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Accelerometer-Measured Daily Activity Levels and Related Factors in Patients with Heart Failure

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Keywords

Heart failure; physical activity; lifestyle behavior; attitude; accelerometer

Guidelines from the Heart Failure Society of America¹ recommend 30 minutes of moderate intensity exercise in a supervised setting five days per week, but this is difficult for patients with heart failure (HF). Symptoms of dyspnea and fatigue are noted as primary reasons for non-adherence to recommended exercise.^{2–4} Avoiding exercise due to presence of symptoms leads to further deconditioning and reduction in exercise capacity.⁵ Given the projections of a 46% increase in the prevalence of HF in the United States by the year 2030, it is critical to maximize beneficial pharmacologic and non-pharmacologic therapy.⁶ Research has demonstrated that exercise is an important non-pharmacologic adjunct to reduce HF-related hospitalizations and improve exercise capacity and health-related quality of life.^{7,8} Unfortunately, there is very little documentation of adherence to the recommended exercise guidelines for patients with HF. Therefore, the purpose of this study was to examine baseline data (accelerometer measured physical activity/exercise) from the Heart Failure Exercise And Resistance Training Camp (HEART Camp) trial, a federally funded (R01- HL112979) 18-month intervention study to promote adherence to exercise in patients with HF. Patients with either heart failure with reduced ejection fraction (HFrEF) or heart failure with preserved ejection fraction (HFpEF) were included in this trial.

Use of accelerometers has afforded researchers the ability to objectively examine both energy expenditure from daily physical activity and minutes of moderate or vigorous

intensity physical activity (MVPA). Self-report measures are used, but are recognized as being less consistent, with both higher and lower estimates of physical activity when compared to direct objective measurement.⁹ Many studies report physical activity and exercise habits in normal healthy adults; however, few studies actually document daily physical activity levels or MVPA minutes for individuals with HF.

The HEART Camp trial provides an excellent opportunity to examine baseline accelerometer measured physical activity levels in patients with HF. Specific aims for the present study were to:

1. Describe physical activity levels (accelerometer physical activity energy expenditure [PAEE] and number of minutes of MVPA per day) in patients with HF entering a longitudinal exercise trial.
2. Determine the proportion of individuals meeting the recommended levels of 150 minutes of MVPA per week.
3. Explore factors (demographic, clinical, psychological, physical functioning and previous exercise behavior) associated with physical activity.

Methods

Design and Setting

Patients were recruited from two urban medical centers in the Midwest. The study used a descriptive design to examine baseline data collected on 182 patients with HF who were recruited for the HEART Camp clinical trial. The study protocol has been previously described.¹⁰

Sample

Inclusion criteria were: (a) diagnosis of HF (Stage C chronic HF confirmed by echocardiography and clinical evaluation); (b) 19 years of age or greater; (c) able to speak and read English; (d) telephone access; and (e) stable pharmacologic therapy per guidelines for past 30 days. Exclusion criteria were: (a) clinical evidence of decompensated HF; (b) unstable angina pectoris; (c) myocardial infarction, coronary artery bypass surgery, or biventricular pacemaker less than 6 weeks prior; (d) orthopedic or neuromuscular disorders preventing participation in aerobic exercise and strength/resistance training; (e) participation in 3 times per week aerobic exercise in the past 8 weeks; (f) cardiopulmonary stress test results that preclude safe exercise training; (g) plans to move more than 50 miles from the exercise site within the next year; (h) peak oxygen uptake ($\dot{V}O_{2\max}$) in females > 21 ml/kg/min and in males > 24 ml/kg/min; and (i) pregnancy planned or current.

Procedure

Permission to conduct the study was obtained from the institutional review boards at the University of Nebraska Medical Center, Wayne State University and Henry Ford Health System. After written informed consent, subjects completed baseline survey questionnaires and the 6-minute walk test (6 MWT). Subjects were instructed by the research assistant about proper care and procedure for wearing the accelerometer and use of an activity diary

to record activities over this 7-day period. Subjects wore the accelerometer for 7 days on an elastic belt worn at the waist of the dominant hip. The accelerometer was returned after 7 full days of wear and the second 6 MWT was completed. The 7-day accelerometer data at baseline was used in this study.

Physical Activity Measures

Physical activity energy expenditure (PAEE) and number of minutes of MVPA were the variables obtained from the Actigraph (Model GT3X, Pensacola, FL) tri-axial accelerometer. All accelerometer data were downloaded and screened for wear time by a research assistant with specific training in use of accelerometers. Minimum valid wear time parameters for subject inclusion in the study were 4 days with at least 10 hours per day as recommended for measurement of physical activity¹¹. The Actilife software was used for data extraction by the research assistant to obtain PAEE and number of minutes of MVPA. Calculations were carried out for daily activity calories (PAEE) and minutes of MVPA. The Freedson, Melanson, and Sirard (1998) cut points,¹² which use data from the vertical axis alone, were used to estimate activity calories and minutes in each activity category. Averages across the valid days of wear were computed for activity calories and minutes of MVPA. For each valid day, minutes in moderate, vigorous, and very vigorous categories (MVPA) were summed and then averaged across days worn. The ActiGraph has established reliability and validity and is an acknowledged standard for field-based activity measurement.¹³

Other Measures

The 6MWT (submaximal measure of functional capacity) was used to assess the distance walked in 6 minutes.^{14,15} The standardized protocol from the American Thoracic Society¹⁵ was followed for the two walk tests 7 days apart. The furthest distance from these two walk tests was used as the measure in this study. The 6MWT has test-retest reliability of 0.90 and has criterion validity in relation to New York Heart Association (NYHA) Class (−0.43) in patients with HF.¹⁶

Four of the PROMIS-29 v1.0 subscales were used to measure anxiety, depression, fatigue, and physical function.¹⁷ The PROMIS item bank has established psychometrics in chronic heart disease patients, including patients with HF.¹⁸ Cronbach's reliability in this study for these four subscales was .92, .92, .95, and .88, respectively.

The Dyspnea Fatigue Index was used to measure the magnitude of task that evokes dyspnea or fatigue, the magnitude of pace at which the task is performed, and the associated functional impairment in general activities as a result of the symptoms.¹⁹ The ratings from each of these three categories are added to form a total score ranging from 0 to 12, with lower scores corresponding to greater impairment. Concurrent validity evidence has been reported with a correlation of 0.87 for the Medical Research Council measure of dyspnea.²⁰

The Attitudes Toward Physical Activity/Exercise measures positive (8 items) and negative attitudes (8 items) toward exercise.²¹ Higher scores indicate more positive or more negative attitude. Internal consistency reliability was reported as .82 for the negative attitudes subscale and .74 for the positive attitudes subscale. Cronbach's alpha in this study was .85 for negative attitudes and .77 for positive attitudes.

The Barriers Specific Self-Efficacy Scale (BARSE) is a 13 item scale used to measure subjects' perceived confidence to exercise 150 minutes per week in the presence of commonly identified barriers to participation.²² The scale is 0 (Not at all confident) to 100 (Completely confident), with higher scores indicating more confidence in the ability to exercise in spite of known barriers. The original instrument developed by McAuley²² has a reported reliability of 0.88 in older adults. Cronbach's alpha for this study was .93.

The Kansas City Cardiomyopathy Questionnaire (KCCQ) is a 23-item disease-specific measure of quality of life in HF.^{23,24} Subscales use a Likert scale with 5–7 response options and include the following: Total symptom score, physical limitation, self-efficacy, quality of life, social limitation, overall summary score, and clinical summary score. Scores for each subscale are standardized to range from 0 to 100, with higher scores indicating better health status, fewer symptoms, and greater disease-specific HRQoL. Test-retest reliability was 0.88 in outpatient stable patients with HF. A mean difference over time of 5 points on the KCCQ Overall Summary Scale is considered a clinically significant change in HF status.^{23,24}

Previous exercise behavior was an investigator developed measure. Subjects were asked to provide information concerning past exercise experience (type of exercise, times per week, length of time participated). Two investigators independently coded this information as “yes” if there was regular (3 times per week or more for at least one month) MVPA and “no” if there was no reported previous regular exercise of moderate intensity or above.

Data Analysis

Descriptive statistics (e.g., mean, median, standard deviation, frequency distributions, and percentages) were computed for study variables. Independent t-tests and Pearson correlation were used to examine factors associated with physical activity/exercise. All data were analyzed using SPSS version 20.0, and the significance level was set at $p < 0.05$.

Results

There were 204 subjects at baseline, but 22 of these subjects did not have complete data (i.e., four 10 hour days of valid wear time on the accelerometer) and were excluded from the analysis. Average age was 60.4 ± 11.5 years with a mean ejection fraction of $39.4 \pm 12.7\%$. There were 80 women (44%) and 76 Black/African-Americans (42%) (Table 1). Most participants (87.4%) had HF with reduced ejection fraction (HFrEF) and were classified as New York Heart Association Class II and III (91.8%). At baseline, accelerometer data indicated that subjects had 10.2 ± 10.5 minutes of MVPA per day. Physical activity energy expenditure (PAEE) was 304 ± 173 kilocalories (kcal) on average per day. There were 23 individuals (12.6%) who met the 150 minutes of MVPA per week.

To explore factors associated with physical activity levels in patients with HF, we focused on kilocalories of physical activity and number of MVPA minutes per day (Table 2). Of the two physical activity variables, the number of minutes of MVPA per day showed the most association with the demographic, psychosocial, and behavioral characteristics. As a group, males were significantly ($p < 0.01$) more active than females, and Caucasians averaged significantly ($p < 0.05$) more MVPA minutes than non-Caucasian (African-American).

NYHA Class II subjects had significantly ($p < 0.0005$) more MVPA as compared to Class III.

Ejection fraction was not related to physical activity levels, while the Charlson Comorbidity Index and the PROMIS-anxiety scale had significant negative relationships to MVPA (Table 3). Subjects with more MVPA had fewer symptoms (DFI and KCCQ), more positive attitudes toward exercise, greater exercise self-efficacy (BARSE), and better physical function (6-MWT and PROMIS physical function).

Discussion

In a diverse sample of patients with HF receiving evidence-based pharmacologic therapies who self-reported exercise two or less times per week over the past 8 weeks, participants spent little time (approximately 10 minutes) engaged in MVPA per day. Engagement in MVPA was significantly influenced by the following factors: demographic (age, gender, race); clinical (co-morbidity, NYHA Class, symptoms); psychological (anxiety, attitudes, self-efficacy for exercise); and physical function. Novel findings in this study relate to the influence of race, anxiety, and attitudes toward exercise which have not been reported in previous exercise studies in patients with HF.

Our finding from objective accelerometry of 10 minutes on average of MVPA per day is consistent with previously reported accelerometer based MVPA measurement in general cardiac patients where 8.4 ± 9.1 minutes of MVPA.²⁵ An additional study considered mean percentage of movement-related activities in a 24 hour day and found that subjects with HF had a lower percent activity in a 24 hour day ($3.9 \pm 1.5\%$) compared to age and gender matched controls ($11.3 \pm 3.0\%$).²⁶ Finally, a pedometer measuring steps per day showed a median number of steps in 84 patients with HF to be 3571 steps/day,²⁷ and, according to Tudor-Locke et al.²⁸ < 5000 steps per day defines a sedentary lifestyle.

Objective evaluation of adherence to the recommended 150 minutes per week of MVPA, specifically with the use of accelerometers, has been limited in patients with HF. The two studies that used accelerometers found only 2% achieving adherence to 150 minutes of MVPA per week²⁵ and none of the patients with HF met this recommendation.²⁹ Our results show a higher percentage (12.6%) of patients with HF meeting the guideline recommended 150 minutes of MVPA per week. While this was a trial of exercise adherence where one might expect a higher percentage of subjects that would meet guidelines, this study did exclude subjects who reported participating in 3 times per week aerobic exercise in the past 8 weeks. A possible explanation for our higher percentage adherence to guidelines may be that some of the individuals employed full time were actually in jobs that accumulated the 150 minutes per week of MVPA. This explanation is consistent with our finding of significantly higher levels of energy expenditure in those who were employed compared to those who were not.

Our observation of diminished levels of daily physical activity energy expenditure (304 ± 173 kcal/day) falls between the findings from doubly-labeled water measures by Toth et al.³⁰ for cachectic (269 ± 307 kcal/day) and non-cachectic (416 ± 361 kcal/day) patients with

HF. An additional study by Dontje et al. 2014 using accelerometer measures found comparable daily energy expenditure of 284 ± 302 kcal/day but with a higher variability level similar to the Toth et al. study.³¹ The large variability in energy expenditure from these comparison studies was explained by the marked decrease in physical activity for patients in the NYHA Class III (143 ± 159 kcal/d) compared to NYHA Class I–II (376 ± 338 kcal/d). Our distribution of subjects included more Class II (56%) as compared to Class III (36%) which could help to explain our finding of less variability in daily energy expenditure.

Our findings regarding factors associated with physical activity levels are consistent with previous studies in terms of the effects of age^{31–33}, gender^{34–36}, BMI^{31,34}, NYHA Class^{31–34}, exercise self-efficacy^{31,34,36} and functional capacity.³³ The significant effects of NYHA Class are consistent between this study and previously reported literature with NYHA Class III patients with HF having less activity compared to NYHA Class II.^{31,37} A marked decrease in physical activity for patients in the NYHA Class III (143 ± 159 kcal/d) compared to NYHA Class I–II (376 ± 338 kcal/d) has been noted.³¹ Additionally, sedentary behavior during the day among patients with NYHA Class I, II, and III was 61%, 64%, and 72%, respectively.³⁷ Given that NYHA Class evaluates symptoms in relation to functional activity level, it is not surprising that we found associations between baseline activity levels and symptoms and physical function.

To our knowledge there has been no study reporting differences in activity levels for Caucasian patients with HF versus non-Caucasian patients. Our study showed higher levels of physical activity in Caucasian patients with HF compared to non-Caucasian patients. This disparate finding calls for further investigation since physical activity is known to impact other health-related outcomes in patients with HF.

One particularly important finding from our study is the negative influence of anxiety on physical activity levels. A meta-analysis in incident CHD has demonstrated that anxiety increases risk of cardiac death independent of demographic variables, biological risk factors and health behaviors.³⁸ However, the impact of anxiety on actual physical activity levels has not been previously reported. Exercise has been shown to significantly reduce reported anxiety symptoms in a systematic review that included cardiovascular patients.³⁹ Additional study is needed to specifically examine anxiety both as a factor impacting physical activity levels and as an outcome of physical activity/exercise trials in patients with HF.

Finally, this study demonstrates the association of both positive and negative attitudes on actual levels of physical activity. Previous studies have highlighted the importance of exercise self-efficacy^{31,34,36} but have not specifically measured attitudes. Qualitative studies of patients with HF have shown that both intrinsic factors (e.g., self-identifying as active, fear of over exertion) and external expectations (e.g., professional interest and advice) influence physical activity levels, but there have been no quantitative studies reporting the relationship between attitudes and physical activity levels.⁴⁰ Additional study to examine the effects of interventional strategies such as cardiac rehabilitation or other innovative programs that might promote more positive and less negative attitudes toward exercise are needed. With only 2.3% of patients with HF participating in traditional cardiac rehabilitation⁴¹, there is an obvious need for more attention to professional provider referrals

to cardiac rehabilitation and advice concerning physical activity/exercise that might positively influence attitudes toward exercise.

These study findings are limited by the cross-sectional, correlational data that do not infer causation. Findings should also not be generalized beyond the study sample, as these were subjects from only two sites in the U.S. Additionally, this study population consented to participate in an exercise study and their behavior and attitudes toward exercise may not be representative of the HF population in general. Strengths of the study, however, reside in the diversity of the sample from both a race and gender perspective. In conclusion, a longitudinal exercise trial that enrolled patients with HF who reported no regular exercise, found, not surprisingly, that at baseline only 13% engaged in 150 minutes or more of MVPA per day, and level of activity was related to age, gender, race, symptom and functional status, anxiety levels, exercise self-efficacy and attitudes. Consistent with previous research, patients with HF are not meeting recommended guidelines for 150 minutes of MVPA per week, and more attention must be given to strategies to promote adherence to guidelines. Health disparities, attitudes toward exercise and anxiety must be further explored and recognized as significant factors that may impact MVPA in patients with HF.

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Table 1

Demographic and Baseline Clinical Characteristics (n=182)

	f (%)			
Gender				
Male	102 (56.0)			
Female	80 (44.0)			
Race				
Black/African-American	76 (41.8)			
Caucasian	103 (56.6)			
American Indian	3 (1.6)			
Marital status				
Married	99 (54.4)			
Not married	83 (45.6)			
Education				
High school or less	98 (53.8)			
Postsecondary degree	78 (42.9)			
Employed full-time				
Yes	32 (17.6)			
No	150 (82.4)			
HFrEF	159 (87.4)			
HFpEF	41 (22.5)			
NYHC Class				
I (mild)	14 (7.7)			
II (mild)	101 (55.5)			
III (moderate)	65 (35.7)			
IV (severe)	2 (1.1)			
	n	Range	Mean (SD)	Median
Age	182	21 – 85	60.4 (11.5)	61.0
BMI	182	20.8 – 65.3	34.9 (8.3)	33.5
pV02(ml/kg/min)	180	7.1 – 23.7	15.2(4.0)	15.1
Ejection fraction	182	13 – 76	39.4 (12.7)	40.0
Charlson Comorbidity Index	182	1 – 7	2.8 (1.6)	2.0
6-Minute Walk Test (meters)	180	119.1 – 605.0	396.9 (94.0)	397.4

Table 2

Relationship of Actigraphy Variables with Baseline Characteristics – Mean Comparisons

		Average daily kcal expended per kg		Average daily minutes		moderate intensity activity	
	n	Mean (SD)	Test statistic ^a (p-value)	Mean (SD)	Test statistic ^a (p-value)	Test statistic ^a (p-value)	
Gender							
Male	102	3.1 (1.7)	t = 1.324 (.187)	12.3 (12.0)		t = 3.220 (.002)	
Female	80	2.8 (1.5)		7.6 (7.6)			
Race							
Caucasian	103	3.0 (1.6)	t = -.367 (.714)	12.0 (10.4)		t = -2.557 (.011)	
Non-Caucasian	79	2.9 (1.7)		8.0 (10.3)			
Degree since high school							
No	98	3.0 (1.5)	t = .966 (.336)	10.1 (10.4)		t = .017 (.987)	
Yes	78	2.8 (1.7)		10.1 (10.9)			
Previous exerciser ^b							
No	67	3.0 (1.6)	t = -.170 (.865)	9.7 (10.1)		t = -.410 (.682)	
Yes	96	3.0 (1.7)		10.4 (10.0)			
Employed full-time							
No	150	2.9 (1.6)	t = -2.210 (.032)	9.6 (10.2)		t = -1.594 (.119)	
Yes	32	3.6 (1.7)		13.2 (11.6)			
NYHC							
I	14	3.3 (1.2)	F = 2.945 (.055)	13.0 (9.4)		F = 7.671 (.001) ^c	
II	101	3.2 (1.8)		12.4 (11.9)			
III/IV	67	2.6 (1.5)		6.4 (6.8)			
HFpEF							
No	23	2.8 (1.4)	t = -.573 (.571)	8.8 (9.9)		t = -.747 (.461)	
Yes	159	3.0 (1.7)		10.5 (10.6)			
HFpEF							
No	141	3.0 (1.7)	t = -.038 (.970)	10.3 (10.5)		t = .238 (.813)	
Yes	41	3.0 (1.5)		9.9 (10.9)			

^a t-tests using separate variance estimates; F-tests reported are standard ANOVA results, but same pattern was seen using Welch or Brown-Forsythe robust tests.

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^q Categorization was based on information provided in qualitative interviews, but not all participants could be classified.

^c Tamhane post hoc tests (not assuming equal variances) showed Class II significantly different from Class III/IV ($p < .0005$). Class I was not different from Class III/IV ($p = .069$) due to low power resulting from small Class I group size.

Table 3
Correlations between Physical Activity, Patient Characteristics, Clinical Variables, and Patient-Reported Outcomes

(2-tailed p-value)	Kcals/kg	Daily mins	moderate activity
Ejection fraction	-.080 (.281)	-.117 (.115)	
Age	-.316 (.000)	-.250 (.001)	
BMI	-.096 (.199)	-.108 (.148)	
Charlson Comorbidity Index	-.153 (.039)	-.183 (.013)	
Higher of two 6MWT	.389 (.000)	.464 (.000)	
Negative attitude toward PA	-.151 (.042)	-.136 (.067)	
Positive attitude toward PA	.178 (.016)	.156 (.035)	
Barriers Self-Efficacy Scale (BARSE)	.100 (.181)	.195 (.008)	
Dyspnea-Fatigue Index (DFI)	.085 (.255)	.152 (.041)	
KCCQ total symptom score	.081 (.278)	.184 (.013)	
KCCQ physical limitation	.149 (.045)	.224 (.002)	
KCCQ self-efficacy	.055 (.459)	.153 (.039)	
KCCQ quality of life	.029 (.699)	.141 (.058)	
KCCQ social limitation	.144 (.055)	.138 (.066)	
KCCQ overall summary score	.112 (.132)	.193 (.009)	
KCCQ clinical summary score	.121 (.104)	.217 (.003)	
PROMIS-29 anxiety	-.021 (.783)	-.157 (.034)	
PROMIS-29 depression	-.078 (.295)	-.133 (.074)	
PROMIS-29 fatigue	-.044 (.559)	-.098 (.187)	
PROMIS-29 physical function	.233 (.002)	.285 (.000)	