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Research Article

Factors Associated with Objectively Assessed Physical Activity Levels of Heart Failure Patients

Grace Olivia Dibben[1*], Melvyn Hillsdon[2], Hasnain M Dalal[2], Brad Metcalf[3], Patrick Doherty[4], Lars HermannTang[5,6], Rod S Taylor[2,7]

[1]University of Exeter Medical School, Knowledge Spa, Royal Cornwall Hospitals NHS Trust, Truro, TR1 3HD, UK; [2] Institute of Health Research (Primary Care), University of Exeter Medical School, St. Luke's Campus, Heavitree Road, Exeter, EX1 2LJ, UK; [3]Departmentof Sport and Health Sciences, University of Exeter, Richard's Building, St Luke's Campus, Exeter EX1 2LU, UK; [4]Departmentof Health Sciences, Seebohm Rowntree Building, University of York, YO10 5DD, UK; [5]National Knowledge Centre for Rehabilitation and Palliative Care, University of Southern Denmark and Odense University Hospital, Denmark; [6]Departmentof Physiotherapy and Occupational Therapy, Næstved-Slagelse-Ringsted Hospitals, Region Zealand, 4200 Slagelse, Denmark; [7]Instituteof Health and Wellbeing, University of Glasgow, Glasgow G12 8QQ, UK

ABSTRACT

Aim: To determine the level of objectively measured moderate-to-vigorous physical activity (MVPA) in patients with heart failure (HF), and to assess the association between MVPA and patient sociodemographic, exercise capacity, and health status factors.

Methods: Baseline MVPA data was available in 247 HF patients with 7-day wrist-worn accelerometry from two randomized controlled trials. Associations between MVPA and patient sociodemographic, exercise capacity, and health status factors were assessed using univariate and multivariable linear regression models.

Results: 247 patients (28% female, mean age 71 ± 10 years) with HF with reduced ejection fraction (n=198) and preserved ejection fraction (n=49) were included in the analysis. Average MVPA was 283. 3 min/week and ranged widely from a minimum of 0 mins/week to maximum of 2626. 7 mins/week (standard deviation: 404. 1 mins/week). 111 (45%) of patients had a level of PA that met current guidelines of at least 150 minutes/week of MVPA. Multivariable regression showed patient's age, body mass index, employment status, smoking status, New York Heart Association class, NT-proBNP and exercise capacity to be strongly associated (p<0. 001) with the level of MVPA (p<0. 001).

Conclusion: Whilst 45% of HF patients had objectively measured levels of MVPA that met current PA recommendations, we observed a wide range in the level of MVPA across this patient sample. As a number of factors were found to be associated with MVPA our findings provide important information for future interventions aiming to increase MVPA in HF patients.

Keywords: Physical activity; Heart failure; Accelerometer; Rehabilitation; Exercise capacity.

ABBREVIATIONS:

BMI: Body Mass Index; HF: Heart Failure; Hfpef: Heart Failure With Preserved Ejection Fraction; Hfref: Heart Failure With Reduced Ejection Fraction; ISWT: Incremental Shuttle Walk Test; MVPA: Moderate-To-Vigorous Physical Activity; NT-Probnp: N-Terminal Brain Natriuretic Peptide; NYHA : New York Heart Association; PA: Physical Activity; REACH-HF: Rehabilitation Enablement In Chronic Heart Failure.

Correspondence to: Grace Olivia Dibben, University of Exeter Medical School, F37b, Knowledge Spa, Royal Cornwall Hospitals NHS Trust, Truro, TR1 3HD, UK, Tel: 0187225519; E-mail: Gd318@exeter. ac. uk

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INTRODUCTION

There are numerous benefits of regular physical activity (PA) that persist across the life course, including prevention and management of chronic disease, prolonging functionality and increasing health-related quality of life [1]. To achieve these health benefits, it is recommended that adults perform at least 150 minutes per week (i. e. ≥ 30 minutes/day over 5 or more days per week) of moderate-to-vigorous PA (MVPA) [1].

A small number of studies to date have quantified the PA levels of HF patients and consistently report daily MVPA levels much lower than the recommended 30 minutes. Some studies have reported that HF patients undertake on average as little as 1 minute of MVPA per day [2-5]. However, these previous studies are limited by small sample sizes (N<100), [2-4] and/or reliance on self-report measures of PA, [5] which have been shown to be less reliable than objective measures [6]. Moreover, studies that did use objective PA methods are based on proprietary algorithms that assess levels of MVPA from data in healthy adults.

The aims of this study were to: (1) Determine the level of objectively measured PA and MVPA in HF patients using HF-specific intensity algorithms and (2) Assess the association between MVPA and patient sociodemographic, exercise capacity, and health status factors.

METHODS

Study design

This study used baseline data pooled from two randomized controlled trials of a home-based cardiac rehabilitation intervention for HF patients (REACH-HF): a single centre study in patients with HF with preserved ejection fraction (HFpEF) (ISRCTN78539530)and a multicenter study in patients in HF reduced ejection fraction (HFrEF) (ISRCTN86234930)[7-10].

Both trials were conducted in accord with the principles of the Declaration of Helsinki and ethical approval was granted by the East of Scotland Research Ethics Service (15/ES/0036) [9] and by the North West Lancaster Research Ethics Committee (14/NW/1351) [10].

Study participants

Participating HF patients were recruited from primary and secondary care settings in five UK centres (Birmingham, Cornwall, Dundee, Gwent, and York) between January 2015 and February 2016 [9,10]. A total of 266 patients completed the baseline visit, 216 with HFrEF(defined as left ventricular ejection fraction<45%) and 50 with HFpEF (defined as left ventricular ejection fraction ≥ 45%). The patients were aged≥ 18 years and had a confirmed diagnosis of HF on echocardiography or angiography within the last 6 months [7,8]. A full list of trial inclusion and exclusion criteria are provided in supplementary file A. All study participants provided written informed consent.

Data collection

Medical history, demographics, blood test, and exercise capacity: During their baseline clinic visit the following categories of data were collected: (1) Medical history, i. e. comorbidities, New York Heart Association (NYHA) class, HF aetiology, concomitant HF medication and presence of implantable cardiac devices; (2) Sociodemographic information i. e. age, ethnicity, weight, employment status, and smoking status; (3) Blood sample was taken for measurement of N-terminal Brain Natriuretic Peptide (NT-proBNP); (4) Health outcome questionnaires – i. e. disease-specific health-related quality of life assessed by Minnesota Living with Heart Failure Questionnaire, and the Health Related Quality of Life (HeartQoL) questionnaire; psychological wellbeing using the Hospital Anxiety and Depression Scale questionnaire; generic health-related quality of lifeusing the EQ-5D-5L questionnaire; and Self-care of HF Index questionnaire; (5) Exercise capacity assessed by an incremental shuttle walk test (ISWT) – the ISWT was performed twice with at least 30 minutes rest between the tests, administered by the PI or research nurse. Standardized instructions were given to patients, and no encouragement was given throughout the test [7,8]. The peak distance (m) walked in either of the two tests was recorded.

Physical activity accelerometry

At baseline visit, patients were also provided a GENEActiv triaxial accelerometer (GENEActiv, Activinsights, Kimbolton, Cambridge, UK) and instructed to wear the accelerometer on their non-dominant wrist for 7 days during waking and sleeping hours [9,10]. Monitors were returned using postage-paid envelopes. Data were downloaded using GENEActiv PC software (version 3. 2; Activ insights, Kimbolton, Cambridge, UK) and analysed in R (R Core Team, Vienna, Austria) using the GGIR software package (version 1. 5-18,). Initial processing included auto calibration, the detection of abnormally high values and non-wear [11,12]. Data were averaged over 5 second epochs and Euclidean Norm Minus One was used to quantify the acceleration related to movement registered and was expressed in units of milligravity (mg) [13]. The Euclidean norm (magnitude) of the 3 raw signals minus 1000 mg, with negative numbers rounded to zero was calculated using the following formula:

$$\sqrt{x^2 + y^2 + z^2} - 1000mg$$

Non-wear was determined over 60 minute windows using 15 minute increments, and was apparent when 2 of the 3 axes had a data range<50 mg and a standard deviation<13 mg[14]. To be included in analysis patients were required to have ≥ 16 hours per day and ≥ 7 days of wear. The first seven days that met the criteria were used for analysis.

For each patient, the following PA metrics were calculated: (1) minutes per week of MVPA,(2) whether patients meet the PA recommendation of ≥ 150 minutes of MVPA per week, (3) average daily PA levels (over all days, weekdays only, and weekend days only) broken down into minutes of inactivity, light PA, and MVPA. These metrics were calculated usingHF population specific accelerometer intensity thresholds for inactivity of 16. 7 mg (left wrist) and 18. 6 mg (right wrist) and MVPA of 43. 6 mg (left wrist) and 45. 5 mg (right wrist). These intensity thresholds were determined by a recent calibration study in 21 HF patients with concurrently assessed acceleration values and directly measured oxygen uptake across a range of activities of daily living [15]. These metrics were calculated using both bouted PA i. e. periods of PA sustained for at least 10 minutes where accelerometer readings lie above the intensity threshold (with a 20% allowance for values to fall outside the threshold) and unbouted i. e. PA accumulated in bouts of any length.

Statistical analysis

Descriptive statistics were used to summarize patient characteristics and levels of PA. Continuous variables are presented as means and standard deviations (SD) and discrete variables presented as counts or percentages.

Univariate linear regression analysis was conducted to examine the association between MVPA in minutes/week and each group of potential predictor variables (i. e. medical history/ sociodemographics, exercise capacity, health status outcomes) separately. Univariate logistic regression was used to examine the association with these groups of variables and the binary outcome of whether patients meet PA guidelines or not. Variables were selected for multivariable analysis if there was statistical evidence of (p<0. 15) of their association in univariate analysis.

Three multivariable PA regression models were developed for both MVPA in minutes/week and binary outcome of meeting PA guidelines or not: model 1 – medical history sociodemographic variables only, model 2 - exercise capacity and health status variables only, and model 3 - medical history sociodemographic and health and disease status variables that were identified as statistically significant (p<0. 05) in models 1 and 2. Checks and diagnostics were performed for model assumptions, residuals, multicollinearity (variance inflation factor) and influential observations (Cook's distance). Akaike information criterion and R^2 values (proportion of variance explained) were used to inform model comparison and selection. We performed two groups of sensitivity analyses: (1) including the patients previously excluded with high residuals and Cook's distances and (2) MVPA was recalculated without the requirement for PA to be in bouts of at least 10 minutes (bouted).

Statistical analyses were performed using Stata (V. 15. 0; StataCorp, College Station, Texas, USA).

RESULTS

Of the 266 patients who completed baseline visits, 247 were included in the analysis (Table 1). Overall, patients had a mean age of 70. 9 years and were predominantly male (72%) and NYHA class I to III (99%). Alongside differences in medications, HFpEF patients were more likely to be older and female, have higher BMI, live alone, have hypertension, chronic renal impairment, arthritis and COPD, have lower generic health-related quality of life (EQ-5D-3L). Hospital Anxiety and Depression Scale depression scores depression, and self-care maintenance scores, and lower ISWT distance. Four patients had missing accelerometer data, and 15 patients were excluded due to inadequate accelerometer wear time (<7 days of wear with ≥ 16 hours per day). Apart from a higher proportion in employment (26 vs. 13%, p=0. 01), excluded patients were similar to those included in the PA analysis.

Level of PA in HF patients

The average level of MVPA across the HF patients was 283. 3 mins/week. MVPA ranged widely across the study population from minimum of 0 mins/week to maximum of 2626. 7 mins/ week (standard deviation: 404. 1 mins/week). A total of 111 (45%) patients had a level of PA that met current guidelines of 150 minutes/week of MVPA. Daily PA of HF patients categorized by intensity, days, and bout rule is reported in Table 2. Patients undertook 40. 5 ± 57. 7 mins/day bouted MVPA and 175. 9 ± 86. 4 min/day unbouted MVPA averaged across all days of the week. Unbouted MVPA levels were higher during the week days compared to weekend days (p<0. 001), but bouted MVPA levels did not differ. Levels of bouted and unbouted light PA were higher during weekdays than weekend days (p<0. 001) and both bouted and unbouted inactivity levels were higher at the weekend than during the week (p<0. 001).

Table 3 summarizes the characteristics and reported MVPA levels of HF patients in this study and across previous HF studies. Daily MVPA levels of the HF patients in the present study are higher than the majority of PA levels reported in previous studies [2-5].

PREDICTORS OF PA IN HF PATIENTS

MVPA minutes per week

Univariate analyses: Supplementary Tables A and B shows the results of the univariate linear regressions between MVPA (min/ week) and the sociodemographic, exercise capacity and health status factors. MVPA (min/week) was positively (p<0. 05) associated with cause of HF, smoking history, ISWT distance, HEART QoL global and physical scores, and overall EQ-5D-3L score. PA was negatively (p<0. 05) related to age, body mass index (BMI), employment status, NYHA class I-III, NT-pro-BNP, living alone, living with child>18years, diabetes, number of comorbidities, number of cardiorespiratory-metabolic comorbidities, taking loop diuretics, Minnesota Living with Heart Failure Questionnaire overall, physical and emotional scores (where lower scores indicate better QoL), and Hospital Anxiety and Depression Scale depression scores. Variables that were closely related to MVPA (0. 05<p<0. 15) included living with a parent, osteoporosis, angina and taking nitrates.

Multivariable analyses: In model 1: NYHA class I-III, age, BMI, smoking history and employment status were all included in the final model as significant contributors, and the model accounted for 30% of the observed variance in MVPA (Table 4).

Two patients were removed from multivariable analysis due to having both high residual (e=2178, e=2040) and Cook's distance (D=0. 07, D=0. 15).

In model 2: ISWT distance was the only significant contributor and explained 27% of the observed variance in MVPA (Table 4). Two patients identified with high residual (e=2288, e=2182) and Cook's distance (D=0. 17, D=0. 14) were removed from the analysis.

In model 3: two patients removed with high residual (e=2202, e=2141) and Cook's distance (D=0. 10, D=0. 14). ISWT distance, age, BMI, and smoking history remained as significant contributors and accounted for 36% of the variance in MVPA.

The variance inflation factor ranged from 1. 1-1. 2 across the three models indicating a low level of multi collinearity (variance inflation factor>5 indicates a level high correlation that may be problematic for modelling).

Including the patients with high residuals and Cook's distances decreased the R^2 across all three models, and resulted in the removal of employment status in model 1, and NYHA class being replaced by smoking status in model 3. Running a model containing all variables with p<0. 15 from the univariate analysis produced findings consistent to model 3. Analysis with unbouted (<10 minutes in duration) MVPA data, which decreased R^2 across all models, and NT-pro BNP replaced employment status in model 1, no other differences were observed.

MVPA meeting PA recommendations

Univariate analyses: Supplementary Table C shows the results of the univariate logistic regressions between meeting PA guidelines and the sociodemographic, exercise capacity and health status factors. The association between meeting PA guidelines was statistically significant with age, BMI, employment status, NYHA class I-III, NT-proBNP, living alone, living with partner, diabetes, number of comorbidities, number of cardiorespiratory-metabolic comorbidities, taking anticoagulants, taking loop diuretics, ISWT distance, Minnesota Living with Heart Failure Questionnaire overall, physical and emotional scores, Hospital Anxiety and Depression Scale depression scores and overall EQ-5D-3L. Variables that were closely related to meeting PA guidelines (0. 05<p<0. 15) included cause of HF and trial site.

Multivariable analyses: In model 1: NYHA class I-III, NT-proBNP level, age, and BMI were statistically significant contributors included in the model (Table 5). One patient with high residual (e=5. 96) was removed.

In model 2 (exercise capacity and health status variables), only ISWT distance was included in the model, all patients were included in this model (Table 5).

In model 3 (overall model with all variables identified in models 1 and 2), ISWT distance and NT-proBNP level were the only significant variables included in the model, all patients were included in this model.

Sensitivity analysis: Including the patient previously excluded with high residuals and Cook's distances in model 1, which made no difference to the included variables, but decreased the pseudo R^2. Running a model containing all variables p<0. 15 made no difference to the included variables but decreased the pseudo R^2.

Table 1: Sociodemographic characteristics and disease and health status factors at baseline of patients included in the analysis. N (%) unless otherwise stated.

Characteristic	All patients	HFrEF patients	HFpEF patients
	N=247 patients	N=198	N=49
Mean (SD) age (years)	70. 9 (10. 4)	70. 1 (10. 7)	74. 3 (8. 0)**
Female sex	70 (28)	43 (22)	27 (55)***
Median (IQR) BMI (kg/m2)	29. 2 (25. 9-33. 6)	25. 4 (28. 1-32. 2)	31. 2 (27. 4-36. 5)**
Employment status			
Retired	199 (81)	153 (77)	46 (94)
In employment or self-employment	31 (12)	30 (15)	1 (2)
Other	17 (7)	15 (7)	2 (4)
Ethnic origin			
White	236 (96)	187 (94)	49 (100)
Other	11 (4)	11 (6)	0 (0)

NYHA class			
I	40 (16. 2)	38 (19)	2 (4)
II	147 (59. 5)	117 (59)	30 (61)
III	59 (23. 9)	42 (21)	17 (35)
IV	1 (0. 4)	1 (1)	0 (0)
Median (IQR) LVEF (%)	35 (30-44)	34 (25-38)	62 (58-64)***
LVEF <45%	114 (46)	144 (73)	0 (0)
LVEF>45%	43 (17)	0 (0)	44 (90)
Unknown	59 (24)	54 (27)	5 (10)
Time since HF diagnosis (years)			
<1	74 (30)	65 (33)	9 (18)
1-2	47 (19)	34 (17)	13 (27)
>2	126 (51)	99 (50)	27 (55)
Live alone	66 (27)	44 (22)	22 (45)**
Current smoker	14 (6)	10 (5)	4 (8)
Cause of heart failure			
Ischaemic	115 (47)	91 (46)	24 (49)
Non-ischaemic	116 (47)	93 (47)	23 (47)
Unknown/Not classified	16 (6)	14 (7)	2 (4)
Trial site			
Truro	56 (23)	56 (29)	0 (0)
Gwent	44 (18)	44 (22)	0 (0)
Birmingham	48 (19)	48 (24)	0 (0)
York	50 (20)	50 (25)	0 (0)
Dundee	49 (20)	0 (0)	49 (100)
Comorbidities			
Diabetes mellitus	59 (24)	44 (22)	15 (31)
Myocardial infarction	70 (28)	61 (31)	9 (18)
Hypertension	113 (46)	82 (41)	31 (63)**
Stroke	29 (12)	26 (13)	3 (6)
Asthma	28 (11)	20 (10)	8 (16)

Chronic renal impairment	45 (18)	32 (16)	13 (27)*
Arthritis	107 (43)	77 (39)	30 (61)**
Atrial fibrillation or atrial flutter	118 (48)	99 (50)	19 (39)
COPD	27 (11)	17 (9)	10 (20)*
Depression	61 (25)	46 (23)	15 (31)
Median (IQR) Number of comorbidities	3 (2-5)	3 (2-5)	4 (3-6)
Medication			
ACE inhibitor/ARB	220 (89)	182 (92)	38 (78)*
Aldosterone antagonist	118 (48)	109 (55)	9 (18)***
Anticoagulant	114 (46)	96 (48)	18 (37)
Beta blocker	194 (79)	163 (82)	31 (63)**
Digoxin	39 (16)	33 (17)	6 (12)
Loop diuretic	170 (69)	127 (64)	43 (88)**
Nitrate	38 (15)	24 (12)	14 (29)**
Mean (SD) NT-proBNP (pg/ml)	1326. 82 (1696. 67)	1467. 58 (1809. 23)	758. 04 (952. 35)**
Mean (SD) ISWT (m) (N=232) peak	230. 4 (150. 8)	245. 3 (147. 7)	171. 9 (150. 4)**
Mean (SD) MLHFQ overall	32. 1 (23. 8)	30. 9 (23. 1)	36. 9 (26. 2)
Mean (SD) HADS			
Anxiety	5. 6 (4. 4)	5. 6 (4. 3)	5. 8 (4. 8)
Depression	4. 8 (3. 5)	4. 5 (3. 3)	5. 8 (4. 0)*
Mean (SD) HeartQoL global	1. 8 (0. 78)	1. 8(0. 74)	1. 5(0. 87)
Mean (SD) EQ-5D-3L	0. 70 (0. 26)	0. 73 (0. 24)	0. 58 (0. 30)***
Mean (SD) SCHFI			
Maintenance	54. 5 (15. 8)	55. 8 (15. 6)	49. 0 (15. 3)**
Management	40. 7 (22. 5)	41. 8 (23. 6)	38. 0 (19. 6)
Confidence	62. 7 (24. 3)	63. 6 (24. 3)	59. 2 (24. 1)

SD: Standard Deviation; IQR: Interquartile Range; BMI: Body Mass Index; NYHA: New York Heart Association; HF: Heart Failure; Hfref: Heart Failure With Reduced Ejection Fraction; Hfpef: Heart Failure With Preserved Ejection Fraction; LVEF: Left Ventricular Ejection Fraction; NT-Probnp: NT-Pro-Brain Natriuretic Peptide; COPD: Chronic Obstructive Pulmonary Disease; ACE: Angiotensin-Converting Enzyme; ARB: Angiotensin II Receptor Antagonist; ISWT: Incremental Shuttle Walk Test; MLHFQ: Minnesota Living With Heart Failure Questionnaire; HADS: Hospital Anxiety And Depression Scale; SCHFI: Self-Care Of Heart Failure Index.

*p<0. 05, **p<0. 01, ***p<0. 001 HFpEF vs. HFrEF groups.

Table 2: Mean (sd) PA mins/day of different intensity (inactivity, Light PA, MVPA) over all days, weekend days and week days.

	All Days	Weekend Days	Week Days
Bouted*			
Inactivity	1199. 6 (145. 7)	1214. 5 (150. 4)	1193. 6 (150. 9)***
Light PA	200. 0 (108. 0)	187. 9 (114. 1)	204. 8 (112. 2)***
MVPA	40. 5 (57. 7)	37. 6 (58. 7)	41. 6 (60. 5)
Unbouted†			
Inactivity	1075. 1 (110. 1)	1089. 3 (115. 7)	1069. 4 (113. 1)***
Light PA	189. 0 (46. 8)	183. 0 (50. 9)	191. 4 (48. 4)***
MVPA	175. 9 (86. 4)	167. 7 (86. 6)	179. 1 (89. 2)***
PA: Physical Activity; MVPA: Moderate-To-Vigorous Physical Activity.			

*Bouted: Activity Accumulated In Continuous 10 Minute Duration, †Unbouted: Activity Accumulated in Any Duration

*** p<0. 001 t-test weekend days vs. week days

Table 3: Summary of studies reporting MVPA levels of patients with heart failure.

Lead study author (year), country	N patients included	PA measurement method	Level of MVPA (minutes/ day)	% patients meeting PA guidelines*
Dontje (2014), Netherlands [2]	N=68, mean age 62 ± 14 years, 71% male, NYHA I-II 60%, NYHA III 40%	Accelerometer – Sense Wear Pro3 Armband worn for 2 consecutive weekdays	Mean 53 ± 54 min/day	56%
Yates (2017), USA [3]	N=29, median age 74 (range 61-85) years, 65% male, NYHA not reported	Modified 7 day physical activity recall questionnaire (self-report). Accelerometer – Actiheart worn for 7 consecutive days	Not reported (self-report) Median 0. 78 (range 0-8. 38) min/day (accelerometer)	38% (self-report) 0% (accelerometer)
Yavari (2017), Canada [4]	HFpEF N=53 , Median age 75 (IQR 66-81) years, 58% male, NYHA I-II 75%, NYHA III 23%. HFrEF N=16 Median age 72. 5 (IQR 63-81) years, 81% male, NYHA I-II 75%, NYHA III 25%	Accelerometer – Sense Wear Mini Armband worn for 4 consecutive days	HFpEF – median 12 (first quartile-third quartile 6-30) mins/day HFrEF – median 36 (first quartile-third quartile 6-84) mins/day	Not reported
Hedge (2017), USA, Canada, Brazil, Argentina [5]	N=1751 Mean age 68. 6 ± 9. 6 years 50% male NYHA I 6% NYHA II 59% NYHA III 34% NYHA IV 1%	Non-validated (self-report) question "What has the subject's usual pattern of exercise been during the past 2 weeks?" for 3 categories of activity (heavy, medium, light)	Not reported	11%

Present study	N=247, mean age 70. 9 ± 10. 4 years, 72% male, NYHA I 16% NYHA II 60% NYHA III-IV 24%	Accelerometer GENEActiv worn for 7 consecutive days	– mean 40. 5 ± 57. 7 min/day	45%

HF: Heart Failure; PA: Physical Activity; MVPA: Moderate-Vigorous Physical Activity; Hfpef: Heart Failure With Preserved Ejection Fraction; Hfref: Heart Failure With Reduced Ejection Fraction.

* i. e. 150 minutes per week MVPA or 30 min/day MVPA

Table 4: Comparison of multivariable linear regression models to predict minutes/week PA.

Multivariable model	Variables included in model (p<0. 05)	Unstandardized beta coefficient (95% CI)	t-statistic	Variable P-value	Model Adjusted R2 (p-value)
Socio-demographic	NYHA class	-133. 06 (-196. 85 to-69. 26)	-4. 11	<0. 001	0. 30 (<0. 001)
	Age	-13. 36 (-17. 25 to-9. 47)	-6. 77	<0. 001	
	BMI	-13. 50 (-20. 06 to-. 94)	-4. 05	<0. 001	
	Smoking history	84. 41 (19. 49 to 149. 32)	2. 56	0. 011	
	Employment status	-40. 94 (-81. 66 to-0. 22)	-1. 98	0. 049	
	constant	1786. 0 (1348. 48 to 2223. 52)	8. 04	<0. 001	
Exercise capacity and health status	ISWT peak	1. 2 (0. 94 to 1. 46)	9. 06	<0. 001	0. 27 (<0. 001)
	constant	-12. 62 (-85. 00 to 59. 76)	-0. 34	0. 73	
Socio-demographic, exercise capacity and health status*	ISWT peak	0. 84 (0. 57 to 1. 11)	6. 17	<0. 001	0. 36 (<0. 001)
	Age	-10. 55 (-14. 39 to-6. 71)	-5. 41	<0. 001	
	BMI	-11. 17 (-17. 54 to-4. 80)	-3. 45	0. 001	
	Smoking history	-65. 09 (2. 11 to-128. 07)	2. 04	0. 04	
	constant	1001. 40 (560. 16 to 1442. 63)	4. 47	<0. 001	

PA: Physical Activity; NYHA: New York Heart Association; BMI: Body Mass Index; NT-proBNP: NT-pro-brain Natriuretic Peptide; ISWT: Incremental Shuttle Walk Test

* All variables p<0. 05 from multivariate models 1 and 2.

Table 5: Comparison of multivariable logistic regression models to predict meeting PA guidelines.

Multivariable model	Variables included in model (p<0.05)	OR (95% CI)	z-statistic	Variable P-value	Model Pseudo R2 (p-value)
Socio-demographic	NYHA	0.39 (0.23 to 0.66)	-3.51	<0.001	0.18 (<0.001)
	NT-proBNP	1.00 (1.00 to 1.00)	-3.76	<0.001	
	Age	0.96 (0.93 to 0.99)	-2.90	0.004	

	BMI	0.93 (0.88 to 0.98)	-2.56	0.01	
	Constant	2235.99 (103.71 to 48209.83)	4.92	<0.001	
Exercise capacity and health status	ISWT peak	1.01 (1.00 to 1.01)	5.17	<0.001	0.11 (<0.001)
	constant	0.21 (0.12 to 0.38)	-5.18	<0.001	
Socio-demographic, exercise capacity and health status*	ISWT peak	1.01 (1.00 to 1.01)	5.00	<0.001	0.15 (<0.001)
	NT-proBNP	1.00 (1.00 to 1.00)	-3.07	0.002	
	Constant	0.34 (0.18 to 0.65)	-3.31	0.001	

PA: Physical Activity; NYHA: New York Heart Association; BMI: Body Mass Index; NT-proBNP: NT-pro-brain Natriuretic Peptide; ISWT: Incremental Shuttle Walk Test

* All variables p<0. 05 from multivariate models 1 and 2.

DISCUSSION

We found that some 45% of HF patients had objectively assessed levels of activity that meet current recommendations of at least 150 minutes per week of MVPA. HF patients undertook an average of 283. 3 min/week MVPA. However, the level of MVPA across patients ranged widely from a minimum of 0 mins/week to a maximum of 2626. 7 mins/week. Results also showed that HF patients have higher levels of MVPA and light PA, and lower levels of inactivity during the week compared to the weekends.

Our results differ somewhat from the majority of previous studies reporting very low levels of MVPA in HF patients [3-5]. However, these previous studies have relied on less accurate methods of measuring PA intensity, either using self-reported measures, or categorising accelerometer measured PA intensity using thresholds derived from studies of healthy adults. In this study, we used recently developed HF specific accelerometer intensity thresholds for MVPA to determine MVPA levels of HF patients. Using HF population specific accelerometer intensity thresholds provides a more accurate estimation of PA intensity as the increased energy cost of physical activities and limited exercise tolerance of HF patients are taken into account. Were we to have used the standard thresholds [16,17], it would have been concluded that HF patients undertook 33. 2 ± 74. 1 mins/week MVPA, and only 19 (8%) of patients met PA guidelines of 150 minutes of MVPA/week.

The three multivariable linear regression models, and three multivariable logistic regression models revealed that lower PA levels were associated with older patients, those with higher BMI, patients who were unemployed, higher NYHA classes, current smokers, higher NT-pro BNP levels, and lower ISWT peak distances. Since PA has been shown to have stronger associations with mortality in HF patients than measures of physical fitness [18], these variables may be useful for clinicians to identify those patients for whom PA promoting interventions may be most beneficial, and to tailor the information, PA and exercise plans provided, as recommended in current cardiac rehabilitation guidelines [19,20].

Our results build up on previous studies that showed PA is associated with a number of HF patient clinical characteristics [18, 21-25]. Previous studies have also shown that patients with lower PA levels had a higher burden of comorbidities [18]. In our univariate analyses, we found that apart from diabetes, the presence of other comorbidities in isolation were not associated with PA level. However, the total number of comorbidities was significantly associated with PA level. We found that the number of cardiorespiratory and metabolic comorbidities was associated with PA whereas the number of physical and musculoskeletal was not associated with PA. We also confirm that reduced PA is moderately associated with reduced exercise capacity in HF patients, with ISWT peak distance giving the highest univariate R^2 value.

Strengths and limitations

Our study has a number of strengths. We believe this to be the first study objectively assessed PA levels of HF patients using accelerometry and HF-specific intensity thresholds, That PA is measured and reported using a range of methods and metrics makes direct comparison across studies difficult [26]. It is common practice to estimate levels of MVPA from accelerometer data using previously reported PA intensity thresholds, or proprietary, private algorithms from commercially available activity monitors [15-17,27]. However, these thresholds and algorithms are based on studies using young, healthy adults, therefore may not be applicable to chronic disease or elderly populations [15,28]. As HF patients have limited exercise capacity, the energy cost of physical activities are higher, [15,29]so applying these intensity thresholds risks misclassification of PA of HF patients, which is highlighted by our previous comment on MVPA conclusions, had we used the standard intensity thresholds. Using improved MVPA assessment methods, with HF specific intensity thresholds as a potentially more accurate measure in this patient population should provide more precise understanding of the relationships between sociodemographics, exercise capacity, and health and disease status factors and PA levels of HF patients. This study also benefits from a relatively large HF patient sample from two clinical and recruited from a number of sites across UK [9,10].

Our study also has some limitations. Because of tolerability, dose of medication was not optimized in all patients. Although each of the multivariable models identified factors with significant associations with PA, over 50% of the variance in MVPA mins/week remained unexplained. Studies have identified motivation, exercise self-efficacy and fear of PA to be barriers to PA in HF patients although these were not assessed in this study [30,31]. Sedentary time has been shown to be a risk factor for poor outcomes in cardiac rehabilitation participants independent of PA level [32]. Inclusion of heart rate data has also been shown to improve accuracy of energy expenditure estimation [33]. Future studies may consider measurement of these additional factors in order to improve PA prediction models.

Although our study sample size was larger than previously reported studies of PA levels in HF patients and associations with various factors in HF [18, 25],the frequency count of some of the demographic variables was low such as ethnic minorities, presence of some comorbidities and taking particular medications. Given the cross-sectional nature of this study, the associations found between PA and sociodemographics, exercise capacity and health status factors cannot be implied to be causal. Longitudinal studies of objectively assessed PA in HF patients using population specific accelerometer intensity thresholds are needed to confirm the results of the present study.

CONCLUSIONS

Almost half of the HF patients in this study had objectively assessed levels of MVPA that met current PA recommendations of at least 150 minutes per week of MVPA. However, we also found the level of MVPA to range widely across patients in our study. Patients were less inactive and performed more PA during the week compared to the weekend. Multivariable regression analyses showed that patient age, BMI, employment status, NYHA class I-III, current smoking status, NT-pro BNP level, and ISWT peak distance to be strongly associated with the PA levels of HF patients. These factors may be useful to help inform clinicians and researchers how best to target subgroups of HF patients who could most benefit from interventions to increase their PA. Future accelerometry studies of PA in chronic disease populations need to consistently apply population specific thresholds when estimating MVPA.

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CONFLICT OF INTEREST

RT, HD, PD and MH were investigators in the REACH-HF study.

AUTHOR CONTRIBUTIONS

Each individual named as an author meets the uniform requirements of the Journal of Clinical and Experimental Cardiology criteria for authorship.

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RT, HD, PD and MH were investigators in the two REACH-HF trials included in this study. For the remaining authors none were declared. This study was supported by a University of Exeter Postgraduate Studentship Grant. REACH-HF was supported by the United Kingdom's National Institute for Health Research (NIHR) Programme Grants for Applied Research (grant number RP-PG-1210-12004).

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