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Influence of Prehospital Function and Strength on Outcomes of Critically Ill Older Adults

D. Clark Files, MD^{*,†,‡}, Rebecca Neiberg, MS[§], Julia Rushing, MStat[§], Peter E. Morris, MD[¶], Michael P. Young, MD^{*}, Hilsa Ayonayon, PhD^{**}, Tamara Harris, MD^{††}, Anne Newman, MD, MPH^{‡‡}, Susan Rubin, MD^{**}, Eric Shiroma, MEd^{††}, Denise Houston, PhD[†], Michael E. Miller, PhD[§], and Stephen B. Kritchevsky, PhD[†]

*Divisions of Pulmonary, Wake Forest University, Winston-Salem, North Carolina †Division of Gerontology and Geriatric Medicine, Department of Internal Medicine, Wake Forest University, Winston-Salem, North Carolina ‡Critical Illness, Injury and Recovery Research Center, Wake Forest University, Winston-Salem, North Carolina §Department of Biostatistical Sciences, School of Medicine, Wake Forest University, Winston-Salem, North Carolina ¶Division of Pulmonary, Critical Care and Sleep Medicine, University of Kentucky, Lexington, Kentucky **University of California, San Francisco, San Francisco, California ††National Institutes of Health, National Institute on Aging, Bethesda, Maryland ‡‡Department of Epidemiology, University of Pittsburgh, Pittsburgh, Pennsylvania

Abstract

OBJECTIVES—To understand the influence of prehospital physical function and strength on clinical outcomes of critically ill older adults.

DESIGN—Secondary analysis of prospective cohort study.

SETTING—Health, Aging and Body Composition (Health ABC) Study.

PARTICIPANTS—Of 3,075 older adult Health ABC participants, we identified 575 (60% white, 61% male, mean age 79) with prehospital function or grip strength measurements within 2 years of an intensive care unit stay.

MEASUREMENTS—The primary analysis evaluated the association between prehospital walk speed and mortality, and secondary analyses focused on associations between function or grip strength and mortality or hospital length of stay. Function and grip strength were analyzed as continuous and categorical predictors.

Address correspondence to D. Clark Files, MD, Pulmonary, Critical Care, Allergy and Immunologic Diseases, Medical Center Boulevard, Wake Forest Baptist Medical Center, Winston-Salem, NC 27157. dfiles@wakehealth.edu.

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RESULTS—Slower prehospital walk speed was associated with greater risk of 30-day mortality (for each 0.1 m/s slower, odds ratio = 1.13, 95% confidence interval (CI) = 1.04–1.23, $P = .004$). Grip strength, chair stands, and balance had weaker, non-statistically significant associations with 30-day mortality. Participants with slower prehospital walk speed (hazard ratio (HR) = 0.94, 95% CI = 0.90–0.98, $P = .005$) and weak grip strength (HR = 0.85, 95% CI = 0.73–0.99, $P = .03$) were less likely to be discharged from the hospital alive. All function and strength measures were significantly associated with 1-year mortality.

CONCLUSION—Slow prehospital walk speed was strongly associated with greater 30-day mortality and longer hospital stay in critically ill older adults, and measures of function and strength were associated with 1-year mortality. These data add to the accumulating evidence on the relationship between physical function and critical care outcomes.

Keywords

critical care; weakness; aging; gait speed; functional outcomes

Older persons are more likely than younger adults to develop and die from critical illnesses requiring intensive care services, such as severe pneumonia, acute respiratory distress syndrome, congestive heart failure, myocardial infarction, and sepsis.^{1–4} The sources of these age-related disparities in death across seemingly different disease states are incompletely understood.

One factor that may contribute to poor outcomes in older adults experiencing an acute illness is their prehospitalization functional status. Previous studies have shown that physical function is a major determinant of hospital admissions, length of stay (LOS), and mortality in older adults with wide-ranging medical conditions.^{5–9} Although these findings support the concept that physical function is an important variable predicting mortality and morbidity across differing domains, the effect of prehospital physical function on individuals subsequently experiencing a critical illness has been understudied. The relevance of preillness physical function to traditional critical care outcomes, such as mortality, is important to understand because critical care severity-of-illness scoring systems do not account for baseline physical function.^{10–12} The lack of longitudinal databases in the critical care field limits the ability to explore this question adequately.

A better understanding of the effect of baseline physical function on the outcomes of individuals with critical illness has important implications for intensive care unit (ICU) clinicians and researchers. Better understanding of this relationship may improve clinical outcome prediction and illuminate the relationship between critical illness and post-ICU functional impairment. To further explore this concept, we examined the effect between objective pre-ICU physical function and grip strength measures on subsequent mortality and hospital LOS using data collected from participants enrolled in the Health, Aging, and Body Composition (Health ABC) Study. Our hypothesis was that pre-ICU physical function and strength would have a previously unrecognized influence on short- and long-term mortality and LOS for persons experiencing a critical illness.

METHODS

Setting

The Health ABC Study is an observational study designed to investigate the effect of changes in body composition on physical function and subsequent disability in older adults.^{13–15} It enrolled 3,075 well-functioning, community-dwelling older adults from Memphis, Tennessee, and Pittsburgh, Pennsylvania, between March 1997 and July 1998. Eligible participants were aged 70 to 79 at enrollment and did not have any self-reported difficulty walking one-quarter of a mile, walking up 10 steps, or performing basic activities of daily living. Persons receiving active treatment for cancer in the prior 3 years or with plans to move from the area over the subsequent 3 years were excluded from the study. Health ABC staff obtained and abstracted all hospital records when a participant or a proxy reported a hospitalization during semiannual interviews. Medical records were also obtained for hospitalizations occurring before death. Trained abstractors indicated the occurrence of an ICU stay on the hospitalization abstraction form. The institutional review boards at the University of Tennessee, Memphis and the University of Pittsburgh approved the protocol, and each participant provided written informed consent.

Study Population

We screened all Health ABC participants for a hospital admission that included an ICU stay. For participants with more than one ICU admission, only the first admission was included in the analysis.

Physical Function and Strength Testing

Walk speed was assessed by asking participants to walk at their usual pace over a 20-m course. Isometric grip strength was performed using a hand-held dynamometer (JAMAR Technologies, Hatfield, PA). Handgrip dynamometry was performed twice per hand at each assessment. We calculated mean grip strength from each hand and used the maximum value from each of these means as the grip strength value at that time. Standing balance tests and chair stands were performed as part of the Health ABC Short Physical Performance Battery, as previously described.¹⁶ Ordinal scores for the balance and chair stand tests were defined as follows. Standing balance scores were 0 for side-by-side stand of 0 to 9 seconds or unable to perform, 1 for side-by-side stand of 10 seconds and semi-tandem stand of less than 10 seconds, 2 for semitandem stand of 10 seconds and tandem stand of 0 to 2 seconds, 3 for semitandem stand of 10 seconds and tandem stand of 3 to 9 seconds, and 4 for tandem stand of 10 seconds. Chair stand scores were 0 for unable to perform 5 consecutive chair stands, 1 for completed 5 chair stands in longer than 16.7 seconds, 2 for completed 5 chair stands in 13.7 to 16.6 seconds, 3 for completed 5 chair stands in 11.2 to 13.6 seconds, and 4 for completed 5 chair stands in less than 11.2 seconds. For all physical performance and strength tests, values from the visit most closely preceding the hospitalization with an ICU admission were used.

Walk speed was of primary interest as a predictor based on its strong association with all-cause mortality in older persons and the frequent assessment of 20-m walk speed in Health ABC Study participants.⁵ Secondary analyses examined the associations between 20-m walk

speed, grip strength, standing balance, and chair stands and mortality and hospital LOS. The predictors were used as continuous and categorized measures.

To assess the association between functional variables and outcomes using categorized variables, we split the performance variables into 3 groups (cannot perform or poor performance, moderate performance, fastest or best performance). The groups were defined as follows. For 20-m walk speed, slow performance was defined as a walk speed of less than 0.8 m/s, moderate performance as 0.8 to 0.9 m/s, and fast performance as 1.0 m/s or faster.⁶ For chair stand, best performance was defined as a score of 3 or 4, moderate performance a score of 1 or 2, and unable to perform a score of 0. For balance testing, best performance was defined as an ordinal score of 4, moderate as a score of 2 or 3, and poor as a score of 1 or 0. Weak grip strength was defined as less than 20 kg for women and less than 33 kg for men and strong grip strength as 20 kg or more for women and 33 kg or more for men, based on similar previously reported cutpoints.^{17,18}

Outcomes

The primary outcome for our analysis was vital status, censored at 30 days, which included participants who died in the hospital and those who died within 30 days after hospital discharge as reported on the local adjudication report. Hospital LOS and 1-year mortality after hospital discharge were secondary outcomes.

Covariates

The association between functional status or strength and mortality and LOS was adjusted for age, race, and sex. Data on age, race, and sex were collected in the Health ABC Study using standard self-reported assessments.

Statistical Analysis

Differences in participant characteristics according to 30-day postdischarge vital status were initially evaluated using *t*-tests for continuous variables and chi-square analysis for categorical variables. Logistic regression was used to investigate the association between physical function or strength and probability of death within 30 days or 1 year of discharge. Cox proportional hazards models, accounting for death as a competing risk,¹⁹ were used to compare functional and strength measures with hospital LOS. This model provided hazard ratios (HRs) comparing functional and strength measures with rate of live hospital discharge. All models included the covariates age, sex, and race. Physical function and strength measures were examined for linear and quadratic continuous effects in addition to categorical analyses. Sensitivity analysis that controlled for time between functional measurements was also performed. Multiple imputation analyses for continuous and categorical grip strength, chair stand score, and balance score used available data from sex, race, age, body mass index, walking speed, grip strength, chair stand, and balance score to create 15 imputations of the complete data that were analyzed as described in preceding statements. Differences were considered statistically significant at $P < .05$. Analyses were conducted using SAS/Stat software version 9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

Of 3,075 Health ABC participants, we identified 930 with one or more ICU admissions. We then excluded 355 participants with no functional or strength measurements within 2 years before the index ICU admission. Excluded individuals were more likely than those in the final cohort to be female (49% vs 39%, $P = .005$) and black (51% vs 41%, $P = .003$), were no different in age at the start of the Health ABC Study (73.6 vs 73.7, $P = .70$), and were less likely to die in the hospital (24% vs 32%, $P = .03$). The final cohort consisted of 575 participants (Figure S1), of whom all had performed the 20-m walk, 371 had performed the chair stands ($n = 204$ missing, imputed), 372 had performed the balance tests ($n = 203$ missing, imputed), and 340 had performed grip strength dynamometry ($n = 235$ missing, imputed) before ICU admission. The mean times between 20-m walk was performed a mean 9.7 ± 6.3 months before the ICU admission, grip strength 9.5 ± 6.2 months before, chair stand 10.6 ± 6.6 months before, and balance testing 10.6 ± 6.6 months before.

Table 1 lists the demographic characteristics, chronic medical conditions, and hospital discharge diagnoses of the final cohort. Mean age at ICU admission was 78.8 ± 4.2 , and 61% of participants were male and 60% white. The most common chronic medical conditions were cardiovascular (75%) and respiratory (22%) diseases. The most common hospital discharge diagnoses were cardiovascular events (53%) and respiratory failure (16%). Participants who died within 30 days of hospital discharge were older, had slower walk speeds, and were more likely to have a hospital diagnosis of respiratory failure or active cancer than those who survived.

Overall 30-day mortality in the cohort was 24%, and 1-year mortality was 35%. Using gait speed as a continuous predictor, we found significant 13% (odds ratio (OR) = 1.13, 95% confidence interval (CI) = 1.04–1.23) greater odds of 30-day mortality (Table 2) and 18% (OR = 1.18, 95% CI = 1.09–1.28) greater odds of 1-year mortality (Table 3) after hospital discharge for each 0.1 m/s slower prehospitalization walk speed (Figure 1). When considered variables as continuous predictors, grip strength, chair stand, and balance performance had weaker associations with 30-day mortality (Table 2), although the associations between these measures were strengthened when 1-year mortality was analyzed, with all predictors being statistically significant (Table 3). The largest effect was seen for participants unable to hold a tandem stand for 10 seconds (balance score 3), who had 77% (OR = 1.77, 95% CI = 1.13–2.78) greater odds of 30-day mortality than those with the best balance (balance score 4) (Table 2).

When physical functioning predictors were categorized, participants in the slowest category of walk speed had 80% (OR = 1.80, 95% CI = 1.02–3.17) greater odds of 30-day mortality and more than twice the risk (OR = 2.15, 95% CI = 1.27–3.65) of 1-year mortality after hospital discharge for a critical illness than those in the fastest walk speed category (Tables 2 and 3). Those with moderate balance function had 52% (OR = 1.52, 95% CI = 1.03–2.25) greater odds of 30-day mortality, and those unable to perform the chair stand had 52% (OR = 1.52, 95% CI = 1.07–2.14) greater odds of 1-year mortality.

Next we evaluated the relationship between functional and strength measures and rate of discharge based upon LOS before live hospital discharge. We found a significant 6% (HR = 0.94, 95% CI = 0.90–0.98) lower rate of discharge for each 0.1 m/s slower prehospitalization walk speed. We also found a significant 15% (HR = 0.85, 95% CI = 0.73–0.99) lower rate of discharge for each 10 kg less grip strength. Poorer performance on chair stands and balance tests revealed nonsignificant trends that were associated with lower rates of discharge (Table S1). A sensitivity analysis that controlled for the time between functional measurement and outcome did not change conclusions from any analyses.

DISCUSSION

Prehospitalization walk-speed was highly associated with short- and long-term mortality and hospital LOS in older adults who developed a critical illness. Other functional and strength measures showed similar but weaker trends in their relationship with mortality and LOS.

Despite ample evidence suggesting that poor physical function in older persons is associated with subsequent hospitalization, disability, and all-cause mortality independent of underlying comorbidities,^{5,8,20,21} little attention has been paid to prehospitalization functional status of persons experiencing a critical illness requiring ICU-level care. Critical illness severity-of-illness scoring systems, such as the Simplified Acute Physiology Score; Acute Physiology, Age, Chronic Health Conditions; and Sepsis-related Organ Failure have reasonable ability to predict ICU mortality.^{10–12,22} These scoring systems include acute physiological and laboratory abnormalities and chronic health conditions but not baseline physical function.

We found a strong relationship between pre-ICU walk speed and 30-day and 1-year mortality. Given the strong association between prehospital physical function and mortality in this study and others,²³ future development of ICU mortality tools should consider incorporation of an assessment of baseline physical function.

We also evaluated the association between physical function and strength and hospital LOS by examining rates of live hospital discharge. Although clinicians have intimated that prehospital strength and function affect morbidity from critical illness, studies with prehospital function and strength are lacking. Our analyses suggest that prehospital walk speed and grip strength are associated with hospital LOS in these individuals.

Strong evidence suggests that ICU-acquired neuromuscular dysfunction causes profound strength and functional impairment and is strongly associated with hospital mortality and longer hospital stays.^{24–27} For example, 450% greater hospital mortality was demonstrated in critically ill individuals with poor grip strength, compared to those with stronger grip strength.²⁶ In another cohort, it was found that weak critically ill individuals had an approximately 42% greater likelihood of dying in the ICU or hospital than those in a matched cohort of nonweak individuals.²⁷ In these and other studies examining ICU-acquired neuromuscular dysfunction, the lack of pre-ICU functional and strength measures limits understanding of the relative contribution of baseline strength and function on ICU mortality. Because ICU-acquired neuromuscular dysfunction has also been associated with

longer hospital stays, our data suggest that unmeasured prehospital weakness may account for some of the mortality and morbidity risk attributed to ICU-acquired weakness.^{24,26,27} More studies are needed to understand the relationship between prehospital strength and function and strength and function after a critical illness, given the growing interest in assessing and improving functional outcomes in survivors of critical illness.^{28–30} These studies and our data highlight the potential importance of function-focused care approaches in these individuals as a strategy to improve outcomes, but studies that have used ICU rehabilitation strategies in heterogeneous critically ill populations have failed to show clear mortality benefits.³¹

One limitation of our study was that ICU severity of illness was not captured in this cohort. The 30-day mortality of 24% in our cohort was higher than reported in a previous study that reported mortality of 11.3% in 2010–2012,³² although our cohort was significantly older than that cohort (79 vs 61). Previous work has demonstrated a clear relationship between increased ICU mortality and older age for critical illnesses such as acute respiratory distress syndrome and sepsis.^{1,33–36} Given that the Health ABC cohort was a well-functioning older cohort, these results may not be generalizable to the population at large, which may have more comorbidities and functional impairment. Similarly, these results may be less applicable to younger individuals. Other limitations include the time gap between physical function tests and ICU admission, which was approximately 10 months, although our sensitivity analysis confirmed that the time between functional measurement and outcome did not change our results. This makes the possibility that the time lag between functional testing and ICU admission altered our results less likely. Others have shown that participant walk speed in the Health ABC cohort slowly declined over time (~0.015 m/s per year), so it is unlikely that there were meaningful changes in walk speed between the functional measurement and ICU admission.³⁷

In summary, we found significant effects of some measures of prehospital function and strength on mortality and LOS in older adults subsequently experiencing a critical illness. In particular, prehospital walk speed was strongly associated with short- and long-term mortality and LOS. Future studies in other longitudinal cohorts are needed to corroborate and expand upon these findings.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

Association between slower prehospital walking speed and intensive care mortality. [Color figure can be viewed at wileyonlinelibrary.com]

Table 1

Sample Characteristics According to Vital Status 30 Days After Discharge

Characteristic	All, n = 575	Alive, n = 438 ^a	Dead, n = 137 ^a	P-Value
Age, mean $\pm$ SD	78.8 $\pm$ 4.2	78.5 $\pm$ 4.2	79.5 $\pm$ 4.0	.02
Sex, n (%)				
Male	348 (61)	260 (59)	88 (64)	.31
Female	227 (40)	178 (41)	49 (36)	
Race, n (%)				
White	342 (60)	268 (61)	74 (54)	.14
Black	233 (40)	170 (39)	63 (46)	
Body mass index, mean $\pm$ SD	27.3 $\pm$ 4.5	27.5 $\pm$ 4.6	26.6 $\pm$ 4.5	.06
Ever smoked, n (%)	369 (64)	278 (63)	91 (66)	.53
20-m walking speed, m/s, mean $\pm$ SD	1.1 $\pm$ 0.2	1.1 $\pm$ 0.2	1.0 $\pm$ 0.3	<.001
Chronic medical conditions, n (%)				
Respiratory disease	124 (22)	94 (21)	30 (22)	.91
Cardiovascular disease	431 (75)	328 (75)	103 (75)	.94
Chronic kidney disease	10 (2)	7 (2)	3 (2)	.64
Active cancer	121 (21)	85 (19)	36 (26)	.08
Diabetes	118 (21)	85 (19)	33 (24)	.24
Hospital discharge diagnosis, n (%)				
Cardiovascular event ^b	306 (53)	235 (54)	71 (52)	.71
Respiratory failure	90 (16)	51 (12)	39 (28)	<.001
Gastrointestinal disease	74 (13)	56 (13)	18 (13)	.91
Cancer	86 (15)	51 (12)	35 (26)	<.001
Orthopedic injury	19 (3)	14 (3)	5 (4)	.80
Other	34 (6)	26 (6)	8 (6)	.97

SD = standard deviation.

^aVital status censored at 30 days after hospital discharge.^bIncludes congestive heart failure, angina pectoris, and myocardial infarction.

Table 2

Effect of Prehospital Strength and Functional Measures on 30-Day Mortality

Physical Function Measure	Alive, n = 438	Dead, n = 137	OR (95% Confidence Interval)	P-Value ^{a,b}
Continuous, mean $\pm$ standard deviation				
20-m walking speed, 0.1 m/s slower	1.09 $\pm$ 0.24	1.00 $\pm$ 0.25	1.13 (1.04–1.23)	.004
Grip strength, 10 kg lower	31.68 $\pm$ 10.30	30.02 $\pm$ 8.80	1.25 (0.90–1.74)	.18
Chair stand score, 1 unit lower	1.85 $\pm$ 1.28	1.55 $\pm$ 1.78	1.17 (0.96–1.42)	.12
Balance stand score, 1 unit lower ^c	3.42 $\pm$ 1.14	3.20 $\pm$ 1.12		
2 vs 3			1.17 (0.96–1.42)	.12
3 vs 4			1.77 (1.13–2.78)	.01
Categorical, n (%)				
Walk speed				
Fast (n = 362)	287 (79)	75 (21)	Reference	.13
Moderate (n = 135)	100 (74)	35 (26)	1.22 (0.75–1.97)	
Slow (n = 78)	51 (65)	27 (35)	1.80 (1.02–3.17)	
Weak grip strength				
No (n = 228)	176 (77)	52 (23)	Reference	.33
Yes (n = 112)	80 (71)	32 (29)	1.14 (0.89–1.46)	
Chair stand				
Best (n = 114)	95 (83)	19 (17)	Reference	.22
Moderate (n = 184)	133 (73)	51 (27)	1.21 (0.88–1.66)	
Cannot perform (n = 73)	54 (74)	19 (26)	1.13 (0.76–1.68)	
Balance				
Best (n = 261)	210 (80)	51 (20)	Reference	.04
Moderate (n = 71)	42 (59)	29 (41)	1.52 (1.03–2.25)	
Poor (n = 40)	31 (78)	9 (22)	0.87 (0.53–1.44)	

^a Adjusted for age, race, and sex.^b Multiple imputation analysis used for grip strength, chair stand, and balance odds ratio (OR) estimates.^c Multiple imputation analysis quadratic effect for balance stand $P = .03$. Effects shown reflect estimates from model with quadratic balance stand score.

Table 3

Effect of Prehospital Strength and Functional Measures on 1-Year Mortality

Physical Function Measure	Alive, n = 371	Dead, n = 204	OR (95% Confidence Interval)	P-Value ^{a,b}
Continuous, mean ± standard deviation				
20-m walking speed, 0.1 m/s slower	1.11 ± 0.24	0.99 ± 0.25	1.18 (1.09–1.28)	<.001
Grip strength, 10 kg lower	32.37 ± 10.17	29.33 ± 9.32	1.35 (1.02–1.80)	.04
Chair stand score, 1 unit lower	1.98 ± 1.26	1.45 ± 1.19	1.28 (1.07–1.54)	.007
Balance stand score, 1 unit lower	3.51 ± 1.03	3.12 ± 1.27	1.21 (1.01–1.43)	.03
Categorical, n (%)				
Walk speed				
Fast (n = 362)	255 (70)	107 (30)	Reference	.01
Moderate (n = 135)	80 (59)	55 (41)	1.37 (0.89–2.10)	
Slow (n = 78)	36 (46)	42 (54)	2.15 (1.27–3.65)	
Weak grip strength				
No (n = 228)	151 (66)	77 (34)	Reference	.26
Yes (n = 112)	66 (59)	46 (41)	1.14 (0.92–1.42)	
Chair stand				
Best (n = 114)	87 (76)	27 (24)	Reference	.01
Moderate (n = 184)	112 (61)	72 (39)	1.07 (0.79–1.45)	
Cannot perform (n = 73)	35 (48)	38 (52)	1.52 (1.07–2.14)	
Balance				
Best (n = 261)	179 (69)	82 (31)	Reference	.07
Moderate (n = 71)	37 (52)	34 (48)	1.12 (0.78–1.60)	
Poor (n = 40)	19 (48)	21 (53)	1.25 (0.81–1.95)	

^aAdjusted for age, race, and sex.^bMultiple imputation analysis used for grip strength, chair stand, and balance odds ratio (OR) estimates.