Association of Long-Distance Corridor Walk Performance With Mortality, Cardiovascular Disease, Mobility Limitation, and Disability

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EXERCISE CAPACITY OR FITNESS1–4 and cardiovascular response to exercise, especially heart rate recovery,5–8 have been shown in middle-aged adults to predict cardiovascular and total mortality. Extended walking tests have been used to assess exercise capacity in medically ill populations.9–12 The long-distance corridor walk is similar to the 6-minute walk test,13 which has been shown to predict mortality in patients with congestive heart failure.14

Both the 6-minute and the long-distance corridor walk test are associated with several long-term health conditions and measures of subclinical disease including cardiovascular, musculoskeletal, and neurological conditions.15,16 Performance on extended walking tests of varying times and distances have been shown to be strongly related to directly measured oxygen consumption.17–19 Potentially, such tests

Context Aerobic fitness, an important predictor of cardiovascular disease and mortality, is difficult to assess by maximal exercise testing in older adults. Extended walking tests have been examined as outcome predictors in medically ill populations but not in community-dwelling older adults.

Objective To determine whether an extended walking test predicts poor outcomes in older adults.

Design, Setting, and Participants Observational cohort study enrolling 3075 community-dwelling adults aged 70 to 79 years living in Pittsburgh, Pa, or Memphis, Tenn. Of those participating in the Health, Aging, and Body Composition Study, 1584 (52%) were women and 1281 (42%) were black. Participants enrolled from March 1997 to April 1998. Ability to complete the long-distance corridor walk and total performance time was assessed at the baseline examination.

Main Outcome Measures Total mortality, incident cardiovascular disease, incident mobility limitation, and mobility disability were ascertained after a mean (SD) of 4.9 (0.9) years.

Results Among patients eligible to exercise, 351 died, 308 had episodes of incident cardiovascular disease, 1116 had occurrences of mobility limitation, and 509 had occurrences of mobility disability. Inability to complete walking 400 m tended to be associated with a higher risk of mortality and incident cardiovascular disease and, after accounting for potential confounders, was associated with incident mobility limitation (212.6 vs 79.1 events/1000 person-years; adjusted hazard ratio [HR], 1.86; 95% confidence interval [CI], 1.58–2.18; P<.001) and mobility disability (85.2 vs 28.8 events/1000 person-years; adjusted HR, 1.95; 95% CI, 1.56–2.44; P<.001). Of those who completed 400 m, each additional minute of performance time was associated with an adjusted HR of 1.29 (95% CI, 1.12–1.48) for mortality, 1.20 (95% CI, 1.01–1.42) for incident cardiovascular disease, 1.52 (95% CI, 1.41–1.63) for mobility limitation, and 1.52 (95% CI, 1.37–1.70) for disability after adjustment for demographics, health behaviors, clinical and subclinical disease, and cardiovascular disease risk factors. Findings were consistent in both men and women and blacks and whites. Among participants who completed the test and after adjusting for potential confounders, those in the poorest quartile of functional capacity (walk time >362 seconds) had a higher risk of death than those in the best quartile (walk time ≤290 seconds; adjusted HR, 3.23; 95% CI, 2.11–4.94; P<.001).

Conclusions Older adults in the community who reported no difficulty walking had a wide range of performance on this extended walking test. Ability to do the test and performance were important prognostic factors for total mortality, cardiovascular disease, mobility limitation, and mobility disability in persons in their eighth decade.

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could discriminate risk for future adverse health events in those with no overt evidence of poor health and who appear to be well functioning. We hypothesized that the ability to complete the 400-m walk component of the long-distance corridor walk, the performance time, and the cardiovascular response to this task would predict mortality, cardiovascular disease, mobility limitation, and disability in a cohort of well-functioning older adults.

**METHODS**

**Population**

The Health, Aging, and Body Composition (Health ABC) study was designed to assess the relationship between body composition, long-term conditions, and incident mobility limitation in an initially well-functioning older adult cohort. From March 1997 to April 1998, the study enrolled 3075 people aged 70 to 79 years, of whom 1584 (52%) were women and 1281 (42%) were black. Potential participants were recruited from a random sample of white and all black Medicare beneficiaries residing in designated ZIP code areas in Pittsburgh, Pa, and Memphis, Tenn, with a mailed invitation followed by a telephone screening interview to determine eligibility. Race was defined by self-report. Eligible participants reported no difficulty walking a quarter of a mile, climbing one flight of stairs without resting, or performing basic activities of daily living (ADLs). Persons with plans to leave the area within 3 years; who required an assistive device, such as a cane or walker; who reported being actively treated for cancer; or who were participating in a clinical trial were excluded. Eligible participants were scheduled for a home visit alternating with a person examination alternating with a comprehensive interview to conduct follow-up. Consent was obtained, and a telephone interview during which eligibility was confirmed, consent was obtained, and a comprehensive interview was conducted followed by a clinic examination that included assessment of mobility. The protocol was approved by the institutional review boards at the 2 field centers and the coordinating center. All participants gave written informed consent.

**Long-Distance Corridor Walk**

The long-distance corridor walk was conducted after enrollment as an objective measure of exercise capacity to complement the self-report of ability to walk a quarter of a mile, which is about 400 m. The methods for the long-distance corridor walk have been published. Briefly, participants received instructions to walk 400 m in a hallway on a 20-m per segment course for 10 laps (40 m per lap) after a 2-minute warm-up with standard encouragement given at each lap. Instructions were to “walk as quickly as you can, without running, at a pace you can maintain.” Participants were scheduled for a home visit alternating with a person examination alternating with a comprehensive interview during which eligibility was confirmed, consent was obtained, and a comprehensive interview was conducted followed by a clinic examination that included assessment of mobility. The protocol was approved by the institutional review boards at the 2 field centers and the coordinating center. All participants gave written informed consent.

**Outcomes**

Surveillance was conducted by in-person examination alternating with a telephone interview every 6 months. Hospital records, death certificates, informant interviews, and autopsy data were reviewed by committee to adjudicate immediate and underlying causes of death. Incident cardiovascular disease was defined as coronary heart disease (coronary heart disease—definite or probable myocardial infarction, hospitalization for angina, coronary heart disease death) or stroke. Persistent mobility limitation was defined as 2 consecutive reports of having any difficulty walking a quarter of a mile or climbing stairs, or based on 1 report followed by the death of the participant prior to the next follow-up, with a proxy report that the difficulty had been present for more than 6 months. Disability for mobility was defined as 2 consecutive reports of severe difficulty or inability to perform these tasks. Final determination of disability status was made based on interview or, if needed, proxy interview, hospital records, or both. Follow-up for all events was complete through 6 years with a mean (SD) follow-up of 4.9 years (0.9) and was 98% complete.

**Long-term Health Conditions**

Coronary heart disease was defined as myocardial infarction, angina, or history of coronary artery bypass graft surgery or percutaneous transluminal coronary angioplasty. Cerebrovascular disease was defined as self-reported history of transient ischemic attack or stroke. Prevalent cardiovascular disease was defined as coronary heart disease or stroke. Peripheral artery disease was present if the participant reported intermittent claudication or history of bypass or angioplasty in the leg arteries. Knee pain was considered to be consistent with osteoarthritis if

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**Figure 1. Long-Distance Corridor Walk Exclusions**

<table>
<thead>
<tr>
<th>Exclusions</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>3075 Adults Aged 70-79 y Enrolled in the Health, Aging, and Body Composition Study</td>
<td></td>
</tr>
<tr>
<td>199 Excluded From Long-Distance Corridor Walk</td>
<td></td>
</tr>
<tr>
<td>173 Abnormal Vital Signs or Electrocardiogram Results</td>
<td></td>
</tr>
<tr>
<td>24 Recent Cardiac Symptoms or Surgery</td>
<td></td>
</tr>
<tr>
<td>198 Recent Chest Pain, Shortness of Breath, or Painting</td>
<td></td>
</tr>
<tr>
<td>2680 Eligible for Long-Distance Corridor Walk</td>
<td></td>
</tr>
<tr>
<td>356 Unable to Complete 400 m</td>
<td></td>
</tr>
<tr>
<td>105 Unable to Walk 2 min</td>
<td></td>
</tr>
<tr>
<td>153 Heart Rate ≥135/min</td>
<td></td>
</tr>
<tr>
<td>82 Leg Pain</td>
<td></td>
</tr>
<tr>
<td>33 Chest Pain, Feel Faint, or Short of Breath</td>
<td></td>
</tr>
<tr>
<td>71 Other</td>
<td></td>
</tr>
<tr>
<td>2324 Completed 400 m</td>
<td></td>
</tr>
</tbody>
</table>

*Participants could have more than 1 reason for not completing the walk.
reported to be present for at least 1 month of the past year. Depression was considered as present if the participant reported treatment for depression and used an antidepressant or if there was no self-report of treatment but antidepressant use was recorded among medications inventoried. Diabetes and hypertension were defined by self-report, confirmed by medication use. β-Blockers, digoxin, and calcium channel blockers were considered as potential confounders when heart rate response and recovery were examined.

Indicators of subclinical or otherwise undiagnosed disease included ankle-brachial index, major electrocardiogram abnormalities (major Q or QS abnormality, major ST or T wave abnormality, ventricular conduction defects, or left ventricular hypertrophy), forced expiratory volume in first second/forced vital capacity (FEV1/FVC), Center for Epidemiological Studies Depression Scale (CES-D) score, fasting glucose (Vitro 950 analyzer, Johnson and Johnson, Rochester, NY), and systolic blood pressure.

**Other Potential Confounders**

Other factors associated with 400-m walk performance that were considered as potential confounders included physical activity, body mass index, smoking, and total cholesterol level. Physical activity was determined using a standardized

### Table 1. Characteristics of Study Participantsa

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Excluded (n = 395)</th>
<th>Stopped (n = 356)</th>
<th>201-&lt;290 (n = 579)</th>
<th>290--323 (n = 579)</th>
<th>323--362 (n = 579)</th>
<th>362-942 (n = 579)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>74.1 (2.9)</td>
<td>73.9 (2.9)</td>
<td>72.9 (2.6)</td>
<td>73.4 (2.8)</td>
<td>73.7 (2.9)</td>
<td>74.1 (3.0)</td>
</tr>
<tr>
<td>Sex and race, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Men</td>
<td>180 (45.6)</td>
<td>122 (34.3)</td>
<td>401 (69.3)</td>
<td>318 (54.9)</td>
<td>256 (44.2)</td>
<td>214 (36.5)</td>
</tr>
<tr>
<td>Black</td>
<td>84 (46.7)</td>
<td>69 (49.4)</td>
<td>85 (21.2)</td>
<td>99 (31.1)</td>
<td>114 (44.3)</td>
<td>111 (51.9)</td>
</tr>
<tr>
<td>White</td>
<td>96 (53.3)</td>
<td>63 (51.6)</td>
<td>316 (78.8)</td>
<td>219 (68.9)</td>
<td>142 (55.5)</td>
<td>103 (48.1)</td>
</tr>
<tr>
<td>Women</td>
<td>215 (54.4)</td>
<td>234 (65.7)</td>
<td>178 (30.7)</td>
<td>261 (45.1)</td>
<td>323 (55.8)</td>
<td>373 (63.5)</td>
</tr>
<tr>
<td>Black</td>
<td>123 (57.2)</td>
<td>140 (59.8)</td>
<td>37 (20.8)</td>
<td>66 (25.3)</td>
<td>128 (39.6)</td>
<td>235 (63.0)</td>
</tr>
<tr>
<td>White</td>
<td>92 (42.8)</td>
<td>94 (40.2)</td>
<td>141 (79.2)</td>
<td>195 (74.7)</td>
<td>195 (60.4)</td>
<td>138 (37.0)</td>
</tr>
<tr>
<td>Prevalent health conditions, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coronary heart disease</td>
<td>112 (29.0)</td>
<td>73 (21.5)</td>
<td>71 (12.4)</td>
<td>91 (16.0)</td>
<td>86 (15.3)</td>
<td>80 (14.0)</td>
</tr>
<tr>
<td>Peripheral arterial disease</td>
<td>25 (6.7)</td>
<td>40 (11.8)</td>
<td>13 (2.3)</td>
<td>24 (4.2)</td>
<td>24 (4.3)</td>
<td>32 (5.6)</td>
</tr>
<tr>
<td>Stroke</td>
<td>44 (11.3)</td>
<td>46 (13.0)</td>
<td>31 (5.4)</td>
<td>33 (5.7)</td>
<td>36 (6.3)</td>
<td>57 (9.9)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>180 (45.6)</td>
<td>156 (43.8)</td>
<td>192 (33.2)</td>
<td>212 (36.6)</td>
<td>229 (39.6)</td>
<td>251 (43.8)</td>
</tr>
<tr>
<td>Diabetes</td>
<td>81 (20.6)</td>
<td>77 (21.8)</td>
<td>53 (9.2)</td>
<td>67 (11.7)</td>
<td>87 (15.1)</td>
<td>103 (17.6)</td>
</tr>
<tr>
<td>Pulmonary disease</td>
<td>36 (9.9)</td>
<td>20 (6.0)</td>
<td>14 (2.5)</td>
<td>17 (3.1)</td>
<td>18 (3.4)</td>
<td>22 (4.1)</td>
</tr>
<tr>
<td>Knee pain</td>
<td>24 (6.2)</td>
<td>30 (8.5)</td>
<td>12 (2.1)</td>
<td>30 (5.3)</td>
<td>30 (5.3)</td>
<td>44 (7.6)</td>
</tr>
<tr>
<td>Depression</td>
<td>28 (7.1)</td>
<td>21 (5.9)</td>
<td>26 (4.5)</td>
<td>33 (5.8)</td>
<td>32 (5.6)</td>
<td>57 (9.7)</td>
</tr>
<tr>
<td>Risk factors, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ankle-brachial index &lt;0.9</td>
<td>122 (30.9)</td>
<td>116 (32.6)</td>
<td>50 (8.6)</td>
<td>71 (12.3)</td>
<td>93 (16.1)</td>
<td>154 (26.2)</td>
</tr>
<tr>
<td>Major ECG abnormalities</td>
<td>166 (42.0)</td>
<td>125 (35.1)</td>
<td>140 (24.2)</td>
<td>153 (26.4)</td>
<td>175 (30.2)</td>
<td>197 (33.6)</td>
</tr>
<tr>
<td>Smoking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>160 (40.5)</td>
<td>149 (42.0)</td>
<td>253 (43.8)</td>
<td>246 (42.5)</td>
<td>278 (48.0)</td>
<td>262 (44.8)</td>
</tr>
<tr>
<td>Former</td>
<td>186 (47.1)</td>
<td>160 (45.1)</td>
<td>289 (50.1)</td>
<td>293 (50.6)</td>
<td>241 (41.6)</td>
<td>235 (40.2)</td>
</tr>
<tr>
<td>Current</td>
<td>49 (12.4)</td>
<td>46 (13.0)</td>
<td>35 (6.1)</td>
<td>40 (6.9)</td>
<td>60 (10.4)</td>
<td>88 (15.0)</td>
</tr>
<tr>
<td>Physical activity group</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sedentary</td>
<td>126 (31.9)</td>
<td>93 (26.1)</td>
<td>68 (11.7)</td>
<td>116 (20.0)</td>
<td>120 (20.7)</td>
<td>197 (33.6)</td>
</tr>
<tr>
<td>Active lifestyle</td>
<td>200 (50.6)</td>
<td>189 (53.1)</td>
<td>247 (42.7)</td>
<td>296 (51.1)</td>
<td>347 (59.9)</td>
<td>326 (55.5)</td>
</tr>
<tr>
<td>Exerciser</td>
<td>69 (17.5)</td>
<td>74 (20.8)</td>
<td>264 (45.6)</td>
<td>167 (28.8)</td>
<td>112 (19.3)</td>
<td>64 (10.9)</td>
</tr>
<tr>
<td>FEV1/FVC, mean (SD)</td>
<td>0.7 (0.1)</td>
<td>0.8 (0.1)</td>
<td>0.8 (0.1)</td>
<td>0.7 (0.1)</td>
<td>0.7 (0.1)</td>
<td>0.8 (0.1)</td>
</tr>
<tr>
<td>Body mass index, mean (SD)†</td>
<td>28.0 (5.5)</td>
<td>29.0 (5.8)</td>
<td>25.8 (3.3)</td>
<td>26.6 (3.9)</td>
<td>27.3 (4.4)</td>
<td>28.5 (5.6)</td>
</tr>
<tr>
<td>Fasting glucose, mean (SD), mg/dL</td>
<td>111 (46.6)</td>
<td>112 (42.6)</td>
<td>99.9 (29.6)</td>
<td>101 (25.8)</td>
<td>104 (32.5)</td>
<td>111 (42.6)</td>
</tr>
<tr>
<td>Systolic blood pressure, mean (SD), mm Hg</td>
<td>143 (28.9)</td>
<td>138 (20.2)</td>
<td>133 (18.7)</td>
<td>134 (18.7)</td>
<td>135 (19.1)</td>
<td>136 (20.4)</td>
</tr>
<tr>
<td>CES-Depression score, mean (SD)</td>
<td>6.0 (6.7)</td>
<td>5.2 (5.8)</td>
<td>3.8 (4.5)</td>
<td>4.4 (6.1)</td>
<td>4.6 (5.1)</td>
<td>4.9 (5.0)</td>
</tr>
<tr>
<td>Total cholesterol, mean (SD), mg/dL</td>
<td>203 (43.0)</td>
<td>206 (36.6)</td>
<td>199 (35.3)</td>
<td>202 (37.7)</td>
<td>204 (38.9)</td>
<td>203 (40.2)</td>
</tr>
<tr>
<td>Short portable performance battery score (range, 0--12), mean (SD)</td>
<td>9.43 (2.2)</td>
<td>9.50 (2.0)</td>
<td>10.85 (1.1)</td>
<td>10.56 (1.1)</td>
<td>10.11 (1.3)</td>
<td>9.34 (1.6)</td>
</tr>
</tbody>
</table>

**Abbreviations:** CES-D, Center for Epidemiologic Studies Depression Scale; ECG, electrocardiogram; FEV1/FVC, forced expiratory volume in first second/forced vital capacity.

†Body mass index is calculated as weight in kilograms divided by height in meters squared.
questionnaire designed specifically for
the Health ABC study, modeled from
commonly used leisure-time physical ac-
tivity assessments including the leisure-
time physical activity question-
naire. Participants who reported at
least 1000 kcal/wk of formal exercise
were defined as exercisers. The remain-
der were classified as sedentary if they
reported expending no more than 2719
kcal/wk of total physical activity and were
classified as having an active lifestyle if
they reported expending more than 2719
kcal/wk of total physical activity. Body
mass index was examined as a continu-
ous variable. Smoking was classified as
current, past, or never. Total serum cho-
lesterol was measured from a fasting
specimen (Vitro 950 analyzer). Lower ex-
tremity function was also assessed us-
ing the Established Populations for the
Epidemiologic Studies of the Elderly
short physical performance battery.

Statistical Analyses
Analysis of variance for continuous vari-
able and $\chi^2$ tests for categorical vari-
able were used to test differences in
characteristics across the completion sta-
tus groups and quartiles of per-
formance. Crude outcome rates were
calculated per 1000 person-years. Cox
proportional hazard models were used
to assess hazard ratios (HRs) for out-
comes of total mortality, incident car-
diovascular disease, mobility limita-
tion, and mobility disability. The
proportional hazards assumption held
for all outcomes. Spline interpolation
smoothing plots supported a linear rela-
tionship between walk time and out-
comes. Hazard ratios were estimated for
completion status groups and sepa-
rately per SD of 400-m walk time (60 sec-
donds or 1 minute). These models were
adjusted for other variables found in ear-
erly analyses to be associated with
400-m walk time as well as other risk
factors for total cardiovascular disease.
Models were subsequently adjusted for
lower-extremity performance. Blood
pressure response, heart rate response,
and heart rate change were examined as
separate independent variables in ad-
ditional multivariate Cox models for each
outcome using, first, adjusted for demo-
graphics and chronic health conditions
and medications, and then for 400-m
walk time. Interactions between comple-
tion group or continuous performance
and race and sex were tested difference
in the association of walk performance
with each outcome and none were sig-
nificant. Exclusion of events in the first
6 months did not change the results. All
analyses were conducted using SAS sta-
tistical software, version 8.0 (SAS Insti-
tute Inc, Cary, NC). All reported $P$ val-
ues are 2-sided; $P<.05$ was considered
statistically significant.

RESULTS
Participant characteristics by com-
pletion categories and quartile of per-
formance time among completers
(TABLE 1) show that those who com-
pleted the walk and those who walked
faster were slightly younger; more often
were men or of white race; were less
likely to have prevalent health condi-
tions, subclinical disease, or cardiovas-
cular risk factors; had lower body mass
index, calculated as weight in kilo-
grams divided by height in meters
squared; and were more physically active.

After 6 years, 430 participants had
died. Among those excluded from or
who stopped, the crude total mortal-
ity rates were higher than for those who
completed the long-distance corridor
walk (TABLE 2). This difference was at-
tenuated after adjustment for sociode-
ographic characteristics, long-term
conditions, subclinical disease indica-
tors, and cardiovascular disease risk
factors. After adding the short physical per-
formance battery score to the model, the
HR for mortality was only
attenuated with adjustment and were not
explained by baseline lower extremity
performance. Similar associations
were found when mobility disability was
considered as the outcome.

Among those who completed the
long-distance corridor walk (TABLE 3),
each additional minute of longer per-
formance time was related to a 35%
higher risk of death after adjustment for
age and sex. After further adjustment
for demographics, long-term condi-
tions, other health indicators, and the
short physical performance battery
score, the HR for mortality was only
minimally attenuated. Hazard ratios
were similar for cardiovascular and
noncardiovascular mortality. The fully
adjusted HR for cardiovascular mor-
tality was 1.26 (95% confidence inter-
val [CI], 1.00-1.58) and for noncardio-
vascular mortality was 1.33 (95% CI,
1.16-1.52) for each minute of walk time.

This same pattern was seen when evalu-
ating incident cardiovascular disease as
the outcome. For all those who com-
pleted the long-distance corridor walk,
the HR for persistent mobility limita-
tion was higher than observed for mor-
tality or cardiovascular disease and only
modestly attenuated after multivari-
ate adjustment, including the short
physical performance battery score. Ad-
justment for the short 6-m gait speed
in place of the full battery gave similar
results. All associations were similar for
mobility disability.

Among participants who completed
the test and after adjusting for poten-
tial confounders, those in the poorest
quartile of functional capacity (walk time

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2021
>362 seconds) had a higher risk of death than those in the best quartile (walk time <290 seconds; crude event rate, 14.2 vs 39.9 per 1000 person-years; adjusted HR, 1.61; 95% CI, 1.05-2.45; P < .03), mobility limitation (27.3 vs 180.0 per 1000 person-years; adjusted HR, 4.43; 95% CI, 3.39-5.78; P < .001), and mobility disability (9.6 vs 60.2 per 1000 person-years; adjusted HR, 4.43; 95% CI, 2.88-6.82; P < .001).

Similarly, they had a higher risk of incident cardiovascular disease (27.7 vs 36.0 per 1000 person-years; adjusted HR, 1.61; 95% CI, 1.05-2.45; P < .03), mobility limitation (27.3 vs 180.0 per 1000 person-years; adjusted HR, 4.43; 95% CI, 3.39-5.78; P < .001), and mobility disability (9.6 vs 60.2 per 1000 person-years; adjusted HR, 4.43; 95% CI, 2.88-6.82; P < .001).

**FIGURE 2 and FIGURE 3 show survival curves for each outcome in men and women. In these analyses, the groups that stopped or were excluded were examined along with the 4 quartiles of walk time. For each outcome, event rates were similar for those stopping the test or excluded from the test and generally were progressively lower for each quartile of better performance. There were no significant differences in risk between men and women, but the associations with incident cardiovascular disease were not significant in women.**

Finally, we assessed the role of the cardiovascular response to the long-distance corridor walk in predicting these outcomes (TABLE 4). Higher heart rate response and faster heart rate recovery were both inversely associated with mortality, incident cardiovascular disease, persistent mobility limitation, and mobility disability, but these associations were largely explained by health conditions and faster long-distance corridor walk times. Blood pressure response was not associated with any of these outcomes. Additional analysis for threshold effects us-
ing quartiles of blood pressure and heart rate change did not show any evidence of a threshold effect in these associations.

**COMMENT**
In a large cohort of well-functioning community-based older adults, inability to complete or exclusion from walking 400 m was associated with a higher risk of mortality, incident cardiovascular disease, and mobility limitation and disability. Among those able to complete a 400-m course, each minute of performance time was associated with a 29% higher rate of mortality, 20% higher rate of cardiovascular disease, and 52% higher rates of mobility limitation and disability. Baseline health status and other tests of function were consistent in both men and women and blacks and whites. These findings reflect the well-established evidence in middle-aged men and women adults that fitness is an independent predictor of cardiovascular and total mortality.1-3

Tests, such as the long-distance corridor walk, were initially developed to evaluate capacity in patients who were unable to complete traditional treadmill test protocols, such as patients with advanced chronic obstructive pulmo-

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**Figure 2. Kaplan-Meier Plots of Mortality and Incident Cardiovascular Disease Event Rates**

**Men**

- **Mortality**
  - Excluded: 180
  - Stopped: 122
  - Quartile 1: 401
  - Quartile 2: 318
  - Quartile 3: 254
  - Quartile 4: 211

- **Incident Cardiovascular Disease**
  - Excluded: 96
  - Stopped: 67
  - Quartile 1: 304
  - Quartile 2: 219
  - Quartile 3: 174
  - Quartile 4: 142

**Women**

- **Mortality**
  - Excluded: 175
  - Stopped: 119
  - Quartile 1: 393
  - Quartile 2: 303
  - Quartile 3: 248
  - Quartile 4: 193

- **Incident Cardiovascular Disease**
  - Excluded: 91
  - Stopped: 55
  - Quartile 1: 285
  - Quartile 2: 202
  - Quartile 3: 159
  - Quartile 4: 123

Rates are according to quartile of long-distance corridor walk and completion status groups in men and women for mortality and cardiovascular disease. The P values are based on the log-rank test.

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nary disease\textsuperscript{27} or heart failure.\textsuperscript{18} These patients and many older adults are unable to walk at the usual starting pace for many treadmill protocols of at least 3.0 mph or 1.34 m/s. In the Health ABC cohort, only 31\% of those who completed the 400-m distance walked at this pace or faster and most performed below the pace of the group in the validation study.\textsuperscript{17} Nevertheless, our findings support the potential for this test to be a useful substitute for treadmill testing as a predictor of adverse outcomes in older adults.

Because the long-distance corridor walk was previously shown to be a good summary measure of multiple long-term health conditions in the Health ABC cohort,\textsuperscript{15} we had hypothesized that its ability to predict poor outcomes might be largely explained when these conditions were considered in the models. We adjusted for all of the chronic health conditions associated with the long-distance corridor walk at baseline as well as measures of the extent of long-term disease using noninvasive tests and for cardiovascular risk factors. After adjustment for these factors and after administering a brief lower-extremity performance battery, the long-distance corridor walk performance time remained an independent predictor of adverse outcomes in older adults.

\textbf{Figure 3. Kaplan-Meier Plots of Mobility Limitation and Disability Event Rates}

Rates are according to quartile of long-distance corridor walk and completion status groups in men and women for mobility limitation and mobility disability. The $P$ values are based on the log-rank test.
mortality, cardiovascular disease, mobility limitation, and disability. To the extent that the long-distance corridor walk assesses fitness or exercise capacity, it suggests that fitness is itself a prognostic factor for these adverse health outcomes in persons in their eighth decade of life and further supports the potential that exercise capacity is a potential target as a modifiable risk factor even in those aged 70 years and older. Alternatively, this test may capture additional information about the severity of underlying long-term conditions not captured by our measures of clinical and subclinical disease.

Heart rate recovery after exercise is a manifestation of reactivated vagal tone that occurs normally after exercise.28 Others have found it to be an independent predictor of mortality after accounting for functional capacity.2-8 Vagal tone appears to protect against fatal arrhythmias.29 In our study, heart rate recovery was not independent of other measures of functional capacity, most likely because our test was self-paced rather than maximal or submaximal. Although the association of heart rate recovery was not independent of the 400-m walk performance time in the Health ABC cohort, it might be a more easily accessible prognostic indicator in clinical settings than walk-time per se.

The protocol for the test was designed to encourage a good effort, but at a pace that could be maintained for 10 laps, thus there was no “ramping up” of the speed or slope as is done with submaximal, symptom-limited or maximal treadmill tests. Such self-paced tests have proven to be very safe when appropriate exclusions are applied.30 For individuals who are unable to walk 400 m or who would be excluded for safety reasons, a short-course gait speed or short lower-extremity performance battery still provides important prognostic information.30 The longer walk may be most useful for those who appear to be well functioning using the shorter tests.31

Poor lower-extremity performance is strongly predictive of future disability, hospitalization, and mortality.26 Gait speed and lower-extremity performance batteries capture many aspects of age-related chronic conditions and overall functional status, but these measures tend to have ceiling effects, limiting discrimination among healthier older adults.30 A 400-m long-distance corridor walk can discriminate levels of function of those with normal performance on a lower-extremity battery.32 Short walks do not adequately assess into aerobic fitness,33 although the best time or length for extended protocols to capture fitness needed is still debated.

There are several important limitations to consider. The Health ABC cohort was selected to be free of disability and mobility impairment by self-report, thus interpretations of these findings are limited to these community-dwelling older adults. The outcomes of mobility limitation and disability were based on self-report. Future studies should assess prediction of other performance-based functional outcomes.

This study demonstrates that the ability to walk 400 m and timed performance discriminate mortality and cardiovascular risk and risk for mobility limitation and disability in community-dwelling older adults without known difficulty performing mobility-related tasks. These findings provide validation of the importance of having the capacity to walk longer distances and show that there is a wide range of functional and risk in apparently well-functioning older adults. This test may be useful in clinical practice for the identification of early decline in function.

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REFERENCES


