 ± 8 %) participated in a single group, pilot study assessing the feasibility and acceptability of a 12-week personalised home-based physical activity intervention aiming to increase daily number of steps by 2000 from baseline (Active-at-Home-HF). Patients completed cardiopulmonary exercise testing with non-invasive gas exchange and haemodynamic measurements and quality of life questionnaire pre- and post-intervention. Patients were supported weekly via telephone and average weekly step count data collected using pedometers.

Results: 43 patients were screened and 20 recruited into the study. Seventeen patients (85%) completed the intervention, and 15 (75%) achieved the target step count. Average step count per day increased significantly from baseline to 3 weeks by 2546 (5108 ± 3064 to 7654 ± 3849 , $P=0.03$, $n=17$), and was maintained until week 12 (9022 ± 3942). Following completion of the intervention, no adverse events were recorded, quality of life improved by 4 points (26 ± 18 vs. 22 ± 19). Peak exercise stroke volume increased by 19% (127 ± 34 vs 151 ± 34 m/beat, $P=0.05$), while cardiac index increased by 12% (6.8 ± 1.5 vs. 7.6 ± 2.0 L/min/m², $P=0.19$). Workload and oxygen consumption at anaerobic threshold also increased by 16% (49 ± 16 vs. 59 ± 14 watts, $P=0.01$) and 10% (11.5 ± 2.9 vs. 12.8 ± 2.2 ml/kg/min, $P=0.39$)

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Conclusion: The Active-at-Home-HF intervention is feasible, acceptable and effective for increasing physical activity in CHF. It may lead to improvements in quality of life, exercise tolerance and haemodynamic function.

Keywords: Physical Activity, Chronic Heart failure, Home-based intervention, Behavioural Change

Key Points:

- A personalized, home-based physical activity intervention is acceptable, feasible and could lead to improvement in exercise tolerance and quality of life in chronic heart failure patients.
- Increasing step count by at least 2000 steps per day may be a realistic goal for chronic heart failure patients.

Trial Registration: www.clinicaltrials.gov - NCT0367727. Retrospectively registered on 17th September 2018.

Background

The benefits of cardiac rehabilitation in chronic heart failure (CHF) have been well documented (1). Evidence-based clinical guidelines recommend that physical activity is integrated into cardiac rehabilitation as a cornerstone of clinical management of CHF (2). Meta-analyses have demonstrated that increased physical activity can improve functional capacity, quality of life, reduce symptom burden, likelihood of hospitalisation and can improve cardiac function (3,4). Consequently, current guidelines now emphasize physical activity as an important component of cardiac rehabilitation in addition to patient education, psychological support and drug therapy (2,5,6).

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Despite numerous benefits, participation of heart failure patients in cardiac rehabilitation is low. In the United Kingdom (UK), less than 10% of patients with CHF participate in cardiac rehabilitation (7). Potential explanations include exclusion of cardiac rehabilitation programmes from local commissioning agreements due to limited funds, lack of capacity for supervised programmes, and inadequate social support for patients (8). Other patient factors include unwillingness to participate in cardiac rehabilitation due to difficulties in attending hospitals, work or domestic commitments and reluctance to attend group-based classes (9).

The barriers highlighted above could be potentially overcome by promoting increased physical activity at home. Daily habitual physical activity (i.e. number of steps and active energy expenditure) is inversely related to patients' symptoms (10). Walking is an independent predictor of outcomes in patients with advanced CHF (11). Current physical activity recommendations for adults is 150 to 300 minutes per week of moderate-intensity activity, or 75 minutes to 150 minutes per week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity while incorporating muscle-strengthening activities if tolerated (6). For adults who are unable to meet these guidelines due to chronic conditions or disabilities, regular physical activity according to their ability is recommended (6). As such, it may be challenging to identify a standardised daily physical activity routine appropriate for all heart failure patients' accounting for individual differences. Pedometer based interventions have demonstrated that increasing steps per day by approximately 2000-2500 steps leads to improvements in blood pressure (12,13) and insulin sensitivity (14). Furthermore, a large cohort study involving 9306 participants reported a 10% risk reduction of cardiovascular events in individuals at high risk of developing type 2 diabetes for every 2000 steps/day increment in daily physical activity observed (15). Considering these findings, we developed a novel, personalised, home-based (Active-at-Home-HF) physical activity intervention aiming to increase daily physical activity by 2000 steps in patients with

1 CHF. The aim of the present pilot study was to assess feasibility, acceptability and preliminary
2 efficacy of the Active-at-Home-HF intervention.
3
4

5 **Methods**

6 *Study design*

7
8
9
10
11 A single group, pilot study assessed the feasibility, acceptability and preliminary efficacy of a
12 home-based physical activity intervention in adults with CHF with reduced left ventricular
13 ejection fraction. Eligible participants attended the Clinical Research Facility of the Royal
14 Victoria Infirmery, Newcastle-upon-Tyne UK for two separate visits (i.e. before and after the
15 12-week intervention). Participants were contacted via email, telephone or spoken to in person
16 to discuss the study and given an opportunity to ask questions to ensure they understood the
17 procedure.
18
19
20
21
22
23
24
25
26
27

28 *Participants*

29
30
31
32 Potentially eligible patients were identified by cardiologists via medical records from heart
33 failure clinics at the Royal Victoria Infirmery and Freeman Hospital in Newcastle-upon-Tyne.
34
35 These patients were subsequently screened by the same cardiologists using the study eligibility
36 criteria. Once eligibility was confirmed, patients were recruited by a member of the research
37 team (NO, SC) by telephone contact. The study included patients with a left ventricular ejection
38 fraction $\leq 40\%$, diagnosed for at least three months, classified according to the New York Heart
39 Association (NYHA) class II – III, clinically stable and receiving an optimal medical treatment.
40
41 Patients were required to have no contraindications to physical activity and had to be capable
42 of performing activities of daily living independently. Patients were excluded during screening
43 or contact if they had uncontrolled cardiac arrhythmias, myocardial infarction, percutaneous
44 coronary intervention and/or bypass graft surgery up to 3 months previously, severe obesity
45 (i.e. body mass index >40), implantation with left ventricular assist device, were currently
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 participating in a cardiac rehabilitation programme, if they already met physical activity
2 recommendations (6) or were unable to provide informed written consent.
3

4 5 *Clinical assessments* 6

7
8 During baseline and 12-week follow-up visits, patients underwent clinical assessments
9 including quality of life using the Minnesota Living with Heart Failure questionnaire, blood
10 sampling for N-Terminal pro b-type Natriuretic Peptide (NTproBNP), cardiopulmonary
11 pulmonary exercise stress testing on a semi-recumbent cycle ergometer (Corival, Lode &
12 Groningen, Netherlands) coupled with non-invasive haemodynamic monitoring (NICOM®,
13 Cheetah Medical, Delaware, USA). A graded exercise test protocol was used for
14 cardiopulmonary exercise testing. This involved maintaining a pedal frequency of 60-70
15 revolutions per minute with workload increasing at the rate of 10 watts per minute. The test
16 was terminated when maximal exertion was achieved, or when the patient was unable to
17 maintain the required cycling cadence, or if the patient desired to stop. Physical activity (step
18 count) was measured continuously using a pedometer (Omron Health care, Model no: HJ-321-
19 E, Japan). Patients recorded daily step counts at the end of each day using a paper-based activity
20 tracker and results were communicated weekly to a member of the study team.
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

41 *The home-based physical activity programme (Active-at-Home-HF)* 42

43
44 The Active-at-Home-HF intervention was designed for patients with CHF to encourage an
45 increase in their overall daily physical activity levels by at least 2000 steps per day from
46 baseline. This behavioural intervention was delivered by telephone to participants in the north-
47 east of England who were patients at the Royal Victoria Infirmary or Freeman Hospital,
48 Newcastle upon Tyne. The intervention team comprised of Cardiologists, Exercise
49 physiologists and health psychologists. Team members (NCO and SC) involved in monitoring
50 patients were experienced clinical exercise physiologists certified by the American College of
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1 Sports Medicine. They also received training delivered by a Chartered health psychologist with
2 expertise in health behaviour change (LA) who was also a member of the research team, on the
3
4 delivery/use of evidence-based behaviour change techniques selected to target physical activity
5
6 behaviour (e.g., physical activity goal setting, problem solving, self-monitoring) (16,17) . The
7
8 same health psychologist developed the brief behavioural intervention, intended for delivery
9
10 by telephone using a proforma to prompt use of the specific behaviour change techniques. This
11
12 proforma also served as a record for future discussions following completion during each
13
14 intervention session delivered. The intervention differed from centre-based programmes in that
15
16 it focussed on free-living physical activity, did not rely on exercise equipment, was delivered
17
18 by weekly telephone sessions, and focussed on providing participants with the knowledge and
19
20 behavioural skills to increase and maintain physical activity levels despite the barriers they
21
22 might face. Once patients enrolled in to the study, they were supported by weekly telephone
23
24 calls lasting approximately 10 minutes in duration, designed to initiate, increase and maintain
25
26 their activity levels. This was achieved through behavioural goal setting where the patient
27
28 would set a physical activity goal with the guidance and support of a trained research team
29
30 member. Barriers to reaching the goal were discussed followed by mutual identification of
31
32 solutions to overcome those barriers. Patients were encouraged to consider times in the past
33
34 where they had been more physically active as a means of increasing confidence and
35
36 motivation. Self-monitoring was used to encourage maintenance of activity levels and patients
37
38 were prompted to involve family members and friends in their attempts to increase physical
39
40 activity levels as a means of social support. At the end of each day, the goal was to achieve at
41
42 least 2000 steps more than the average daily number of steps obtained at baseline as indicated
43
44 on the pedometer. Physical activity levels were adjusted on an individual basis as conditioning
45
46 took place, with the emphasis on volume of activity i.e. duration and number of steps rather
47
48 than intensity.
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3 *Outcomes*
4
5

6 The primary outcomes of interest were acceptability and feasibility of the intervention.
7
8 Secondary outcomes were changes in functional capacity assessed by peak exercise oxygen
9 consumption and power output, quality of life, haemodynamic function and changes in
10 NTproBNP. Feasibility was defined as willingness of patients to enrol on to the Active-at-
11 Home-HF intervention and was confirmed by recruiting the targeted number of patients. The
12 recruitment target deadline was set at nine months after recruiting first patient. Acceptability
13 was defined as willingness to engage with and adhere to the intervention and was reported as
14 the percentage of patients who completed intervention. The intervention was considered
15 acceptable if $\geq 80\%$ of patients completed it. This included weekly engagement by telephone
16 and completion of daily physical activity records. If engagement with each of these components
17 was recorded, the intervention was considered acceptable.
18
19
20
21
22
23
24
25
26
27
28
29
30
31

32
33 *Statistical analysis*
34
35

36 The primary aim of the present study was to assess acceptability and feasibility of the
37 intervention. It is generally accepted that pilot feasibility studies do not require a formal power
38 calculation (18). However, it was important to assess whether the Active-at-Home-HF
39 intervention, if acceptable and feasible, was capable of improving outcomes of interest to allow
40 a judgement to be made as to whether the intervention is comparable to a centre-based
41 intervention. It was therefore estimated that a sample size of 20 patients would provide
42 sufficient power to detect a clinically acceptable change/increase in peak oxygen consumption
43 of 3 ml/min/kg post intervention, at the significance level of 5% ($\beta=0.82$, $\alpha=0.05$). The
44 relationship between physical activity and physiological variables was assessed using
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Pearson's coefficient of correlation. Statistical significance was indicated if $P < 0.05$. All statistical analyses were carried out using SPSS version 24.0 (SPSS, Chicago, IL, USA).

Results

Acceptability and Feasibility

Out of 43 CHF patients contacted by telephone after initials screening, 20 patients met the study inclusion criteria and were willing to take part and were subsequently recruited. Recruitment took place between December 2015 and September 2016. Patients were excluded (n=23) if they already met recommended physical activity guidelines (5)(n=4), were too ill to participate (NYHA stage IV) or recent hospitalisation (n=8). Patients were also excluded if they refused to participate for personal reasons (n=4), time commitment (n=3), 'feeling not be able to due to age' (n=1), or too nervous to participate in a physical activity intervention (n=3). Recruited patients' demographic and clinical characteristics are presented in Table 1. No adverse events occurred as a result of participating in the intervention/study. Seventeen participants completed the 12-week physical activity intervention. However, two patients were unable to meet or sustain the required minimum target of 2000 steps above baseline due to severe arthritis. The intervention was considered acceptable and feasible as the required number of patients were recruited, and the majority of patients completed the intervention (completion rate 85%; n=17) (see Figure 1).

[INSERT FIGURE 1]

In situations where patients expressed concerns about their arrhythmias or ischaemia, they were further assessed by the team's consultant cardiologist and were reassured about safety of participation in the intervention before they took part in the study.

[INSERT TABLE 1]

1 The target step count goal of 2000 steps from baseline was achieved at week three with average
2 number of steps per day increasing significantly by 2546 from (5108±3064 to 7654±3849
3 steps/day, p=0.03), and was maintained until week 12 (8890±3713 steps/day, Figure 2). Two
4 patients dropped out of the study for undisclosed reasons and one participant discontinued due
5 to implantable cardiac defibrillator malfunction.
6
7
8
9
10

11 [INSERT FIGURE 2]
12

13 *Metabolic changes* 14 15

16 There was no statistically significant change in exercise tolerance with peak oxygen
17 consumption and peak workload increasing post intervention by 4.8% and 11% respectively.
18
19 However, workload and oxygen consumption at submaximal exercise (i.e. anaerobic threshold)
20 increased by 20% (49±16 vs 59±14 watts, P=0.01) and 11% (11.5±2.9 vs 12.8±2.2 ml/kg/min,
21 P=0.39) post intervention (Table 2).
22
23
24
25
26
27
28
29
30

31 *Haemodynamic changes* 32 33

34 The Completion of the intervention resulted in significant improvements in peak exercise
35 stroke volume (126.5±33.8 vs 150.8±33.5 ml/beat, P= 0.05) and stroke volume index (64.6±14
36 vs 75.2 ±17 ml/beat/m², P=0.04). There was also a 10-15% improvement in peak exercise
37 cardiac output and cardiac index, although these were not statistically significant (Table 2).
38
39
40
41
42
43
44

45 [INSERT TABLE2]
46
47

48 *Blood biomarkers and Quality of life* 49 50

51 There were no statistically significant changes in metabolic biomarkers following completion
52 of the intervention. There was a 4 point improvement in quality of life score (Table 3).
53
54
55
56

57 [INSERT TABLE 3]
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Daily number of steps correlated positively with peak oxygen consumption post-intervention ($r=0.58$, $P=0.01$), but not pre-intervention ($r=0.39$, $P=0.08$). The significant correlation observed post intervention, although moderate, suggests that daily physical activity is positively associated with functional capacity (exercise tolerance) in active but not sedentary patients with chronic HF (Figure 3). This suggest that increasing daily walking improves fitness levels in heart failure patients.

[INSERT FIGURE 3]

Discussion

The major findings of this study are that the Active-at-Home-HF intervention demonstrated to be both acceptable and feasible to patients with CHF and led to modest changes in exercise tolerance and haemodynamics. This was shown by the number of patients (85%) who engaged with and completed the intervention after enrolment. This figure is comparable to adherence rates (>75%) reported from centre based studies (19,20). Piotrowicz et al. (20), who compared a homebased tele-monitored cardiac rehabilitation to centre-based rehabilitation reported 100% adherence in the home-based group. Seventy five percent of dropouts in the centre-based group of the above study were due to inadequate funds and availability of transport while 25% dropped out due to difficulty in matching the centre based training with their daily activities. These findings are important because the intervention has shown to provide a viable and potentially low-cost (i.e. brief behavioural intervention delivered by telephone, no reliance on exercise equipment provision in clinical settings) alternative to centre-based programmes for patients not wanting to engage in group-based rehabilitation and is a solution to overcome other barriers including travel constraints.

1 Patients with heart failure often experience a decline in health related quality of life. Following
2 clinical presentation/diagnosis, psychological distress can limit activity and lead to a decline in
3
4 quality of life (21). Exercise training has been reported to improve quality of life in CHF (22)
5
6 and a reduction of 5 points or more in the Minnesota living with heart failure questionnaire is
7
8 accepted as being clinically significant (23). The present pilot feasibility study reported a 15%
9
10 (4 point) reduction in quality of life score (i.e. an improvement in quality of life) which is
11
12 deemed clinically insignificant and as thus, contrast studies that have reported a significant
13
14 improvement in quality of life following exercise intervention (24). However, a 15%
15
16 improvement is positive in a group of participants who reported a higher than average quality
17
18 of life score at baseline (i.e. mean values of 26 points out of a possible score of 105 points in
19
20 the questionnaire). Cowie et al., (25) also reported no significant change in quality of life in
21
22 CHF patients following home-based or hospital-based intervention, even though there was a
23
24 significant improvement in exercise capacity. They further suggested that in older CHF
25
26 patients, maintaining quality of life rather than improving it might be a realistic aim for a
27
28 physical activity or rehabilitation programme.
29
30
31
32
33
34
35
36

37 At anaerobic threshold, participants were able to tolerate significantly greater workload (17%
38
39 increase). This finding is similar to previous studies that also reported a delay in reaching
40
41 anaerobic threshold (26) and a significant increase in power output at anaerobic threshold (27).
42
43
44

45 Similarly, increased daily physical activity resulted in a 19% significant increase in peak stroke
46
47 volume. Our results suggest positive adaptation to the intervention and the improvement of
48
49 systemic oxygen delivery. Other studies have also reported significant improvements in an
50
51 echocardiogram generated stroke volume as a result of long term (>12 weeks) exercise
52
53 training (28). The capacity to increase physical activity depends on the ability of the heart to
54
55 generate adequate cardiac output and the ability of skeletal muscles to utilise the oxygen
56
57 delivered (29). Therefore, this provides strong evidence for the assessment of cardiac
58
59
60
61
62
63
64
65

1 heamodynamics in response to a physical activity intervention. These findings have been
2 extended by other studies which demonstrated that aerobic training also improves diastolic
3 filling, myocardial contractility and left ventricular ejection fraction in individuals severe left
4 ventricular systolic dysfunction (30,31). Based on the findings of the current study and
5 evidence from the above-mentioned studies, it is reasonable to suggest that physical activity in
6 CHF can improve cardiac contractility and stroke volume, potentially leading to reverse
7 remodelling. The present study also found that increased physical activity as recorded from
8 step counts following the Active-at-Home-HF intervention had a stronger correlation with peak
9 oxygen consumption compared with lower step counts (sedentary behaviour) pre intervention.
10 Jehn et al., who reported a positive correlation between the times spent in light activity/exercise
11 (≤ 3 METs) and improved peak oxygen consumption (11), had demonstrated this previously.

12 Although the use of steps per day has been criticised for not taking into account exercise
13 intensity (32), a recent study by Tudor-Locke et al., (33) has shown that linear trends for steps
14 per day were statistically significant for cardio-metabolic risk factors including blood pressure
15 for men, weight, waist circumference, insulin, high density lipoprotein, triglycerides and
16 homeostasis model assessment-estimated insulin resistance. Even at step counts of around 70
17 steps per minute, which is below the recommended 100 steps per minute suggesting moderate
18 intensity (32), clinically favourable values for many of the cardio-metabolic outcomes were
19 observed. The present study provides further justification for the use of steps per day
20 recommendations in national physical activity guidelines (34). Furthermore, the present study
21 results are of clinical importance for the management of CHF patients, particularly older adults
22 as most patients have concomitant exercise-limiting co-morbidities such as neuromuscular or
23 orthopaedic problems making the traditional 10,000 step target (35) or steps per minute
24 unrealistic and potentially harmful. As such, it may be appropriate to encourage such patients

1 to exercise at a lower intensity than has been considered necessary to increase maximal exercise
2 capacity.
3

4 5 *Limitations* 6

7
8 The following limitations should be considered in the present study. Firstly, it could be argued
9 that sample size limits generalisability of findings. Of the 43 patients screened, only 20 were
10 enrolled into the study meaning a recruitment rate of 46%. However, this was a pilot study with
11 the primary aim of establishing acceptability and feasibility of the intervention. A further
12 criticism could be that this study lacked a control group. However, the primary intention of this
13 study was not to establish the effect of the intervention, instead it was to assess feasibility and
14 acceptability with a view to informing a larger scale evaluation (i.e. controlled trial) should the
15 intervention prove to be feasible and acceptable. Secondly, it could be argued that stroke
16 volume was measured non-invasively which is not the gold standard. However, the
17 reproducibility of stroke volume measurements using the NICOM have previously been
18 reported (36). Lastly, only two female patients were recruited into the study limiting
19 generalisability of the study findings in terms of gender. The nature of this pilot study did not
20 necessitate the use of digital technologies. However, digital technologies which offer additional
21 evaluation of haemodynamic function such as heart rate and blood pressure will be useful in
22 future studies to improve safety of patients while engaging in physical activity, and would
23 likely increase feasibility. Further evaluation of the ACTIVE-at-HOME intervention: clinical
24 and cost-effectiveness is warranted in an adequately powered randomised controlled trial
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49

50 **Conclusion** 51

52
53 The present study demonstrates that the novel, home-based physical activity intervention (i.e.
54 Active-at-Home-HF) is acceptable and feasible and can provide clinical and physiological
55 benefits to people living with CHF. The intervention is associated with increased habitual
56
57
58
59
60
61
62
63
64
65

1 physical activity level, functional capacity and haemodynamic response to exercise. Significant
2 changes in response to the Active-at-Home-HF intervention were observed in submaximal
3
4 exercise capacity and cardiac response to exercise. The Active-at-Home-HF intervention
5
6 provides a viable alternative to centre-based programmes. This helps to overcome barriers
7
8 including travel cost, and reluctance to participate in group-based activity. A larger multicentre
9
10 study is warranted to further substantiate preliminary findings from the present study.
11
12
13
14
15
16
17
18
19
20
21
22
23

24 **Abbreviations**

25
26
27 CHF: Chronic Heart Failure

28
29
30 COPD:Chronic Obstructive Pulmonary Disease

31
32
33 HF: Heart Failure

34
35
36 NTproBNP: n-Terminal pro b-type Natriuretic Peptide

37
38
39 NYHA: New York Heart Association

40
41
42 UK: United Kingdom

43 **Declarations**

44 **Ethics approval and consent to participate**

45
46
47 The Health Research Authority- North East Tyne and Wear South Research Ethics Committee
48
49 approved the study protocol (REC reference: 15/NE/0190). Informed consent was obtained
50
51 from all individual participants included in the study in accordance with Declaration of
52
53 Helsinki.
54
55
56
57
58
59
60
61
62
63
64
65

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Consent for Publication

“Not applicable”

Availability of data and material

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing Interests

All authors report no conflict of interest.

Funding

The National Institute for Health Research Newcastle Biomedical Research Centre research grant to D.G.J. (number BH142109) funded this research. The Research Councils UK Newcastle Centre for Ageing and Vitality supports D.G.J. The European Horizon 2020 research and innovation programme supports N.C.O. and S.J.C. under grant agreement Number 777204.

Authors contributions

DGJ, GAM, NO, LA, KB, IO, and LV designed the study. NCO, SC, SJC, LA and DGJ performed the study and collected the data. NCO and DGJ analysed the data and drafted the manuscript. GAM, KB, IO, LV and PB reviewed the manuscript. All authors read and approved the final manuscript.

Acknowledgements

The authors would like to thank all study participants and nurses at the Clinical Research Facility, Royal Victoria Infirmary, Newcastle-upon-Tyne Hospitals NHS Foundation Trust.

References

1. Zwisler A-D, Norton RJ, Dean SG, Dalal H, Tang LH, Wingham J, et al. Home-based cardiac rehabilitation for people with heart failure: A systematic review and meta-analysis. *Int J Cardiol.* 2016;221:963–9.
2. NICE Guideline. Chronic heart failure in adults: diagnosis and management. National Institute for Health and Care Excellence. 2018.
3. Lewinter C, Doherty P, Gale CP, Crouch S, Stirk L, Lewin RJ, et al. Exercise-based cardiac rehabilitation in patients with heart failure: a meta-analysis of randomised controlled trials between 1999 and 2013. *Eur J Prev Cardiol.* 2015;22(12):1504–12.
4. Taylor RS, Sagar VA, Davies EJ, Briscoe S, Coats AJS, Dalal H, et al. Exercise-based rehabilitation for heart failure. *Cochrane database Syst Rev.* 2014;4:CD003331.
5. Ponikowski P, Voors AA, Anker SD, Bueno H, Cleland JGF, Coats AJS, et al. 2016 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. *Eur Heart J.* 2016;37(27):2129–2200m.
6. Piercy KL, Troiano RP, Ballard RM, Carlson SA, Fulton JE, Galuska DA, et al. The Physical Activity Guidelines for Americans. *JAMA.* 2018;9762:1–9.
7. NICE. National Institute for Health and Clinical Excellence. *Curr Pract.* 2015;2009(April):1–78.
8. Dalal HM, Wingham J, Palmer J, Taylor R, Petre C, Lewin R, et al. Why do so few patients with heart failure participate in cardiac rehabilitation? A cross-sectional survey from England, Wales and Northern Ireland. *BMJ Open.* 2012;2(2):e000787.
9. Beswick AD, Rees K, Griebisch I, Taylor FC, Burke M, West RR, et al. Provision, uptake and cost of cardiac rehabilitation programmes: Improving services to under-

represented groups. Vol. 8, Health Technology Assessment. 2004.

10. Sato N, Origuchi H, Yamamoto U, Takanaga Y, Mohri M. The importance of daily physical activity for improved exercise tolerance in heart failure patients with limited access to centre-based cardiac rehabilitation. *Exp Clin Cardiol.* 2012;17(3):121–4.
11. Jehn M, Schmidt-Trucksäss A, Schuster T, Weis M, Hanssen H, Halle M, et al. Daily walking performance as an independent predictor of advanced heart failure. Prediction of exercise capacity in chronic heart failure. *Am Heart J.* 2009;157(2):292–8.
12. Bravata DM, Smith-Spangler C, Sundaram V, Gienger AL, Lin N, Lewis R, et al. Using Pedometers to Increase Physical Activity and Improve Health. *JAMA.* 2007 Nov 21;298(19):2296.
13. Richardson CR, Newton TL, Abraham JJ, Sen A, Jimbo M, Swartz AM. A meta-analysis of pedometer-based walking interventions and weight loss. *Ann Fam Med.* 2008 Jan 1;6(1):69–77.
14. Yamanouchi K, Shinozaki T, Chikada K, Nishikawa T, Ito K, Shimizu S, et al. Daily walking combined with diet therapy is a useful means for obese NIDDM patients not only to reduce body weight but also to improve insulin sensitivity. *Diabetes Care.* 1995;
15. Yates T, Haffner SM, Schulte PJ, Thomas L, Huffman KM, Bales CW, et al. Association between change in daily ambulatory activity and cardiovascular events in people with impaired glucose tolerance (NAVIGATOR trial): A cohort analysis. *Lancet.* 2014;383(9922):1059–66.
16. Avery L, Sniehotta FF, Denton SJ, Steen N, McColl E, Taylor R, et al. Movement as Medicine for Type 2 Diabetes: protocol for an open pilot study and external pilot

1 clustered randomised controlled trial to assess acceptability, feasibility and fidelity of a
2 multifaceted behavioural intervention targeting physical activity in primary care.
3

4
5 Trials. 2014 Dec 3;15(1):46.
6

- 7
8 17. Avery L, Flynn D, Dombrowski SU, van Wersch A, Sniehotta FF, Trenell MI.
9 Successful behavioural strategies to increase physical activity and improve glucose
10 control in adults with Type 2 diabetes. *Diabet Med.* 2015 Aug 1;32(8):1058–62.
11
12
13 18. Moore CG, Carter RE, Nietert PJ, Stewart PW. Recommendations for Planning Pilot
14 Studies in Clinical and Translational Research. *Clin Transl Sci.* 2011;4(5):332–7.
15
16
17 19. Belardinelli R, Georgiou D, Cianci G, Purcaro A. Randomized, Controlled Trial of
18 Long-Term Moderate Exercise Training in Chronic Heart Failure : Effects on
19 Functional Capacity, Quality of Life, and Clinical Outcome. *Circulation.*
20
21 1999;99(9):1173–82.
22
23
24 20. Piotrowicz E, Baranowski R, Bilinska M, Stepnowska M, Piotrowska M, Wójcik A,
25 et al. A new model of home-based telemonitored cardiac rehabilitation in patients with
26 heart failure: Effectiveness, quality of life, and adherence. *Eur J Heart Fail.*
27
28 2010;12(2):164–71.
29
30
31 21. Ades PA, Keteyian SJ, Balady GJ, Houston-Miller N, Kitzman DW, Mancini DM, et
32 al. Cardiac Rehabilitation Exercise and Self-Care for Chronic Heart Failure. Vol. 1,
33
34 JACC: Heart Failure. 2013. p. 540–7.
35
36
37 22. Keteyian SJ. Exercise rehabilitation in chronic heart failure. *Coron Artery Dis.*
38
39 2006;17(3):233–7.
40
41
42 23. Riegel B, Moser DK, Glaser D, Carlson B, Deaton C, Armola R, et al. The Minnesota
43 Living With Heart Failure Questionnaire: sensitivity to differences and responsiveness
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

to intervention intensity in a clinical population. *Nurs Res.* 2002;51(4):209–18.

24. Piotrowicz E, Zieliński T, Bodalski R, Rywik T, Dobraszkiwicz-Wasilewska B, Sobieszcańska-Małek M, et al. Home-based telemonitored Nordic walking training is well accepted, safe, effective and has high adherence among heart failure patients, including those with cardiovascular implantable electronic devices: a randomised controlled study. *Eur J Prev Cardiol.* 2014;22(11):1368–77.
25. Cowie A, Thow MK, Granat MH, Mitchell SL. Effects of home versus hospital-based exercise training in chronic heart failure. *Int J Cardiol.* 2012;158(2):296–8.
26. van Tol B a F, Huijsmans RJ, Kroon DW, Schothorst M, Kwakkel G. Effects of exercise training on cardiac performance, exercise capacity and quality of life in patients with heart failure: a meta-analysis. *Eur J Heart Fail.* 2006;8(8):841–50.
27. Giannuzzi P, Temporelli PL, Corrà U, Tavazzi L. Antiremodeling effect of long-term exercise training in patients with stable chronic heart failure: Results of the exercise in left ventricular dysfunction and chronic heart failure (ELVD-CHF) trial. *Circulation.* 2003;108(5):554–9.
28. Lee B-A, Oh D-J. The effects of long-term aerobic exercise on cardiac structure, stroke volume of the left ventricle, and cardiac output. *J Exerc Rehabil.* 2016;12(1):37–41.
29. McCoy J, Bates M, Eggett C, Siervo M, Cassidy S, Newman J, et al. Pathophysiology of exercise intolerance in chronic diseases: the role of diminished cardiac performance in mitochondrial and heart failure patients. *Open Hear.* 2017;4(2):e000632.
30. Karapolat H, Demir E, Bozkaya YT, Eyigor S, Nalbantgil S, Durmaz B, et al. Comparison of hospital-based versus home-based exercise training in patients with heart failure: effects on functional capacity, quality of life, psychological symptoms,

and hemodynamic parameters. *Clin Res Cardiol.* 2009;98(10):635–42.

31. Mezzani A, Corra U, Giannuzzi P. Central adaptations to exercise training in patients with chronic heart failure. *Heart Fail Rev.* 2008;13(1):13–20.
32. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, et al. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc.* 2011;
33. TUDOR-LOCKE C, SCHUNA JM, HAN H, AGUIAR EJ, GREEN MA, BUSA MA, et al. Step-Based Physical Activity Metrics and Cardiometabolic Risk. *Med Sci Sport Exerc.* 2017 Feb;49(2):283–91.
34. Kraus WE, Janz KF, Powell KE, Campbell WW, Jakicic JM, Troiano RP, et al. Daily Step Counts for Measuring Physical Activity Exposure and Its Relation to Health. *Med Sci Sports Exerc.* 2019 Jun;51(6):1206–12.
35. Duncan MJ, Brown WJ, Mummery WK, Vandelanotte C. 10,000 Steps Australia: a community-wide eHealth physical activity promotion programme. *Br J Sports Med.* 2018 Jul;52(14):885–6.
36. Jones TW, Houghton D, Cassidy S, MacGowan GA, Trenell MI, Jakovljevic DG. Bioreactance is a reliable method for estimating cardiac output at rest and during exercise. *Br J Anaesth.* 2015;115(3):386–91.

List of Figures

Figure 1 Flow diagram showing patient screening and recruitment into Active-at-home HF intervention

1 Figure 2 Mean (+SD) number of steps achieved at baseline and at the end of weeks 3 and 12
2 of physical activity intervention
3
4

5 Figure 3 Relationship between number of steps and peak oxygen consumption pre and post
6 intervention.
7
8
9

10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65

Table 1. Mean and SD (\pm) patients' demographic and clinical characteristics

<i>Parameter</i>	
Age (years)	68 \pm 7
Men/women	18/2
Weight (kg)	84 \pm 15
Height (cm)	1.72 \pm 0.1
Aetiology of HF (IHD/DCM)	10/10
LVEF (%)	31 \pm 8
<i>Medication</i>	
ACE inhibitors	15
B- blockers	20
ARBs	5
Diuretics	13
Anti-arrhythmic	3
NSAIDs/Pain Killers	6
Warfarin	5
ICD/Pacemakers	13
<i>Comorbidities</i>	
COPD	1
Type 2 Diabetes	5
Obesity	6
Hypertension	20
Depression	2
Arthritis	1
ACE, angiotensin converting enzyme; ARB, angiotensin receptor blockers; LVEF, left ventricular ejection fraction; NSAID, non-steroid anti-inflammatory drugs; IHD, ischaemic heart disease; DCM, dilated cardiomyopathy; COPD, chronic obstructive pulmonary disease; ICD, Implantable cardioverter defibrillator	

Table 2. Cardio-metabolic changes (mean ± SD) following 12 weeks of Active-at-Home-HF intervention

	Pre intervention	Post intervention	P Value	% Change
<i>Measurements at Rest</i>				
Oxygen Consumption (ml/kg/min)	3.8±1.0	4.1±0.8	0.36	7.9
Respiratory Exchange Ratio	0.85±0.1	0.85±0.1	0.92	0
Heart Rate (beats/min)	67±7	70±7	0.24	4.5
Stroke Volume Index (ml/beat)	48±9	49±8	0.75	2.0
Cardiac Output (l/min)	6.1±1	6.6±1	0.14	8.2
Systolic Blood Pressure (mmHg)	118±18	124±18	0.41	4.0
Diastolic Blood pressure (mmHg)	74±8	76±12	0.74	2.6
Mean Arterial Pressure (mmHg)	90±9	92±13	0.66	2.2
<i>Measurements at Peak Exercise</i>				
Oxygen Consumption (ml/kg/min)	16.8±3.8	17.6±4.2	0.54	4.8
Respiratory Exchange Ratio	1.05±0.1	1.07±0.1	0.62	1.9
Heart Rate (beats/min)	106±19	107±16	0.92	1.0
Stroke Volume (ml/beat)	127±34	151±34	0.05*	18.9
Stroke Volume Index (ml/beat/m ²)	64±14	75±17	0.04*	17.2
Cardiac Output (l/min)	13.4±4	15.3±4.9	0.19	14.2
Cardiac Index (l/min/m ²)	6.8±1.5	7.6±2.0	0.19	11.7
Systolic Blood Pressure (mmHg)	155±30	150±30	0.62	3.2
Diastolic Blood pressure (mmHg)	80±8	79±8	0.72	1.3
Mean Arterial Pressure (mmHg)	103±13	102±13	0.87	1.0
Peak exercise workload (watts)	82±10	91±19	0.21	11
Exercise workload at anaerobic threshold (watts)	49±16	59±14	0.01*	20
Oxygen consumption at anaerobic threshold (ml/kg/min)	11.5±2.9	12.8±2.2	0.39	11.3
Rate of perceived exertion	16±2.4	17±2.3	0.22	6.3

Table 3. Blood biomarkers and quality of life (mean \pm SD) following 12 weeks of Active-at-Home-HF

	Pre Intervention	Post Intervention	P Value	% Change
Cholesterol (mmol/L)	4.0 \pm 0.9	3.9 \pm 0.9	0.59	2.5
Triglyceride (mmol/L)	1.5 \pm 0.7	1.8 \pm 0.9	0.45	20
HDL (mmol/L)	1.2 \pm 0.3	1.1 \pm 0.3	0.67	8.3
LDL (mmol/L)	2.1 \pm 0.7	1.9 \pm 0.7	0.46	9.5
HbA1c (mmol/mol)	49.2 \pm 17.3	47.5 \pm 12	0.77	3.5
FBG (mmol/L)	6.2 \pm 2.9	7.0 \pm 3.8	0.56	12.9
NT proBNP (pg/ml)	823 \pm 1085	876 \pm 1114	0.89	6.4
Renal function eGFR	65.4 \pm 18.6	61.4 \pm 17.4	0.61	6.1
QoL	26 \pm 18	22 \pm 23	0.50	15.4

HDL, high density lipoprotein; LDL, low density lipoprotein; HbA1c, glycated Haemoglobin; FBG, fasting blood glucose; NT proBNP, N-terminal brain natriuretic peptide; QoL, quality of life; eGFR, glomerular filtration rate

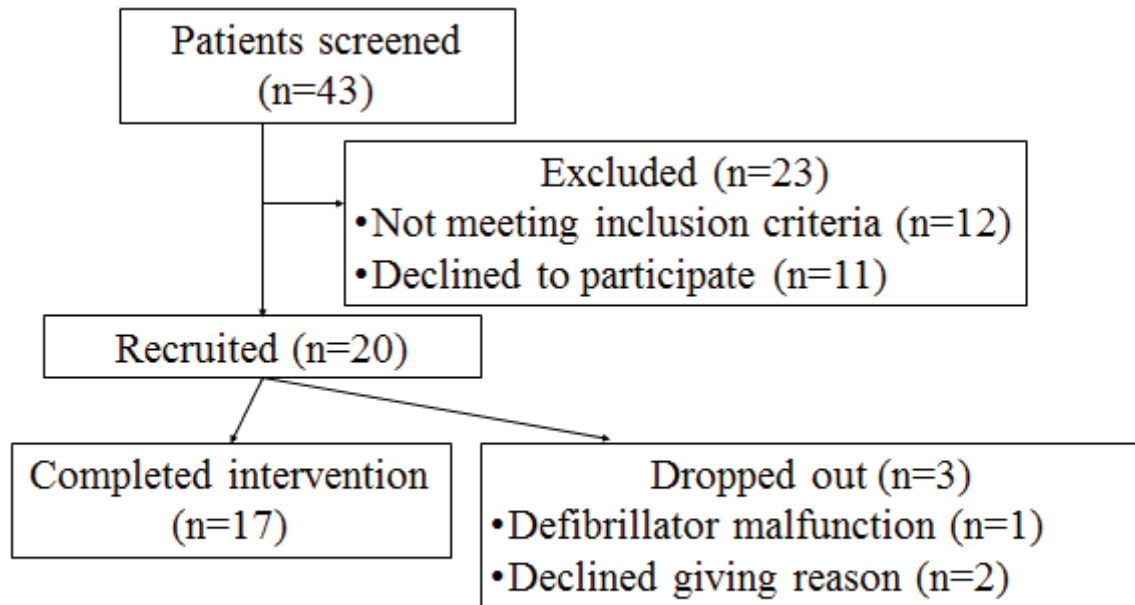


Figure 1 Flow diagram showing patient screening and recruitment into Active-at-home HF intervention

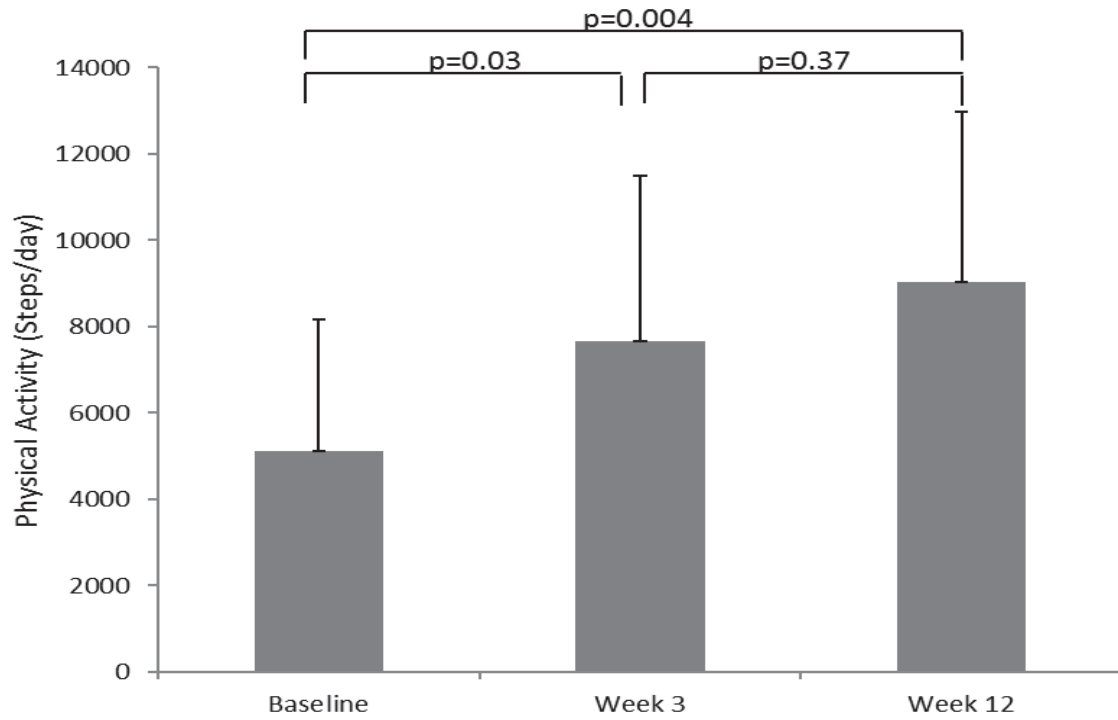


Figure 2. Mean (+SD) number of steps achieved at baseline and at the end of weeks 3 and 12 of physical activity intervention

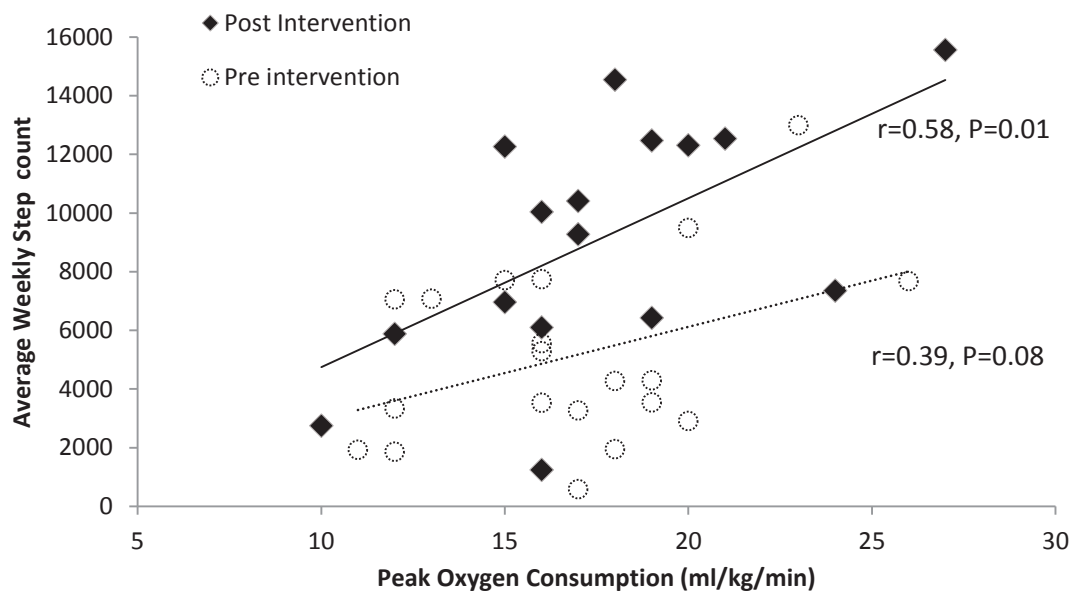


Figure 3. Relationship between number of steps and peak oxygen consumption pre and post intervention.