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Decreases in Daily Physical Activity Predict Acute Decline in Attention/Executive Function in Heart Failure

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Abstract

Background—Reduced physical activity (PA) may be one factor that contributes to cognitive decline and dementia in heart failure (HF). Yet, the longitudinal relationship between PA and cognition in HF is poorly understood due to limitations of past work, including single time assessments of PA. This is the first study to examine changes in objectively measured PA and cognition over time in HF.

Methods—At baseline and 12-weeks, 57 HF patients completed psychosocial self-report measures, a neuropsychological battery, and wore an accelerometer for seven days.

Results—At baseline, HF patients spent an average of 597.83 (SD = 75.91) minutes per day sedentary. Steps per day declined from baseline to the 12-week follow-up; there was also a trend for declines in moderate-vigorous PA. Regression analyses controlling for sex, HF severity, and depressive symptoms showed that decreases in light (p = 0.08) and moderate-vigorous (p = 0.04)

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daily PA emerged as strong predictors of declines in attention/executive function over the 12-week period, but not memory or language.

Conclusions—Reductions in daily PA predicted acute decline in attention/executive function in HF, but not memory or language. Modifications to daily PA may attenuate cognitive decline and prospective studies are needed to test this possibility.

Keywords

Physical activity; heart failure; cognitive function; accelerometry

Introduction

Heart failure (HF) affects >5 million American adults and leads to poor outcomes (e.g., premature death), including nearly a two-fold increased risk for Alzheimer's disease.[1,2] Early onset cognitive impairment can also be found in approximately 80% of persons with HF. [3] In particular, cross-sectional work shows that HF participants exhibit greater cognitive impairments in domains such as executive function, episodic memory, and language. [4,5] In addition to these cross-sectional findings, growing longitudinal work now links HF with accelerated cognitive decline executive function and episodic memory.[6,7] Indeed, the nature and trajectory of cognitive impairments are consistent with what is typically found in vascular and neurodegenerative (e.g., Alzheimer's disease) populations. Cognitive deterioration in HF is concerning because it can result in early death, loss of functional independence, and decreased quality of life.[8-10]

Contrary to expectations, longitudinal work examining cognitive changes in HF is not entirely consistent and there is evidence for improvements over time in this population.[11] Based on these findings, it is likely that cognitive decline in HF is dependent on a wide range of factors. Supporting this notion is past work that shows HF severity, and co-existing medical (i.e., hypertension, diabetes) and clinical (i.e., depression) factors are all key modifiers of poor neurocognitive outcomes in older adults with HF.[12]

The high levels of daily physical inactivity in HF may represent an important and modifiable risk factor for cognitive decline in this population. Patients with HF rarely engage in any form of meaningful physical activity (PA), as this patient population has been shown to spend >550 minutes per day being sedentary[13] and up to 44% of patients are active for <30 minutes each day.[14] Patients with HF often avoid physical activity as a result of exercise intolerance stemming from the inability of the heart to deliver sufficient blood to the peripheral muscles.[15] Consequently, HF patients experience discomfort during physical exertion due to symptoms such as dyspnea and fatigue.[15] Such discomfort can be negatively reinforcing and lead to avoidance of physical activity. Exercise intolerance is closely correlated with HF severity and participation in PA is thus likely to decline over time as HF severity worsens. This is concerning because physical inactivity is a sensitive indicator of traditional prognostic outcomes in HF (e.g., all-cause mortality, hospitalizations) [16] and these findings likely extend into the realm of cognitive function. For instance, recent work in HF patients demonstrates a cross-sectional relationship between reduced daily step count and cognitive dysfunction and also shows that lower baseline PA levels predict poorer

cognitive status at a later time point, with specific effects noted for attention/executive function.[13,17] Yet, work in other older adult samples shows that low levels of PA predicts risk for cognitive decline and Alzheimer's disease,[18] suggesting that PA in HF may also affect domains such as memory and language, cognitive hallmarks of aging and Alzheimer's disease.

A comprehensive literature review on PubMed using keywords such as "heart failure," "physical activity," "cognitive function," "accelerometer," "pedometer," "longitudinal," and "prospective" revealed that the literature on daily PA and cognition in HF is limited by single time assessments of PA. [13,17] Indeed, no study to date has simultaneously examined PA and cognitive function over time in patients with HF. The purpose of the current study was to examine whether changes in accelerometer measured PA predicted cognitive changes over a 12-week period in older adults with HF. Cognitive domains examined in this study included attention/executive function, memory, and language. As described above, these domains are commonly affected in HF, sensitive to PA outcomes, and dysfunction of these domains are also hallmarks of aging and neurological conditions (e.g., vascular cognitive impairment, mild cognitive impairment) that have been found to be associated with cardiac dysfunction.

Materials and Methods

Participants

The original sample consisted of 145 persons with HF that were recruited from a larger prospective National Institutes of Health (NIH)-fund study that examined the benefits of cardiac rehabilitation on neurocognitive function in patients with HF.[19] The larger NIH-funded study involved two groups of participants, including those that completed cardiac rehabilitation and those who did not. The current sample consisted of only those participants that did not complete the intervention. All participants were stable HF patients involved in routine cardiology care for cardiac dysfunction and recruited via flyers and/or face-to-face methods from outpatient cardiology clinics at Summa Health System, a mid-sized Midwestern hospital. Participants underwent identical assessments at baseline and follow-up time points, including, but not limited to, comprehension cognitive testing and accelerometer assessment. The current sample consisted of participants that had complete data at the baseline and the follow-up time point. In-turn, the original sample size of 145 was reduced to 57 after factors such as participant attrition, missing data, and invalid accelerometer data due to invalid wear or mechanical issues were taken into consideration. Those participants excluded were not different from participants of this study in terms of age, sex, education, HF severity, depression, attention/executive function, memory, language, or accelerometer wear time ($p > 0.05$ for all). These findings suggest that those excluded had similar levels of cognitive function and were just as likely as the current sample to wear the accelerometer as instructed.

The larger NIH study implemented strict inclusion/exclusion criteria that also applied to the current sample. For inclusion, participants must have been between the ages of 50-85 years, English speaking, and had a diagnosis of New York Heart Association (NYHA) HF class II, III, or IV at the time of enrollment. Potential participants were excluded for a history or

current diagnosis of a significant neurological disorder (e.g. dementia, stroke), head injury with ≥10 minutes loss of consciousness, severe psychiatric disorder (e.g. schizophrenia, bipolar disorder), substance abuse/dependence, and/or stage 5 chronic kidney disease. The Kent State University and Summa Health System Institutional Review Boards (IRB) approved the study procedures and all participants provided written informed consent prior to study enrollment.

Procedures

At baseline and 12-week follow-up, participants completed demographic, medical history, and psychosocial self-report measures, followed by a brief neuropsychological test battery to examine attention/executive function, memory, and language. Participants then received an accelerometer and were instructed to wear the device each day for 7 days from the moment they wake until they go to sleep. Additional details are provided below.

Measures

Physical Activity—A GT1M accelerometer (Actigraph, Pensacola, FL) was used to assess PA over a 7-day period. Participants were instructed in how to wear the accelerometer and also provided with a set of instructions for wear over the 7 days. Specifically, participants were instructed to place the accelerometer over the right hip, affixed to an elastic belt, and preferably worn under their waistbands. Daily step count was calculated by the accelerometer, and for the current population a daily step count between 0 and 2,499 represented sedentary, 2,500 to 4,999 as limited PA, and a 5,000 to 12,000 daily step count was considered to be physically active.[20] Step count was analyzed in conjunction with a diary entry of daily routine. Daily step count served as a global indicator of PA and was used to characterize the PA status of the sample.

To more thoroughly examine the impact of PA in the sample, the number of minutes the participants engaged in different lifestyle intensity activity levels each day was calculated. The activity levels were based on cutoff values from counts per minute that was derived by dividing total activity counts by total wear time. The levels of activity used in this study were as follows: sedentary (<100 counts per minute), light intensity (100-760 counts per minute), free-living moderate intensity (760 -5,724 counts per minute), and vigorous intensity activity (> 5,724 counts per minute).[21-23] A cut point of 760 counts per minute was used to capture free-living moderate intensity activities[23]and the cut point for vigorous activities was based on its correspondence to energy expenditures of greater than 6 METs.[22] Vigorous activities that correspond to >6METs include hiking, jogging, playing basketball or soccer. Light activity typically involves slow walking or standing while do light work, while more moderate intense activities include brisk walking, cleaning, and mowing the lawn.

A valid day of wear was considered greater than or equal to 10 hours per day and the activity data was restricted to participants with at least 3 valid days of accelerometer wear. Average number of minutes per waking hours of the day spent in each activity level was calculated for each participant, as well as average minutes per day of accelerometer wear. Of

note, bivariate correlations showed that cognitive function was not associated with accelerometer wear time in this sample ($p > 0.05$ for all).

Cognitive Function—A brief neuropsychological test battery was administered to assess cognitive function in multiple domains, including attention/executive function, memory, and language. All tests employed are commonly used in clinical settings and exhibit strong psychometric properties, including excellent validity and reliability. The domains and neuropsychological tests administered included:

Attention/Executive Function: Digit Symbol Coding, Letter Number Sequencing,[24,25] and the Frontal Assessment Battery (FAB).[26] These measures were combined into a single domain because they represent mental abilities mediated by similar brain regions (e.g., frontosubcortical) and for data reduction purposes in order to limit type 2 error.

Memory: The California Verbal Learning Test-Second Edition (CVLT-II).[27] An alternate version of the CVLT-II was administered at the follow-up time point to limit practice effects.

Language: Boston Naming Test[28]and Animal Fluency Test.[29]

Demographic, Clinical, and Medical Characteristics—Demographic characteristics and medical history were ascertained through participant self-report and corroborated by medical record review. In particular, participants first self-reported demographic information (e.g., age, sex) and prevalent co-existing medical conditions (e.g., diagnostic history of hypertension, diabetes, sleep apnea, myocardial infarction, elevated total cholesterol) via a medical history questionnaire. The Beck Depression Inventory-II (BDI-II),[30] a well-validated self-report measure of affective and somatic depressive symptoms, was used to assess and control for depressive symptomatology. A trained research assistant then completed a medical chart review to corroborate and supplement participant self-report. Left ventricular ejection fraction (LVEF) and New York Heart Association (NYHA) were also ascertained through the medical record review and were used to operationalize HF severity.

Statistical Analyses

Neuropsychological raw scores were converted to T-scores (a mean of 50 and a standard deviation of 10) using normative data that takes into account age; memory indices were also corrected for sex. The normative data used included a combination of Halstead-Reitan norms and/or specific test developer manuals. T-score conversion was performed to maintain consistency across scales, facilitate clinical interpretation, and account for the influence of demographic variables on cognitive outcomes. To characterize the baseline and 12-week cognitive status of the sample, a T-score 1.5 SD below the normative mean (i.e., <35) was reflective of cognitive impairment. To limit the number of analyses, composite scores were computed for attention/executive function, memory, and language that consisted of the mean of the T-scores of the neuropsychological measures that comprise their respective domains. There was one case with missing data on Digit Symbol Coding at the 12-week follow-up and the attention/executive function composite score in this instance

consisted of the mean of the remaining measures that comprise this domain. For PA variables, essentially no time was spent in vigorous activity (i.e. mean of 0.05 minutes per day) and thus a summary composite between moderate and vigorous activity was computed at each time point.

Repeated measures analyses of variance (ANOVA) examined longitudinal changes (i.e., baseline to 12-weeks) across the PA indices. Repeated measures analyses require significant power to detect medium size changes and thus no covariates were included in these analyses in order to preserve statistical power in the context of the relatively modest sample size. A series of multivariable hierarchical regression analyses were then performed to investigate the longitudinal relationship between each PA intensity level (i.e., light intensity, moderate-vigorous intensity) and cognitive function. The dependent variables included 12-week attention/executive function, memory, and language. Covariates were carefully selected in order to preserve statistical power. For all analyses, sex, LVEF and baseline and 12-week BDI-II total score were included as covariates. Sex and depression are sensitive to PA and cognitive outcomes and we sought to account for their variance.[31-33] HF severity was also included as a covariate because cognitive function worsens with increasing HF severity and as cardiac function deteriorates physical capacity becomes limited. 12-week BDI-II score was also included as a covariate given the tendency for depression to worsen over time in HF patients.[34] Because less is known about the effects of other medical variables on PA in HF, independent samples *t*-tests were performed between daily step count and diagnostic status of the most prevalent medical conditions (i.e., diabetes, hypertension, sleep apnea) in HF in order to determine other relevant medical covariates. For all models, covariates were entered in block 1. Block 1 also included baseline performance of the dependent cognitive variable. A difference score for each accelerometer intensity level was then calculated (i.e., 12-week PA – baseline PA) and individually entered in block 2. A single block with all PA indices included was not conducted due to statistical concerns that may arise and affect the reliability of the results, including multicollinearity.

Results

Sample Descriptives

The average age of the sample was 69.67 (SD = 10.34) years and 40.4% were female. A medical chart review showed that the average baseline LVEF of the sample was 41.52 (SD = 16.24) and 40.4% of the sample had an LVEF < 40. In addition, 19.5% of the sample also had an LVEF >55%, raising the possibility that a proportion of the sample had HF with preserved ejection fraction. Of the sample, 84.2% were NYHA class II, 14.0% class III, and 1.8% class IV. Of note, we included LVEF as a covariate (as opposed to NYHA) because it is a direct and more objective assessment of cardiac function. Comorbid medical conditions were common in the sample at baseline and these conditions remained prevalent at the 12-week follow-up. See Table 1. Independent samples *t*-tests revealed that baseline daily step count was not associated with diagnostic history of diabetes, hypertension, sleep apnea, myocardial infarction, or elevated total cholesterol ($p > 0.05$ for all). In terms of baseline cognitive function, elevated total cholesterol demonstrated a significant association with attention/executive function ($t(55) = -2.16$, $p = 0.04$), but no other domain. All other

medical comorbidities were not associated with baseline cognitive function in any domain ($p > 0.05$ for all). Taken together, given the overall lack of correlation between medical comorbidities and PA and cognitive function, medical comorbidities were not included as covariates.

Depressive Symptoms

The current sample had a mean baseline BDI-II of 7.81 (SD = 7.54) with a range of 0 to 34. According to standing BDI-II symptom cutoffs (i.e., 0-13 = minimal symptoms; 14-19 = mild depression; 20-28 = moderate depression; and 29-63 = severe depression), a majority of the participants (78.9%) exhibited minimal symptoms and only 2 participants reported severe depressive symptoms. However, bivariate correlations showed that decreased baseline daily steps was correlated with greater baseline depressive symptoms ($r(55) = -0.35$, $p = 0.01$) and there was a trend between 12-week daily step count and 12-week BDI-II total score ($r(55) = -0.24$, $p = 0.075$). These analyses justified inclusion of baseline and 12-week BDI-II as a covariate in the primary analyses.

Baseline and 12-Week Physical Activity

Table 2 presents baseline and 12-week descriptive statistics of PA in the current sample. At baseline, participants exhibited high rates of physical inactivity and spent, on average, 597.83 (SD = 75.91) minutes per day being sedentary. According to the daily step count cutoffs, 36.8% of the sample exhibited a daily step count considered to be sedentary, 43.9% demonstrated limited PA, and only 19.3% were physically active. Most time was spent in light activity with nearly all participants (with the exception of 1) spending >60 minutes per day in this category. Participants spent an average of 46.01 (SD = 34.58) minutes per day in moderate-vigorous activity with 24 participants spending < 30 minutes per day in this activity level. Of note, time spent in vigorous activity was almost absent, as 51 of the 57 participants spent no time at all in vigorous activity.

At the 12-week assessment, participants continued to exhibit high levels of sedentary behaviors [mean (SD) = 583.32 (62.91) minutes per day]. Repeated measures ANOVA revealed daily step count declined over the 12-week period [$F(1, 56) = 8.02$, $p = 0.01$]. Although not significant at the p = 0.05 level, there were also a trend for decline in moderate-vigorous PA [$F(1, 56) = 2.72$, $p = 0.105$]; slightly more participants (n = 25) fell below 30 minutes per day in this category at the follow-up. Light intensity PA also declined over time, but this did not approach significance [$F(1, 56) = 0.70$, $p = 0.41$]; similarly, all participants spent >60 minutes per day in this activity level at 12-weeks.

Baseline and 12-week Cognitive Function

See Table 1 for mean baseline cognitive test performance. At baseline, 14.0% of the sample exhibited a T-score < 35 on the attention/executive function composite, 10.5% on the memory composite, and only 5.3% on the language composite. Examination of the individual cognitive measures showed a greater prevalence of impairment, including 22.8% of participants with performances that were >1.5 SD below the normative mean on the Frontal Assessment Battery and 17.5% on the CVLT-II recognition task. Less than 10% of participants exhibited cognitive impairments (i.e., T-score < 35) on the other measures of

attention/executive function and memory. Likewise, no participants exhibited impairments on the Animal Fluency Test and only 8.8% of the sample performed below a T-score of 35 of the Boston Naming Test.

At the 12-week follow-up, impairments in cognitive function remained common. Specifically, 10.5% of the sample exhibited a T-score <35 on the attention/executive function composite, 12.3% on the memory domain, and 3.5% were below 35 on the language composite. Impairments were again most prevalent on the Frontal Assessment Battery (21.1%) and the CVLT-II recognition task (19.3%).

Directionality of overall cognitive change in this sample was variable, but there was evidence that a significant proportion of the sample exhibited decline. In terms of attention/executive function, 33.3% of the sample declined, 5.3% remained stable (e.g., <1 unit change), and 61.4% exhibited improvements. For memory, 47.4% declined, 10.5% remained stable, and 42.1% demonstrated improvements. In regards to language, 35.1% declined, 14.0% were stable, and 50.9% improved.

Physical Activity and Cognitive Function

Hierarchical regression analyses controlling for baseline attention/executive function, sex, baseline LVEF, and baseline and 12-week BDI-II revealed that the difference score for moderate-vigorous intensity PA ($\beta = 0.22$, $p = 0.04$) predicted changes in 12-week attention/executive function; there was also a trend for the difference score in light intensity PA ($\beta = 0.19$, $p = 0.08$). Specifically, decreases in PA from baseline to 12-weeks later predicted declines in attention/executive function. See Table 3. There were no other longitudinal associations between any of the actigraphy intensity indices with memory or language ($p > 0.05$ for all).

Discussion

Cognitive impairment and physical inactivity were prevalent in this sample of HF patients. Although growing attention has been paid to daily PA as a contributor to cognitive function in HF, the longitudinal relationship between these variables has been poorly understood due to limitations of past work. The current study extends the literature by showing that daily PA levels decreased over time in HF and such reductions predicted reduced attention/executive function in this population. Surprisingly, there was no longitudinal association between PA and memory and language abilities. Several aspects of these findings warrant further discussion.

We found that reductions in PA predicted acute decreases in attention/executive function in older adults with HF. Attention/executive dysfunction is indeed a cognitive hallmark in vascular populations and it is possible that declines in PA and accompanying physiological deficits in HF may be more sensitive to brain regions that mediate attention/executive functions (e.g., frontal lobes). For instance, the mechanisms for the adverse effects of reductions in PA on attention/executive worsening likely involve deterioration in health-related factors closely linked with disease status such as cardiovascular fitness levels. Lower daily PA is correlated with reduced physical fitness in HF[13] and fitness is a key modifier of

vascular health, including cerebral hemodyanmic function.[35,36] This is noteworthy, as cerebral blood flow is reduced in HF[37] and believed to be the primary culprit of cognitive impairment (via structural brain alterations) in this population, including heightened sensitivity to attention/executive function. [13, 38] In fact, declines in cerebral blood flow with increasing HF severity[39] may help explain past work that provides evidence for cognitive worsening in this population, including in executive function.[6,34] Reductions in PA may exacerbate the relationship between cerebral hypoperfusion and attention/executive function and further longitudinal work is much needed to determine the exact mechanisms by which physical inactivity contributes to cognitive changes in patients with HF.

The lack of PA effects on memory and language is a bit surprising, particularly given that memory test performance has been linked with cerebral blood flow in past studies among HF patients. [31] Our null findings are also inconsistent with past work that demonstrates an association between PA and memory function in older adults with mild cognitive impairment and Alzheimer's disease risk,[40] as well as with word fluency in older Latinos. [41] It is possible that the cognitive effects of PA may be distinct across participant populations. Alternatively, most of past work examining PA and cognition is cross-sectional and the longitudinal associations among PA, memory, and language may present with a different pattern. Memory and language changes in this study may have also lacked sensitivity to the short time period employed and longer time intervals may be necessary for these domains to be affected. Methodological limitations may also partially explain our lack of findings such as the relatively small sample size and/or insensitivity of the memory and language tests employed to PA. Clearly, prospective work is needed to clarify the differential effects of PA across the cognitive domains in HF.

There is reason to believe that increases in daily PA may lead to improved neurological outcomes in HF. There is already some support for this notion in past work that shows exercise training and cardiac rehabilitation (a combination of exercise training and psychoeducation on HF management) confers cognitive benefits in older adults with HF, including in attention/executive function.[42,43] Yet, the literature on exercise training and cognitive outcomes in HF remains in its infancy and limited by small sample sizes, lack of control groups, and relatively short follow-up periods. While exercise training is known to contribute to healthy brain aging to yield better cognitive outcomes (for a review, see Hayes et al., 2013),[44] it is also possible that simply being non-sedentary may be sufficient to promote cognition in HF. For instance, increases in moderate PA has been shown to improve endothelial function, a known correlate of cerebral blood flow levels, among a sample of sedentary older adults.[45] Likewise, fitness-derived benefits from just walking predict better brain outcomes in sedentary older adults, including increases in white matter integrity.[46] Prospective studies with extended follow-ups (e.g., 2-5 years) are much needed to determine whether increases in daily PA can attenuate the known risk for brain atrophy,[34] cognitive decline,[6,7] and severe neurological conditions such as Alzheimer's disease in HF.[2]

The current findings are limited in several ways. First, the current study lacked a control group. Moreover, the current sample was relatively modest in size and required judicious selection of covariates and therefore precluded inclusion of important medical (e.g., comorbidities, orthopedic problems) and/or demographic factors that may have been

potential confounds to our results. In particular, cardiac medications such as ACE inhibitors can improve cognitive outcomes and medication therapy (or lack thereof) may have interacted with PA to affect cognitive changes in this sample. Taken together, case-controlled prospective studies with longer follow-ups are much needed to account for extraneous variables, confirm the directionality of our findings, attenuate concerns regarding practice effects as a possible confound, and determine the long-term benefits of regular PA on cognitive function in HF.

Several other limitations deserve further discussion. Deterioration in cardiac function over time may also underpin the longitudinal association between PA and cognition in HF and larger studies that employ pre- and post-echocardiography to better characterize cardiac status and changes in HF severity (including examination of factors such as ICD placement) are needed to test this possibility. In addition, nearly no time was spent in vigorous PA and thus this domain was combined with moderate vigorous activity to avoid limited variability and range restriction. Higher levels of PA would be expected to yield greater cognitive benefits and larger studies in non-HF populations with control groups are needed to clarify the dose-response relationship between physical activity and cognitive function. Unexpectedly, daily step count declined over time, but did not predict cognitive worsening, and there were non-meaningful decreases in sedentary behaviors. It is possible that differences in wear time across the time points may help to explain these conflicting findings, as participants at the 12-week follow-up wore the accelerometer for significantly less time relative to baseline; although, it is noted that the derivation of each PA intensity level factored in wear time. Alternatively, daily step count may lack sensitivity to cognitive outcomes and light to moderate PA may be optimal. Future work in larger samples is needed to elucidate the differential effects of intensity varying PA on cognitive outcomes in HF. Lastly, it is possible that a small subset (19.5%) of the current sample had HF with preserved ejection fraction and further work is needed to determine the differential effects of PA on cognitive function across the varying cardiac subtypes.

Conclusions

In brief summary, HF patients exhibited low levels of PA and further decreases in PA over time predicted acute decline in attention/executive function in this population, but no association was noted for memory or language abilities. Prospective studies that employ extended follow-ups are needed to confirm these findings, elucidate mechanisms, and determine whether increases in daily PA can attenuate risk for cognitive decline and/or dementia in patients with HF.

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References

1. Go AS, Mozaffarian D, Roger VL, Benjamin EJ, Berry JD, Blaha MJ, et al. Heart disease and stroke statistics—2014 update: a report from the American Heart Association. Circulation. 2014; 129:e28–e292. [PubMed: 24352519]
2. Qiu C, Winblad B, Marengoni A, Klarin I, Fastbom J, Fratiglioni L. Heart failure and risk of dementia and Alzheimer's disease: a population-based cohort study. Arch Intern Med. 2006; 166:1003–1008. [PubMed: 16682574]
3. Hajduk AM, Lemon SC, McManus DD, Lessard DM, Gurwitz JH, Spencer FA, et al. Cognitive impairment and self-care in heart failure. Clin Epidemiol. 2013; 5:407–416. [PubMed: 24187511]
4. Pressler SJ, Subramanian U, Kareken D, Perkins SM, Graduz-Pizlo I, Sauve MJ, et al. Cognitive deficits in chronic heart failure. Nurs Res. 2010; 59:127–139. [PubMed: 20216015]
5. Harkness K, Demers C, Heckman GA, McKelvie RS. Screening for cognitive deficits using the Montreal cognitive assessment tool in outpatients ≥65 years of age with heart failure. Am J Cardiol. 2011; 107:1203–1207. [PubMed: 21310371]
6. Alwerdt J, Edwards JD, Athilingam P, O'Connor ML, Valdes EG. Longitudinal differences in cognitive functioning among older adults with and without heart failure. J Aging Health. 2013; 25:1358–1377. [PubMed: 24084526]
7. Hjelm C, Dahl A, Brostrom A, Martensson J, Johansson B, Stromberg A. The influence of heart failure on longitudinal changes in cognition among individuals 80 years of age and older. J Clin Nurs. 2012; 21:994–1003. [PubMed: 21883570]
8. Alosco ML, Spitznagel MB, Raz N, Cohen R, Sweet LH, Colbert LH, et al. Executive dysfunction is independently associated with reduced functional independence in heart failure. J Clin Nurs. 2014; 23:829–836. [PubMed: 23650879]
9. Zuccala G, Pedone C, Cesari M, Onder G, Pahor M, Marzetti E, et al. The effects of cognitive impairment on mortality among hospitalized patients with heart failure. Am J Med. 2003; 115:97–103. [PubMed: 12893394]
10. Pressler SJ, Subramanian U, Kareken D, Perkins SM, Graduz-Pizlo I, Sauve MJ, et al. Cognitive deficits and health-related quality of life in chronic heart failure. J Cardiovasc Nurs. 2010; 25:189–198. [PubMed: 20357665]
11. Stanek KM, Gunstad J, Paul RH, Poppas A, Jefferson AL, Sweet LH, et al. Longitudinal cognitive performance in older adults with cardiovascular disease: evidence for improvement in heart failure. J Cardiovasc Nurs. 2009; 24:192–197. [PubMed: 19390336]
12. Hjelm C, Brostrom A, Dahl A, Johansson B, Fredrikson M, Stromberg A. Factors associated with increased risk for dementia in individuals age 80 years or older with congestive heart failure. J Cardiovasc Nurs. 2014; 29:82–90. [PubMed: 23369853]
13. Alosco ML, Spitznagel MB, Cohen R, Raz N, Sweet LH, Josephson R, et al. Decreased physical activity predicts cognitive dysfunction and reduced cerebral blood flow in heart failure. J Neurol Sci. 2014; 339:169–175. [PubMed: 24581672]
14. Dontje ML, van der Wal MH, Stolk RP, Brugemann J, Jaarsma T, Wijtvliet PE, et al. Daily physical activity in stable heart failure patients. J Cardiovasc Nurs. 2014; 29:218–226. [PubMed: 23416939]
15. Pina IL, Apstein CS, Balady GJ, Belardinelli R, Chaitman BR, Duscha BD, et al. Exercise and heart failure: A statement from the American Heart Association Committee on Exercise, Rehabilitation, and Prevention. Circulation. 2003; 107:1210–1225. [PubMed: 12615804]
16. O'Connor CM, Whellan DJ, Lee KL, Keteyian SJ, Cooper LS, Ellis SJ, et al. Efficacy and safety of exercise training in patients with chronic heart failure: HF-ACTION randomized controlled trial. JAMA. 2009; 301:1439–1450. [PubMed: 19351941]
17. Fulcher KK, Alosco ML, Miller L, Spitznagel MB, Cohen R, Raz N, et al. Greater physical activity is associated with better cognitive function in heart failure. Health Psychol. 2014; 33:1337–1443. [PubMed: 24467254]
18. Buchman AS, Boyle PA, Yu L, Shah RC, Wilson RS, Bennett DA. Total daily physical activity and the risk of AD and cognitive decline in older adults. Neurology. 2012; 78:1323–1329. [PubMed: 22517108]

19. Alosco ML, Spitznagel MB, Cohen R, Sweet LH, Josephson R, Hughes J, Rosneck J, Gunstad J. Cardiac rehabilitation is associated with lasting improvements in cognitive function in older adults with heart failure. Acta Cardiol. 2014; 69:407–414. [PubMed: 25181916]
20. Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps/day in U.S. adults. Med Sci Sports Exerc. 2009; 41:1384–1391. [PubMed: 19516163]
21. McLoughlin MJ, Colbert LH, Stegner AJ, Cook DB. Are women with fibromyalgia less physically active than health women? Med Sci Sports Exerc. 2011; 43:905–912. [PubMed: 20881881]
22. Freedson P, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc., accelerometer. Med Sci Sports Exerc. 1998; 30:777–781. [PubMed: 9588623]
23. Matthews CE. Calibration of accelerometer output for adults. Med Sci Sports Exerc. 2005; 37:S512–S522. [PubMed: 16294114]
24. Wechsler, D. Wechsler Adult Intelligence Scale—Third edition (WAIS-III). Psychological Corporation; San Antonio, TX: 1997.
25. Wechsler, D. Wechsler Memory Scale—Third edition (WMS-III). Psychological Corporation; San Antonio, TX: 1997.
26. Dubois B, Slachevsky A, Litvan I, Pillon B. The FAB: a frontal assessment battery at bedside. Neurology. 2000; 55:1621–1626. [PubMed: 11113214]
27. Delis, D.; Kramer, J.; Kaplan, E.; Ober, B. California Verbal Learning Test-Second Edition: Adult Version. Psychological Corporation; San Antonio (TX): 2000. Manual
28. Hawkins KA, Sledge WH, Orleans JE, Quinlan DM, Rakfeldt J, Huffman RE. Normative implications of the relationship between reading vocabulary and Boston Naming Test performance. Arch Clin Neuropsychol. 1993; 8:525–537. [PubMed: 14591992]
29. Morris J, Heyman A, Mohs R, Hughes JP, van Belle G, Fillenbaum G, Mellits ED, Clark C. The consortium to establish a registry for Alzheimer's disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimers disease. Neurology. 1989; 39:1159–1165. [PubMed: 2771064]
30. Beck, AT.; Steer, RA.; Brown, GK. Beck Depression Inventory (2nd ed.). The Psychological Corporation; San Antonio, TX: 1996.
31. Alosco ML, Spitznagel MB, Raz N, Cohen R, Sweet LH, Garcia S, et al. The interactive effects of cerebral perfusion and depression on cognitive function in older adults with heart failure. Psychosom Med. 2013; 75:632–639. [PubMed: 23873714]
32. Lin YC, Yeh MC, Chen YM, Huang LH. Physical activity status and gender differences in community-dwelling older adults with chronic disease. J Nurs Res. 2010; 18:88–97. [PubMed: 20592654]
33. Alosco ML, Spitznagel MB, Miller L, Raz N, Cohen R, Sweet LH, et al. Depression is associated with reduced physical activity in persons with heart failure. Health Psychol. 2012; 31:754–762. [PubMed: 22924448]
34. Almeida OP, Garrido GJ, Etherton-Beer C, Lautenschlager NT, Arnolda L, Alfonso H, et al. Brain and mood changes over 2 years in healthy controls and adults with heart failure and ischaemic heart disease. Eur J heart Fail. 2013; 15:650–658. [PubMed: 23388090]
35. MacIntosh BJ, Swardfager W, Crane DE, Ranepura N, Saleem M, Oh PI, et al. Cardiopulmonary fitness correlates with regional cerebral grey matter perfusion and density in men with coronary artery disease. PLoS One. 2014; 9:e91251. [PubMed: 24622163]
36. Ainslie PN, Cotter JD, George KP, Lucas S, Murrell C, Shave R, et al. Elevation in cerebral blood flow velocity with aerobic fitness throughout healthy human ageing. J Physiol. 2008; 586:4005–4010. [PubMed: 18635643]
37. Gruhn N, Larsen FS, Boesgaard S, Knudsen GM, Mortensen SA, Thomsen G, et al. Cerebral blood flow in patients with chronic heart failure before and after heart transplantation. Stroke. 2001; 32:2530–2533. [PubMed: 11692012]
38. Alosco ML, Brickman AM, Spitznagel MB, Garcia SL, Narkhede A, Griffith EY, et al. 2013; 19:E29–E34.
39. Loncar G, Bozic B, Lepic T, Dimkovic S, Prodanovic N, Radojicic Z, et al. Relationship of reduced cerebral blood flow and heart failure severity in elderly males. Aging Male. 2011; 14:59–65. [PubMed: 20873985]

40. Tanigawa T, Takechi H, Arai H, Yamada M, Nishiquchi S, Aoyama T. Effect of physical activity on memory function in older adults with mild Alzheimer's disease and mild cognitive impairment. Geriatr Gerontol Int. 2014; 14:758–762. [PubMed: 24646035]

41. Wilbur J, Marquez DX, Fogg L, Wilson RS, Staffileno BA, Hoyem RL, Morris MC, Bustamante EE, Manning AF. The relationship between physical activity and cognition in older Latinos. J Gerontol B Psychol Sci Soc Sci. 2012; 67:525–534. [PubMed: 22321957]

42. Alosco ML, Spitznagel MB, Cohen R, Sweet LH, Josephson R, Hughes J, et al. Decreases in BMI After Cardiac Rehabilitation Predict Improved Cognitive Function in Older Adults with Heart Failure. J Am Geriatr Soc. 2014; 62:2215–2216. [PubMed: 25413196]

43. Tanne D, Freimark D, Poreh A, Merzeliak O, Bruck B, Schwammenthal Y, et al. Cognitive function in severe congestive heart failure before and after an exercise training program. Int J Cardiol. 2005; 103:145–149. [PubMed: 16080972]

44. Hayes SM, Hayes JP, Cadden M, Verfaellie M. A review of cardiorespiratory fitness-related neuroplasticity in the aging brain. Front Aging Neurosci. 2013; 5:31. [PubMed: 23874299]

45. Suboc TB, Strath SJ, Dharmashankar K, Coulliard A, Miller N, Wang J, et al. Relative importance of step count, intensity, and duration on physical activity's impact on vascular structure and function in previously sedentary older adults. J Am Heart Assoc. 2014; 3:e000702. [PubMed: 24572255]

46. Voss MW, Heo S, Prakash RS, Erickson KI, Alves H, Chaddock L, et al. The influence of aerobic fitness on cerebral white matter integrity and cognitive function in older adults: results of a one-year exercise intervention. Hum Brain Mapp. 2013; 34:2972–2985. [PubMed: 22674729]

Highlights

- Physical inactivity was common and worsened over time in persons with heart failure
- Decreases in physical activity predicted declines in attention/executive function
- Physical activity interventions may attenuate cognitive decline in heart failure

Table 1

Baseline Sample Characteristics

Demographic Characteristics	**% or mean (SD)**
Age, mean (SD) years	69.67 (10.34)
Sex (% Women)	40.4
Race (% Caucasian)	84.2
Education, mean (SD) years	13.35 (2.53)
Medical and Clinical Characteristics	% or Mean (SD)
Ejection Fraction (% mean (SD))	41.52 (.24)
New York Heart Association Class (%II, III, IV)	84.2%, 14.0%, 1.8%
Hypertension (%)	64.9
Diabetes (%)	22.8
Sleep Apnea (%)	21.1
Elevated Total Cholesterol (%)	63.1
Myocardial Infarction (%)	54.4
Beck Depression Inventory-II	7.81 (7.54)
Cognitive Function	Mean (SD) raw score; T-score
Digit Symbol Coding	49.23 (13.82); 47.51 (8.73)
Frontal Assessment Battery	15.79 (2.31); 43.41 (21.73)
Letter Number Sequencing	8.77 (2.30); 50.65 (8.93)
CVLT-II Long Delayed Free Recall	8.07 (3.63); 47.19 (10.57)
CVLT-II Recognition	13.40 (2.79); 44.04 (13.41)
Boston Naming Test	54.05 (4.75); 50.36 (12.21)
Animal Fluency	19.61 (5.14); 55.53 (11.57)

Table 2

Physical Activity Descriptives

Activity Level	Baseline Mean (SD)	12-Weeks Mean (SD)	F-statistic	p
Wear Time	831.43 (71.18)	807.24 (75.39)	6.26	0.02
Daily Step Count	3461.12 (1821.05)	3118.38 (1702.58)	8.02	0.01
Sedentary Time	597.83 (75.91)	583.32 (62.91)	2.44	0.12
Time in Light Intensity	187.59 (55.70)	182.78 (57.88)	0.70	0.41
Time in Moderate-Vigorous Intensity	46.01 (34.58)	41.14 (29.85)	2.72	0.11

Note. Values for intensity levels are minutes per day.

Table 3

Reductions in Physical Activity Predict Cognitive Decline

	12-Week Attention/Executive Function		12-Week Memory		12-Week Language	
	β	SE b	B	SE b	β	SE b
Block 2 Model 1						
Moderate-vigorous Intensity	0.22*	0.04	−0.04	0.11	0.05	0.07
Adjusted R^2	0.52		0.38		0.68	
F for ΔR^2	4.30*		0.11		0.43	
Block 2 Model 2						
Light Intensity	0.19	0.02	−0.11	0.03	−0.05	0.02
Adjusted R^2	0.51		0.39		0.68	
F for ΔR^2	3.13 (p = 0.08)		0.87		0.31	

Note.

** $p < 0.01$; Moderate-vigorous intensity and light intensity are difference scores between the time points; for all models, block 1 included sex, left ventricular ejection fraction, baseline Beck Depression Inventory-II, 12-week Beck Depression Inventory-II, and baselineperformance of the respective cognitive domain.

* $p < 0.05$;