Reduced Physical Fitness in Patients With Heart Failure as a Possible Risk Factor for Impaired Driving Performance

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MeSH TERMS

- automobile driving
- cognition disorders
- computer simulation
- heart failure
- physical fitness
- risk factors

OBJECTIVE. Reduced physical fitness secondary to heart failure (HF) may contribute to poor driving; reduced physical fitness is a known correlate of cognitive impairment and has been associated with decreased independence in driving. No study has examined the associations among physical fitness, cognition, and driving performance in people with HF.

METHOD. Eighteen people with HF completed a physical fitness assessment, a cognitive test battery, and a validated driving simulator scenario.

RESULTS. Partial correlations showed that poorer physical fitness was correlated with more collisions and stop signs missed and lower scores on a composite score of attention, executive function, and psychomotor speed. Cognitive dysfunction predicted reduced driving simulation performance.

CONCLUSION. Reduced physical fitness in participants with HF was associated with worse simulated driving, possibly because of cognitive dysfunction. Larger studies using on-road testing are needed to confirm our findings and identify clinical interventions to maximize safe driving.

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As many as 75% of people with heart failure (HF) are dependent on others for performance of important instrumental activities of daily living (IADLs) such as shopping (Norberg, Boman, & Löfgren, 2008). Recent research has raised the possibility that many people with HF may be unfit to drive. For example, a history of heart disease has been correlated with driving cessation, and people with HF have exhibited more errors on driving simulation scenarios relative to healthy control participants (Alosco et al., 2012; Forrest, Bunker, Songer, Coben, & Cauley, 1997).

Risk factors for impaired driving performance in HF are poorly understood. Cognitive dysfunction is one likely contributor to reduced driving ability in this population. HF is associated with increased risk for Alzheimer's disease (Qiu et al., 2006), and approximately 25% of people with HF exhibit milder forms of impairment in cognitive domains important for safe driving, including attention, psychomotor speed, and executive function (Pressler et al., 2010). Indeed, deficits in these domains have been linked with more mistakes on a driving simulation task among older adults with HF (Alosco et al., 2012) and poorer driving abilities in many other patient and healthy samples (Carr & Ott, 2010; Rizzo, 2011).

Although not previously studied, other noncognitive clinical problems that accompany cardiac dysfunction may increase risk for impaired driving performance. In particular, poor physical fitness is a primary symptom of HF (Wegrzynowska-Teodorczyk et al., 2010) that is believed in part to underlie

cognitive dysfunction and impaired IADLs in HF (Alosco, Spitznagel, Cleveland, & Gunstad 2013; Alosco et al., 2014). There is reason to believe that reduced physical fitness may contribute to unsafe driving in people with HF. For example, decreased physical fitness has been associated with worse performance in driving-relevant cognitive domains (e.g., executive function; Alosco et al., 2012) and reduced self-reported independence in driving among people with HF (Alosco et al., 2014). Exercise, a promoter of physical fitness, has been shown to be an important modifier of on-road driving performance in healthy older adults (Marmeleira, Godinho, & Fernandes, 2009; Marottoli et al., 2007).

To our knowledge, no study has examined the impact of physical fitness on objectively measured driving performance in people with HF. The purpose of this study was to investigate the association of physical fitness, cognitive function, and driving simulation performance among older adults with HF. We hypothesized that poor physical fitness secondary to HF would be associated with worse simulated driving performance, possibly because of its negative impact on cognitive function.

Method

Research Design

This cross-sectional study examined physical fitness, cognitive function, and driving simulation performance in people with HF. We administered a neuropsychological test battery to assess global cognition, attention and executive function, and psychomotor speed. All participants completed the 2-minute step test (2MST), a physical fitness test, and completed a brief driving simulation task. The Kent State University institutional review board approved the study procedures, and all participants provided written informed consent before study enrollment.

Participants

A sample of HF participants was randomly recruited from an ongoing National Institutes of Health (NIH) study examining neurocognitive function in older adults with HF. All participants in the NIH study were screened for neurological and psychiatric conditions that might influence cognitive function or restrict their performance of IADLs. Strict inclusion and exclusion criteria were implemented for the current study. Inclusion criteria were age of 50–85 yr, English as a primary language, and diagnosis of New York Heart Association Class II, III, or IV HF at the time of enrollment. Additional inclusion criteria were a valid driver's license and current participation in driving. Potential participants were excluded if they had a history of neu-

rological disorder (e.g., dementia, stroke, multiple sclerosis), head injury with >10 min loss of consciousness, severe psychiatric disorder (e.g., schizophrenia, bipolar disorder), past or current substance abuse or dependence, or Stage 5 chronic kidney disease.

Measures

Driving Simulation. We used the STISIM Driving Simulator (Build 2.08.03, Systems Technology, Inc., Hawthorne, CA) to assess driving ability. This computer-based interactive driving simulator software package is configured to control three elements: (1) a high-fidelity steering wheel with two analog levers for left and right turn indication, (2) an analog pedal set consisting of a brake pedal and another pedal for gas, and (3) a 46-in. high-definition LCD television at an average presentation distance of 4.5 ft. The STISIM driving software was used to devise the driving scenarios that all participants completed.

Participants first completed a standardized practice scenario with the driving simulation technology to become comfortable with the simulator. The practice scenario was nearly 3 mi, lasted approximately 15 min, and assessed driving performance in multiple settings, including city, country, and highway environments.

Participants then completed the Kent Multidimensional Assessment Driving Simulation (K-MADS) driving scenario, which is distinct from the practice simulation. All participants were instructed to drive as they normally would on the road; they followed a predetermined course with standard road and traffic signs (e.g., speed and stop signs). The K-MADS is a roughly 7-mi driving scenario that takes approximately 20–25 min to complete. It has demonstrated good psychometric properties. Among an adult population, test–retest indexes at 2 wk were $r = .68$ – $.83$, and performance has been correlated with history of traffic violations in real-world driving at $r = .76$. The K-MADS measures driving performance in a number of environments including a quiet suburb, a country road, a small town, and a busy city, each with its own speed limit restrictions and lane configurations. For a full description and review of the K-MADS course, refer to Alosco and colleagues (2012). The K-MADS automatically tracks several indexes of driving performance, including total collisions, number of stop signs missed, number of center line crossings, number of off-road excursions (e.g., steering off of the road onto nonroad land), percentage of time over the speed limit, and percentage of time out of lane.

Physical Fitness. All participants completed the 2MST to assess physical fitness (Jones & Rikli, 2002). The 2MST requires participants to step in place for 2 min.

Participants lift their knees to a marked target on the wall set at the midpoint between the kneecap and the crest of the iliac. Greater step count indicates better physical fitness. Average step count for healthy older men ages 50–85 ranges from 71 to 115 and for women from 60 to 107 steps (Jones & Rikli, 2002). The 2MST is a valid measure of physical fitness in older adults. It has been correlated with metabolic equivalents and demonstrates sensitivity to cognitive outcomes in people with HF (Alosco et al., 2012; Garcia et al., 2013).

Neuropsychological Battery. A brief battery of neuropsychological tests was administered to assess multiple domains of cognitive function. The Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) was used to assess global cognitive function. Scores on the Trail Making Test Parts A and B (Reitan & Wolfson, 1993), Digit Symbol Coding (Dikmen, Heaton, Grant, & Temkin, 1999), Letter–Number Sequencing (Wechsler, 1997), and Grooved Pegboard dominant and nondominant hand (Dikmen et al., 1999; Klove, 1963) provided a composite measure of the domains of attention, executive function, and psychomotor speed. All neuropsychological tests in the current study demonstrate strong psychometric properties and were chosen because they operationalize cognitive domains that demonstrate sensitivity to driving abilities (Carr & Ott, 2010; Rizzo, 2011).

Demographics and Medical History. All participants completed a self-report questionnaire requesting demographic information (e.g., age, sex, race) and medical history (e.g., hypertension, diabetes, sleep apnea). A trained research assistant then completed a medical record review to corroborate and supplement participants' self-report and to ascertain participants' left ventricular ejection fraction (LVEF), a fraction of blood pumped from the left ventricle in each heartbeat.

Data Collection

A trained research assistant under the supervision of a licensed clinical neuropsychologist (John Gunstad) collected all data. The licensed neuropsychologist trained the research assistant on the formal procedures for cognitive test administration and scoring using standardized protocols. The research assistant was also trained on the protocol for assessment of physical fitness using the 2MST. The neuropsychologist and research assistant met regularly to ensure minimal deviation from the standardized test protocols.

Participants completed the driving simulation task under the supervision of an advanced graduate student (Michael Alosco) with monitoring by a licensed neuropsychologist (John Gunstad). Administration and scoring for

the driving simulation task are standardized; participants follow the route and instructions provided by the driving simulation technology, and the STISIM software automatically derives performance indexes (e.g., number of collisions, stop signs missed). All study procedures were performed in the confines of a medical examination room.

Data Analysis

LVEF data were missing for 2 participants and thus simple mean imputation was used to estimate their LVEF to retain these participants in all analyses. The neuropsychological measures of attention, executive function, and psychomotor speed were converted to age-adjusted *T* scores using clinical normative data. A *T* score <35 reflects clinically meaningful impaired test performance. The composite score of attention, executive function, and psychomotor speed was computed from the mean *T* scores of the measures. One participant's Letter–Number Sequencing data were missing; the participant was retained in all analyses, but the cognitive composite consisted of the mean of the remaining measures with complete data. Independent samples *t* tests and bivariate correlations were used to examine the associations of medical and demographic factors with driving simulation and 2MST performance.

A series of partial correlation analyses were performed to examine the associations among the 2MST, cognitive function (i.e., MMSE, composite score of attention, executive function, psychomotor speed), and the driving simulation indexes. Covariates were carefully selected and limited for each analysis to preserve statistical power. LVEF, age, sex, and education were controlled for in all analyses examining cognitive function to account for the well-known effects of HF severity and demographic factors on cognitive outcomes. LVEF was included as the only covariate in analyses examining 2MST and driving simulation performance because of the close association between HF severity and physical fitness. However, we also examined correlations between medical and demographic variables and 2MST scores and driving performance to help identify additional covariates. Because of the exploratory nature of this study and the modest sample size, Bonferroni corrections were not made for multiple comparisons.

Results

Sample Size and Characteristics

We recruited 21 participants with HF from the larger NIH-funded study to complete the driving simulation task. We randomly contacted potential participants by phone to participate in the driving study and screened all participants

who expressed interest for study eligibility. Among the 21 participants who enrolled in the study, 2 were excluded because of failure to meet inclusion and exclusion criteria on further assessment during the study session; these participants did not have an active driver's license or were not currently driving. In addition, 1 participant withdrew from the study. Thus, the final sample included 18 people with HF who had complete driving simulation data. Average age was 67.72 yr (standard deviation [*SD*] = 8.56), and 11.1% were female. Medical chart review revealed that the sample had an average LVEF of 39.38 (*SD* = 12.45); normative LVEF in healthy people is >55% (American Heart Association, 2013). Table 1 provides participants' demographic and medical information.

Driving Simulation Performance

The 18 participants committed frequent errors on the driving simulation task. They averaged a total of 2.00 (*SD* = 1.28) collisions and 4.83 (*SD* = 6.39) off-road excursions (Table 2); 55.5% missed at least one stop sign, and 77.9% had ≥3 center line crossings. Of the sample, 61.1% were >65 yr old; however, those age >65 exhibited worse performance on only one of the driving simulation indexes: number of off-road excursions, $t(10.80) = 2.83, p = .02$. Bivariate correlations and independent samples *t* tests showed that education, sex, and diagnostic history of hypertension, diabetes, and sleep apnea were not associated with driving simulation performance ($p > .05$ for all).

Physical Fitness and Driving Simulation

The 18 participants averaged 85.56 (*SD* = 24.30) on the 2MST, indicating poor physical fitness relative to normative data; 27.8% scored <70 steps over the 2-min period. Bivariate correlations and independent-samples *t* tests showed that 2MST scores were not associated with age, sex, education, or diagnostic history of hypertension, diabetes, or sleep apnea ($p > .05$ for all). Because demographic and medical variables were largely unrelated to

Table 1. Participant Demographic and Medical Characteristics (N = 18)

Characteristic	M (SD) or %
Demographic	
Age, yr	67.72 (8.56)
Education, yr	13.78 (2.13)
Female	11.1
Medical	
Left ventricular ejection fraction	39.38 (12.45)
Hypertension	72.2
Diabetes	38.9
Sleep apnea	27.8

Note. M = mean; SD = standard deviation.

Table 2. Partial Correlations Between Driving Simulation Performance and Physical Fitness

Driving Simulation Index	M (SD)	Correlation With 2MST
Collisions	2.00 (1.28)	−.52*
Stop signs missed	0.78 (0.81)	−.48*
Center line crossings	5.83 (3.96)	−.14
Off-road excursions	4.83 (6.39)	−.23
% of time over speed limit	9.06 (8.57)	−.17
% of time out of lane	4.75 (3.16)	−.28

Note. Partial correlations are adjusted for left ventricular ejection fraction. 2MST = 2-min step test; M = mean; SD = standard deviation. * $p \leq .05$.

2MST scores and driving simulation performance in this sample, we did not include these variables as covariates in analyses examining physical fitness and driving.

Physical fitness demonstrated a significant association with poorer driving simulation performance. Partial correlations controlling for LVEF showed that 2MST score was negatively associated with total collisions, $r(15) = -.52, p = .03$, and number of stop signs missed, $r(15) = -.48, p = .05$. Worse physical fitness correlated with a greater number of collisions and stop signs missed. No such pattern emerged for any of the other driving simulation indexes ($p > .05$ for all; see Table 2).

Physical Fitness, Cognitive Function, and Driving Simulation

Table 3 provides cognitive test performance data for the sample. Average MMSE score was 27.83 (*SD* = 2.09); 27.8% of the sample scored <27. With a *T* score cutoff of 35, many participants exhibited impairments in executive function and psychomotor speed. Partial correlations adjusting for age, sex, education, and LVEF showed that decreased performance on the 2MST was associated with a worse composite score of attention, executive function, and psychomotor speed, $r(12) = .58, p = .03$. No such pattern emerged for the MMSE ($p > .05$).

Cognitive dysfunction was correlated with poorer driving simulation performance. Indeed, analyses controlling for age, sex, education, and LVEF showed significant associations between composite score of attention, executive function, and psychomotor speed and number of center line crossings, $r(12) = -.56, p = .04$, and percentage of time spent out of lane, $r(12) = -.53, p = .049$. Trends were found for total collisions, $r(12) = -.51, p = .06$, and percentage of time spent over the speed limit, $r(12) = -.46, p = .099$. In each case, worse composite attention, executive function, and psychomotor speed score were associated with poorer driving simulation performance. A trend was found between worse MMSE score and greater number of stop signs missed, $r(12) = -.50, p = .07$ (Table 4).

Table 3. Cognitive Test Performance

Test	<i>T</i> Score, <i>M</i> (<i>SD</i>)	Participants With <i>T</i> score <35, %
Mini-Mental State Examination	27.83 (2.09)	—
Trail Making Test, Part A	51.75 (10.55)	11.1
Trail Making Test, Part B	47.54 (15.85)	22.2
Letter–Number Sequencing	53.82 (8.19)	0.0
Digit Symbol Coding	50.56 (10.05)	0.0
Grooved Pegboard, dominant hand	46.84 (13.23)	11.1
Grooved Pegboard, nondominant hand	44.21 (9.34)	16.7

Note. — = not applicable; *M* = mean; *SD* = standard deviation.

Discussion

This study, like others, demonstrates that cognitive dysfunction is common in people with HF and contributes to poor simulated driving performance (Alosco, Spitznagel, et al., 2013). Other clinical risk factors for impaired driving ability in people with HF, however, are not well understood. The current study extends the literature and suggests that reduced physical fitness secondary to HF, a known correlate of cognitive impairment, is a possible contributor to unsafe driving performance and can also serve as a proxy measure for driving fitness among people with HF.

Poorer physical fitness in our sample was associated with worse simulated driving performance, including more collisions and stop signs missed. Reduced physical fitness is a primary symptom of HF because of exercise intolerance (Piña et al., 2003), and past work in HF linked poor physical fitness with decreased functional capacity, including worse self-reported independence in driving (Alosco et al., 2014). The mechanism for the negative effects of decreased physical fitness on driving performance may in part involve cognitive dysfunction. Decreased physical fitness might result in poor cognitive outcomes in people with HF through its association with reduced cerebrovascular integrity (e.g., brain hypoperfusion; Alosco, Brickman, et al., 2013; Corvera-Tindel, Doering, Woo, Khan, & Dracup, 2004; Tarumi et al., 2013). Indeed, poor physical fitness in this sample of people with HF was associated with worse performance on a composite measure of attention, executive function, and psychomotor speed. Impairments in complex mental abilities such as these have been linked with impaired on-road driving in older adults with HF and poorer driving simulation performance (Alosco et al., 2012; Anstey, Wood, Lord, & Walker, 2005; Daigneault, Joly, & Frigon, 2002). Executive functions and other higher-order cognitive processes (e.g., divided attention) are critical for safe driving because of their role in planning, multitasking, and quick decision making (Marmeleira et al., 2009; Sakai et al., 2012). Future work using on-road testing is needed to

confirm poor physical fitness as a risk factor for unsafe driving in people with HF.

Our observations have therapeutic implications. Structured exercise is a common treatment recommendation in HF that may help preserve IADLs in this population, including safe driving. Past research in healthy older adults has shown that exercise interventions decrease on-road test errors by as much as 37% (Marottoli et al., 2007). The reasons for these findings may include the beneficial effects of exercise on physical fitness and cognitive function. Exercise in older adults promotes driving-relevant cognitive abilities such as reaction time, visual attention (e.g., processing speed, divided attention), and psychomotor performance (Marmeleira et al., 2009). A similar pattern may also be evident in HF. For example, cardiac rehabilitation has been shown to improve neurocognitive outcomes in people with cardiovascular disease (Stanek et al., 2011). Alternatively, exercise and better physical fitness may influence other factors believed to play a key role in safe driving, such as improved shoulder flexibility and trunk rotation, reduced stress and fatigue, increased alertness, and better overall health status (Marmeleira et al., 2009; McGwin, Sims, Pulley, & Roseman, 2000; Ostrow, Shaffron, & McPherson, 1992; Sagberg, 2006; Taylor & Dorn, 2006). Future work should examine whether clinical interventions such as occupational therapy and exercise improve cognitive, physical, and psychological function in people with HF and, in turn, help them preserve on-road driving performance.

Limitations and Future Research

The current findings are limited in several ways. First, although the literature strongly supports cognitive dysfunction as one possible mechanism underlying poor physical fitness

Table 4. Partial Correlations Between Driving Simulation Indexes and Cognitive Function

Index	Correlation With MMSE Score	Correlation With Composite Score of Attention, Executive Function, and Psychomotor Speed
Collisions	.15	–.51 (<i>p</i> = .06)
Stop signs missed	–.50 (<i>p</i> = .07)	–.42
Center line crossings	–.18	–.56*
Off-road excursions	–.01	.18
% of time over speed limit	.01	–.46 (<i>p</i> = .099)
% of time out of lane	–.17	–.53*

Note. Partial correlations are adjusted for age, sex, education, and left ventricular ejection fraction. MMSE = Mini-Mental State Examination.

**p* < .05.

and decreased simulated driving performance, other variables not accounted for in this study may also help explain our findings. For example, poor physical fitness may serve as a proxy for physical inactivity. In this instance, it is possible that factors such as reduced motor flexibility or worsened physical and psychological health (e.g., depression) may underlie the association between reduced physical fitness and poor driving performance (Ostrow, Shaffron, & McPherson, 1992; Taylor & Dorn, 2006). Future studies should examine the aims of the current study after accounting for these possible confounds in addition to other factors that may have influenced the results, such as driving duration and amount.

In addition, studies with larger samples and more rigorous and standardized assessments and procedures would help increase the reliability and validity of the current findings. Driving simulation and the 2MST are safe, cost-effective, and valid methods for assessing driving abilities and physical fitness, respectively (Brown & Ott, 2004; Garcia et al., 2013; Reger et al., 2004). However, future work using on-road testing and more rigorous measures of physical fitness (e.g., stress testing) is much needed to increase the ecological validity of the current findings. Studies with larger samples that use age-matched control participants are also needed to confirm our findings and help clarify the risk of impaired driving in people with HF.

Occupational therapy plays a key role in the management of chronic medical conditions by identifying strategies to maintain participation in IADLs (Foster et al., 2011). Future work should examine the role occupational therapy plays in preserving driving independence in people with HF. For instance, occupational therapy often targets physical function and disability to optimize daily functioning in older adult medical populations (Foster et al., 2011). However, our findings suggest that the role of occupational therapy practitioners may be expanded to include examination of cognition and physical fitness to help identify clients with HF who are at heightened risk for impaired IADLs and unsafe driving. Consideration of these factors will help guide occupational therapy treatment to maximize independence in IADLs among clients with HF.

Implications for Occupational Therapy Practice

The findings of this study have several implications for occupational therapy practice:

- Reduced physical fitness in people with HF may increase risk for unsafe driving because of its negative effects on cognitive function.
- Occupational therapy clients may benefit from screening for cognitive function and fitness levels to aid in

disease management of HF and help identify risk for unsafe driving.

- Occupational therapy interventions that target improved fitness (e.g., exercise) or cognitive function may preserve driving abilities, among other IADLs, in older adults with heart failure.

Conclusion

Reduced physical fitness was associated with poorer simulated driving performance in a sample of older adults with HF, possibly, at least in part, because of its negative effects on cognitive function. Poor physical fitness is a hallmark of HF, and thus this study provides additional preliminary evidence that people with HF may be an at-risk population for unsafe driving. Such findings suggest that occupational therapy practitioners treating clients with HF should routinely assess cognitive function and fitness levels to help guide treatment and maximize independence in IADLs, including driving. Larger studies using on-road testing are needed to confirm our findings and to determine whether exercise interventions can improve and preserve IADLs in people with HF, including driving skills. ▲

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