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Handgrip Strength Predicts Persistent Walking Recovery After Hip Fracture Surgery

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ABSTRACT

BACKGROUND: In older people, hip fractures often lead to disability and death. We evaluated handgrip strength, an objective measure of physical function for bedridden patients, as a predictor of walking recovery in the year after fracture surgery.

METHODS: This multicenter prospective cohort study included 504 patients, aged 70 years or more, who were admitted to the hospital for hip fracture surgery and were formerly able to walk independently. A multidimensional geriatric evaluation that included a physical examination, Short Portable Mental Status Questionnaire, Geriatric Depression Scale, Charlson Index, Basic Activities of Daily Living, and grip strength was administered at the time of admission. Follow-ups were performed every 3 months for 1 year after surgery to assess functional status and survival. The walking recovery probability was evaluated using multivariable logistic regression models.

RESULTS: The mean age of the participants was 85.3 ± 5.5 years, and 76.1% of the participants were women. The mean grip strength was greater in men (β: 6.6 ± 0.62, $P < .001$) and was directly related to the Short Portable Mental Status Questionnaire results ($P < .001$), Basic Activities of Daily Living results ($P < .001$), serum vitamin D levels ($P = .03$), and time before surgery ($P < .001$), whereas it was inversely related to age ($P < .001$), Geriatric Depression Scale score ($P < .001$), and Charlson Index ($P < .001$). After adjusting for confounders, the grip strength was directly associated with the probability of both incident and persistent walking recovery (odds ratio highest tertile vs lowest tertile, 2.84, confidence interval, 1.76-4.59 and 2.79, confidence interval, 1.35-5.79, respectively).

CONCLUSIONS: In older patients with hip fractures, early grip strength evaluation might provide important prognostic information regarding the patient's future functional trajectory.

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KEYWORDS: Grip strength; Hip fracture; Walking recovery

In older people, hip fractures are catastrophic events that often lead to dramatic consequences, such as disability, immobilization syndrome, and death.[1] The ability to remain mobile is an essential aspect of quality of life and is critical for the preservation of independence in old age. Most of the patients who survive hip fracture lose mobility function and the ability to live independently, and more than 30% of those who were independent before the fracture cannot walk independently 1 year later.[2,3]

The early identification of patients at high risk of functional decline or other adverse events after hip fracture is of paramount importance for acute care planning, rehabilitation strategy, and post-hospital discharge assessment and management. Functional evaluation is a cornerstone of multidimensional geriatric assessment and is fundamental for

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determining the appropriate care strategy and evaluating the patient's clinical course over time.[4] Recent studies suggest that performance-based functional assessment might provide important prognostic information in the acute care setting.[5] Handgrip strength can be assessed in bedridden patients and is considered an index of whole-body resilience to the aging process.[6] For example, Rantanen et al[7] showed that grip strength assessment in healthy middle-aged subjects could predict the risk of functional limitations 25 years later. Low grip strength has been associated with higher risk of limited mobility,[8] cognitive decline,[9] hospitalization,[10,11] and death.[12] Grip strength declines more quickly than muscle mass over time,[8] is used as a specific indicator of the neuromuscular status and functional reserve,[13] and is considered a marker of nutritional status and sarcopenia.[14,15] Furthermore, a previous study from our group conducted in a sample of older patients hospitalized for an acute medical event showed that a greater grip strength assessed at hospital admission was associated with a shorter length of stay,[16] which is considered a proxy measure of health status and length of recovery.[17] Nevertheless, most of the studies concerning grip strength have been conducted in community-dwelling older people,[18] and the prognostic value of grip strength assessment in patients hospitalized for hip fracture surgery has not been investigated.

The aim of this analysis was to assess the independent prognostic value of grip strength in terms of walking recovery after surgery in older patients hospitalized after hip fracture and followed by means of a 12-month observational study.

CLINICAL SIGNIFICANCE

- Grip strength was directly related to other standard geriatric evaluation measures, such as Basic Activities of Daily Living.
- Grip strength was independently associated with the probability of both incident and persistent walking recovery, providing additional and independent information in predicting functional outcome after hip fracture surgery.
- Grip strength at hospital admission can help clinicians in better identifying high risk subjects who could benefit from intensive multi-domain intervention programs.

MATERIALS AND METHODS

Study Design and Data Collection

The data were obtained from a prospective inception cohort study of 974 consecutive patients, aged 70 years or more, who were admitted for fragility hip fracture between March 2008 and February 2009 to 4 hospitals within the Regional Healthcare System. The hospitals were located in different districts of the Emilia Romagna Region (Bologna, Ferrara, Parma, and Reggio Emilia, Italy).[19,20] Patients with fracture due to secondary causes (eg, bone metastatic cancer or Paget's disease of the bone), those who had sustained a fracture due to a major trauma, and those who had previously fractured the same hip were excluded. The data from 1 hospital (Parma, N = 168) were incomplete because of lack of grip strength assessment, and therefore this clinical center was excluded from this specific analysis. Furthermore, patients who did not undergo hip surgery (N = 33), those unable to walk independently before the fracture (N = 228), and those whose grip strength was not assessed (N = 41) also were excluded, leaving a final sample of 504 patients. Patients excluded from the analysis were significantly older and were more likely to have Activities of Daily Living disability, walking impairment, and cognitive decline; furthermore, they had a greater level of comorbidity than included patients (all $P < .05$).

All clinical centers worked with preexisting co-managed care models, according to which responsibility was shared by orthopedics, geriatricians, and an interdisciplinary team including nurses, social workers, rehabilitation specialists, physiotherapists, and anesthesiologists. After a formal training, the research physicians responsible for patient care collected data at admission and during the hospital stay with a standardized comprehensive geriatric assessment. The patients were reevaluated at 3, 6, and 12 months after discharge by telephone interviews to assess vital and functional status. Data regarding mortality were obtained using anagraphic registries. The study protocol was approved by the ethics committee of the coordinating center at University Hospital Policlinico S. Orsola-Malpighi Bologna, and a notification was sent to other local ethics committees. The patients provided informed consent before participation. When the subjects were too confused to understand the informed consent process, proxy consent was obtained.

Measures

Handgrip Strength. Handgrip strength was measured using a JAMAR hand dynamometer (Model BK-7498, Fred Sammons Inc, Brookfield, Ill). Patients were in the supine position and encouraged to exhibit the greatest possible force; the best value of 3 assessments of the dominant hand was used for the analysis. The assessment of grip strength using a handheld dynamometer has been shown to be reliable and valid among hospitalized older patients,[21] with no difference between the sitting and supine positions.[22]

Self-reported Measures of Physical Function. The prefracture functional status (2 weeks before hospital admission) was measured for activities of daily living using the Katz Index,[23] and information about Instrumental Activities of Daily Living was collected using a modified version of the Lawton-Brody Scale.[24] The walking ability 2 weeks before the fracture was assessed using a scale developed in the

Table 1 Selected General and Clinical Characteristics of the Sample by Gender-specific Handgrip Strength Tertiles

	Handgrip Strength Tertiles (N = 504)			
	Lowest (n = 172)	Intermediate (n = 173)	Highest (n = 159)	*P* Value
Age (mean ± SD)	86.5 (5.7)	85.6 (5.5)	83.8 (4.8)	<.001
Men, n (%)	45 (26.2)	40 (23.1)	39 (24.5)	.81
Married, n (%)	41 (23.8)	28 (16.2)	53 (33.3)	.02
Home residents, n (%)	154 (89.5)	159 (91.9)	153 (96.2)	.20
Caregiver assistance, n (%)	123 (71.5)	114 (65.9)	74 (46.5)	<.001
Cognitive impairment, n (%)	117 (68.0)	87 (50.3)	48 (30.2)	<.001
Depressive symptoms, n (%)	85 (49.4)	69 (39.9)	54 (34.0)	<.001
Charlson Index, median (IQR)	2 (1-4)	2 (1-3)	1 (0-3)	<.001
No. of medications at admission, median (IQR)	5 (3-7)	4 (2-6)	4 (3-5)	.04
BADL difficulty, n (%)	129 (75.0)	95 (54.9)	36 (22.6)	<.001
IADL difficulty, n (%)	170 (98.8)	172 (99.4)	159 (100)	.39
Vitamin D (25-OH) ng/mL, median (IQR)	7.5 (4.3-13.2)	9.0 (6.1-13.2)	9.0 (5.7-14.1)	.03
C-reactive protein mg/L, median (IQR)	4.2 (2.3-9.8)	5.3 (2.6-8.0)	4.1 (1.8-9.1)	.19
Hemoglobin g/dL, median (IQR)	12.0 (10.9-13.3)	12.4 (10.9-13.5)	12.2 (11.0-13.3)	.55
Type of fracture: n (%)				
Intracapsular	77 (44.8)	83 (48.0)	81 (50.9)	
Trochanteric	87 (50.6)	82 (47.4)	60 (37.7)	.03
Subtrochanteric	8 (4.6)	8 (4.6)	18 (11.3)	
Days before surgery, median (IQR)	2 (2-4)	3 (2-4)	3 (2-5)	<.001
Type of surgery, n (%)				
Endoprosthesis	75 (43.6)	71 (41.0)	76 (47.8)	
Arthroplasty	3 (1.7)	6 (3.5)	3 (1.9)	<.001
Other	94 (54.7)	96 (55.5)	80 (50.3)	
Early rehabilitation, n (%)	157 (91.3)	162 (93.6)	136 (85.5)	.04

BADL = Basic Activities of Daily Living; IADL = Instrumental Activities of Daily Living; IQR = interquartile range; SD = standard deviation.

Cutoffs for men: first tertile 0.5-14 kg, second tertile 15-22 kg, third tertile 23-40 kg. Cutoffs for women: first tertile 0.5-9 kg, second tertile 10-15 kg, third tertile 16-28 kg. Cognitive decline was defined as an SPMSQ score ≤7. Depressive symptoms were detected using the Five-item Geriatric Depression Scale (score ≥2).

European Standardized Audit for fractured proximal femur.[25] For subjects living at home at the time of the fracture, assistance requirements were recorded, including the employment of private home assistance. The same information regarding functional status and walking ability was collected by phone interview during the 12-month follow-up.

Outcomes. By using the information about walking ability collected by phone interview, incident walking recovery was defined as the recovery of independent walking at any follow-up during the year after surgery, whereas persistent walking recovery was defined as the ability to walk independently for at least 2 consecutive follow-up interviews. Data from patients who died before the first follow-up were excluded from the walking recovery analysis. The analysis of incident walking recovery was conducted with a total sample of 437 subjects, because 53 subjects died before the first follow-up and 14 subjects were lost before the first interview. For the analysis of persistent walking recovery, the sample size included a total of 409 individuals, because 76 participants died before the second follow-up and 19 participants were lost to follow-up before the second interview.

Other Covariates. Sociodemographic information, including gender, marital status, and living arrangements, was collected by standardized interview. Cognitive functioning was assessed using the Short Portable Mental Status Questionnaire (SPMSQ) (range, 0−10)[26]; scores <8 were classified as cognitive impairment. Patients scoring at least 2 on the 5-item Geriatric Depression Scale were considered to have depressive symptoms.[27] Comorbidity level was measured using the Charlson Index.[28] Information recorded stay included the type of fracture, time to surgery (from admission), type of surgery, data regarding early rehabilitation, length of stay, and destination at discharge. Blood samples were collected in the morning under fasting conditions within 24 hours of hospital admission. Along with routine laboratory assessment, serum C-reactive protein and serum 25-hydroxyvitamin D levels were measured. The C-reactive protein levels were assessed using the immunoturbidimetric method (detection limit of 0.3 mg/dL; Roche, Mannheim, Germany), and the serum 25-hydroxyvitamin D levels were measured by radioimmunoassay using a commercial kit (detection limit of 3.75 nmol/L; DiaSorin, Saluggia, Italy).[29]

Statistical Analysis

Grip strength was analyzed as both a continuous and an ordinal variable (sex-specific tertiles). The association with

Table 2 Multivariable Logistic Regression Analyses Predicting Incident Walking Recovery in Patients with Independent Walking Before Fracture (N = 437)

		Odds Ratio (95% CI)			
	No. of Events (%)	Model 1	Model 2	Model 3 (Fully Adjusted)	Model 3* (Most Parsimonious)
Grip strength, tertiles					
Lowest	80 (54.0)	1	1	1	1
Intermediate	116 (74.8)	2.48 (1.75-3.52)	1.74 (1.19-2.55)	1.79 (1.19-2.71)	1.86 (1.25-2.78)
Highest	112 (83.6)	4.58 (3.02-6.97)	2.45 (1.53-3.89)	2.79 (1.69-4.60)	2.84 (1.76-4.59)
P value of test for trend		<.001	<.001	<.001	<.001
Age, y		0.94 (0.91-0.96)	0.94 (0.91-0.97)	0.97 (0.94-1.00)	0.97 (0.94-1.00)
Gender, m		0.86 (0.62-1.20)	0.71 (0.50-1.02)	0.67 (0.45-0.99)	0.64 (0.44-0.95)
Cognitive impairment			0.80 (0.58-1.10)	0.95 (0.67-1.35)	
Depressive symptoms			0.55 (0.40-0.75)	0.61 (0.43-0.86)	0.59 (0.42-0.83)
BADL difficulty			0.48 (0.35-0.67)	0.57 (0.39-0.82)	0.55 (0.38-0.78)
Caregiver assistance				0.40 (0.27-0.58)	0.39 (0.27-0.56)
Charlson Index Score					
0				1	1
1				1.07 (0.66-1.75)	
2				0.63 (0.39-1.03)	0.64 (0.45-0.93)
>2				0.85 (0.54-1.35)	
Vitamin D, tertiles					
Lowest				1	1
Intermediate				1.35 (0.91-2.00)	
Highest				2.01 (1.35-3.00)	1.73 (1.24-2.43)
Time before surgery, tertiles					
Lowest				1	1
Intermediate				1.59 (1.12-2.27)	1.52 (1.10-2.11)
Highest				1.18 (0.72-1.94)	
Early rehabilitation				3.37 (1.85-6.14)	3.14 (1.76-5.60)
c-statistic (of the model)		0.69	0.74	0.79	0.80
Grip strength continuous variable	308 (70.5)	1.09 (1.06-1.12)	1.04 (1.01-1.07)	1.05 (1.02-1.08)	1.05 (1.02-1.08)
c-statistic (of the model)		0.69	0.74	0.79	0.79

BADL = Basic Activities of Daily Living; CI = confidence interval.

Model 1 includes age, gender, and medical center. Model 2 includes age, gender, medical center, cognitive decline, depressive symptoms, and Basic Activities of Daily Living difficulty. Model 3 includes age, gender, medical center, cognitive decline, depressive symptoms, Basic Activities of Daily Living difficulty, caregiver assistance, time before surgery, type of surgery, early rehabilitation, Charlson Index, and vitamin D levels.

*Unnecessary variables were removed from the model using backward stepwise selection method (*P* for removal .1).

clinical and self-reported functional characteristics was evaluated across gender-specific tertiles of strength by analysis of variance and the chi-square test.

Logistic regression models were used to estimate the probability of walking recovery according to the baseline grip strength. Discrete-time survival analysis with logistic regression was used to estimate the association between grip strength and the likelihood of incident walking recovery. Each participant potentially contributed 1 observation for each follow-up interval (for a maximum of 3 intervals), until the round at which he/she first reported walking recovery, died, or was lost to follow-up and not evaluated thereafter (censored). Traditional logistic regression analysis was fitted to estimate the likelihood of persistent walking recovery. This second outcome definition was created to reduce the likelihood of misclassification of a patient's walking ability. Three multivariable models were built to assess the role of potential confounders on the association of grip strength with walking recovery. Model 1 was adjusted for age, gender, and medical center. Model 2 also was adjusted for pre-admission Basic Activities of Daily Living difficulty, cognitive decline, and depressive symptoms. Model 3 also was adjusted for Charlson Index, caregiver assistance, time before surgery, type of surgery, early rehabilitation, and vitamin D levels. To obtain the most parsimonious model, unnecessary variables were removed from the fully adjusted models using a backward selection method ($P < .1$ for removal). The c-statistics were calculated for both tertiles and continuous grip strength.

Kaplan-Meier survival curves and Cox proportional hazard models were used to investigate the probability of death according to grip strength. All analyses were performed using Stata statistical software (release 11; StataCorp LP, College Station, Tex).

RESULTS

The sample was composed of 504 patients aged 70 to 99 years. The mean age was 85.3 ± 5.5 years, and 76.1% of the participants were women. Fifty percent of subjects had cognitive impairment (SPMSQ <8 points), and 41.8% of subjects showed depressive symptomatology. In the week before hip fracture, 51.6% of subjects had difficulty in at least 1 Basic Activities of Daily Living, and 61.3% of subjects reported need of caregiver assistance.

At the time of hospital admission, grip strength was directly related to cognitive function (SPMSQ $P < .001$), Activities of Daily Living ($P < .001$), vitamin D levels ($P = .03$), and time before surgery ($P < .001$), whereas it was inversely related to age ($P < .001$), depressive symptoms (Geriatric Depression Scale score, $P < .001$), comorbidity level (Charlson Index $P < .001$), and need of caregiver assistance ($P < .001$) (**Table 1**).

Tables 2 and **3** display logistic analyses predicting walking recovery after surgery. The patients with higher levels of grip strength showed higher probabilities of incident walking recovery than those with lower grip strength (odds ratio [OR] for highest tertile vs lowest, 4.58; confidence interval [CI], 3.02-6.97). After adjustment for potential confounders including age, gender, comorbidity level, neuropsychologic status, self-reported functional ability, vitamin D level, time to surgery, and early rehabilitation, the relationship between grip strength and probability of incident walking recovery was confirmed, although the strength of the association was partially attenuated (OR for highest tertile vs lowest, 2.84; CI, 1.76-4.59). The analysis using grip strength as a continuous variable showed similar and consistent results (**Table 2**). We also investigated the association between grip strength and persistent walking recovery, a more clinically relevant outcome. We again found that

Table 3 Multivariable Logistic Regression Analyses Predicting Persistent Walking Recovery in Patients with Independent Walking Before Fracture (N = 409)

		Odds Ratio (95% CI)			
	No. of Events (%)	Model 1	Model 2	Model 3 (Fully Adjusted)	Model 3* (Most Parsimonious)
Grip strength, tertiles					
Lowest	66 (49.6)	1	1	1	1
Intermediate	103 (70.1)	2.83 (1.64-4.90)	2.12 (1.16-3.87)	2.40 (1.24-4.62)	2.33 (1.25-4.34)
Highest	99 (76.7)	4.07 (2.11-7.85)	2.09 (1.00-4.37)	2.46 (1.11-5.44)	2.79 (1.35-5.79)
P value of test for trend		<.001	.04	.02	.005
Age, y		0.95 (0.91-0.99)	0.95 (0.91-1.00)	0.98 (0.93-1.03)	
Gender, m		0.78 (0.47-1.30)	0.57 (0.33-0.99)	0.50 (0.27-0.92)	0.51 (0.29-0.92)
Cognitive impairment			0.78 (0.47-1.31)	0.99 (0.56-1.73)	
Depressive symptoms			0.55 (0.33-0.92)	0.60 (0.35-1.03)	0.62 (0.37-1.05)
BADL difficulty			0.36 (0.21-0.61)	0.42 (0.24-0.76)	0.41 (0.23-0.71)
Caregiver assistance				0.34 (0.18-0.63)	0.33 (0.18-0.59)
Charlson Index Score					
0				1	
1				0.92 (0.42-2.01)	
2				0.57 (0.26-1.25)	
>2				0.85 (0.40-1.78)	
Vitamin D, tertiles					
Lowest				1	1
Intermediate				1.89 (1.01-3.54)	1.89 (1.03-3.44)
Highest				2.29 (1.22-4.28)	2.22 (1.21-4.09)
Time before surgery, tertiles					
Lowest				1	1
Intermediate				1.72 (0.98-3.02)	1.63 (0.97-2.73)
Highest				1.35 (0.61-2.96)	
Early rehabilitation				2.38 (0.92-6.16)	2.24 (0.90-5.58)
c-statistic (of the model)		0.68	0.74	0.80	0.79
Grip strength continuous variable	268 (65.5)	1.09 (1.04-1.13)	1.04 (0.99-1.08)	1.05 (1.00-1.01)	1.06 (1.01-1.10)
c-statistic (of the model)		0.68	0.74	0.79	0.78

BADL = Basic Activities of Daily Living; CI = confidence interval.

Model 1 includes age, gender, and medical center. Model 2 includes age, gender, medical center, cognitive decline, depressive symptoms, and Basic Activities of Daily Living difficulty. Model 3 includes age, gender, medical center, cognitive decline, depressive symptoms, Basic Activities of Daily Living difficulty, caregiver assistance, time before surgery, type of surgery, early rehabilitation, Charlson Index, and vitamin D levels.

*Unnecessary variables were removed from the model using backward stepwise selection method (*P* for removal .1).

the patients with the greatest strength had a higher likelihood of walking recovery during the follow-up period than patients with lower grip performance (OR for highest tertile vs lowest, 4.07, CI, 2.11-7.85; OR continuous variable, 1.09, CI, 1.04-1.13); these results also were confirmed in the fully adjusted models (OR highest tertile vs lowest, 2.79, CI, 1.35-5.79; OR continuous variable, 1.05, CI, 1.01-1.10). Both fully adjusted models demonstrated good discrimination ability (c-statistic values of 0.80 for both outcomes) in predicting incident and persistent walking recovery (**Table 3**). To formally test the hypothesis that grip strength evaluation would improve the predictive value of the model on the basis of variables traditionally collected and used in clinical practice, we used the likelihood ratio test to compare the fully adjusted models with models that did not include the variable of grip strength. For both outcomes, the model including grip strength was statistically better than the model without grip strength (likelihood ratio test $P < .001$ and .02 for incident and persistent walking recovery, respectively).

Twenty percent of patients (n = 103) died during the follow-up period. Kaplan-Meier survival estimates showed that patients in the lowest tertile of grip strength had the highest probability of death during the 1-year follow-up (**Figure 1**). Nevertheless, this association was not confirmed in Cox proportional hazard models adjusted for age, gender, and other potential confounders (Supplemental Table 1, available online).

DISCUSSION

In this sample of older patients who underwent hip fracture surgery, greater grip strength, which was assessed at hospital admission before hip surgery, was significantly related to a higher probability of independent walking recovery within the year after surgery. Grip strength significantly correlated with several prognostic factors traditionally considered in clinical practice, including age, gender, neuropsychologic and functional status, comorbidity level, vitamin D plasma levels, and time before the surgical procedure. Nevertheless, our analysis demonstrated that the association between grip performance and walking recovery was clinically relevant and statistically independent of potential confounders, suggesting that grip strength assessment before hip surgery might provide important prognostic information for clinicians.

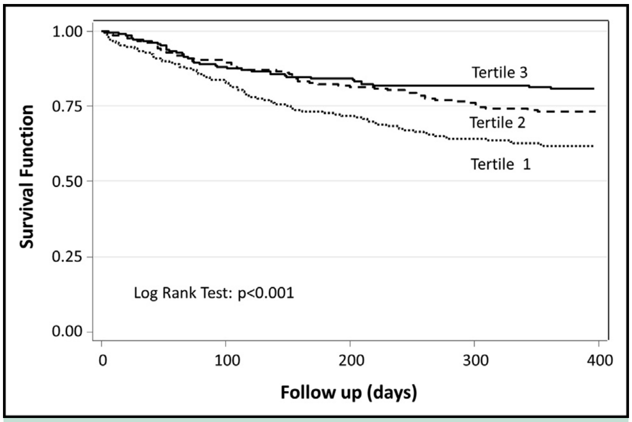

Figure 1 Kaplan-Meier survival estimates for probability of death according to grip strength tertiles.

Our results, based on 2 different outcome definitions, are in agreement with the findings of previous studies evaluating community-dwelling individuals, demonstrating that grip strength in older persons correlates with the strength of other muscular groups and that this measurement is highly predictive in terms of functional decline, disability, risk of hospitalization, and mortality.[12] For example, Visser et al[30] showed that reduced grip strength is related to poor lower-extremity performance, especially in men, whereas other studies demonstrated that older people with poor grip strength are at greater risk of falling and consequent hip fracture.[31] However, little was known about the predictive value of grip strength in terms of walking recovery after hip fracture. Indeed, Visser et al[32] reported that grip strength decline in the 12 months after hip fracture was associated with a lower likelihood of mobility recovery. More recently, Beloosesky et al[33] showed that grip strength, assessed after hip surgery and combined with other covariates (age, upper limb functioning, and Functional Independence Measure), could predict motor functioning in the 6 months after hip fracture.

Despite several investigations, the biological relationship between grip strength and health status is still not completely known. Grip strength correlates with the strength of other muscular groups[34] and is influenced both by muscular and extramuscular factors, such as age, gender, genetic features, anthropometric characteristics, neuropsychologic status, level of comorbidity, disease severity, inflammation, oxidative stress, medications, physical activity, and environmental factors.[7,35,36] Furthermore, grip strength can be considered an indicator of hand bone mineral density in adults,[37] but it also can be used as a predictor of the risk of vertebral fracture in postmenopausal women[38] and of long-term, fracture-free survival in perimenopausal women.[39] Thus, it is reasonable to consider grip strength, like other objective measures of physical function,[40] a good indicator of health status and functional reserve[13] and to hypothesize that this simple functional test is able to provide information regarding the integrated and multisystemic effects of aging, comorbidity, disease severity, malnutrition, motivation, cognition, and body resilience on the health status of older persons.[6]

Although several epidemiologic studies have demonstrated the long-term association between grip strength and mortality in community-dwelling older people,[18] only a few studies have investigated this association in the acute care setting. In our study, we found a graded crude relationship between grip strength and 1-year mortality, but the association was not confirmed after adjusting for potential confounders. One of the possible explanations for this unexpected result could be that the acute event, hip fracture, exerted a stronger influence on survival and therefore hid the protective effect of increased grip strength.

Study Limitations

First, the sample was composed primarily of women, limiting the external validity and the generalizability of our findings to men. Second, anthropometric data regarding weight and height were not collected because patients were not able to stand at the time of hospital admission. Finally, the primary outcome of the study, walking recovery over the follow-up period, was assessed with only self-reported information collected by phone interview. Although our outcome definition was simple (independent walking) and information collected from the patients was confirmed by the usual caregiver, a certain degree of outcome misclassification cannot be completely ruled out.

CONCLUSIONS

Grip strength is a simple clinical parameter that is easily assessable at bedside, with an independent role in predicting functional outcome after hip fracture surgery and the ability to provide additional information irrespective of other characteristics commonly used in clinical practice. Approximately one third of the patients who walked independently before hip fracture lost their self-sufficiency during the 1-year follow-up period. Assessing grip strength at hospital admission can help clinicians better identify high-risk individuals who could benefit the most from intensive multidomain intervention programs, including but not limited to earlier surgery strategy, intensive nutritional support, and rehabilitation programs.[41]

References

1. Cooper C. The crippling consequences of fractures and their impact on quality of life. *Am J Med*. 1997;103:12S-19S.
2. Jette AM, Harris BA, Cleary PD, Campion EW. Functional recovery after hip fracture. *Arch Phys Med Rehabil*. 1987;68:735-740.
3. Magaziner J, Hawkes W, Hebel JR, et al. Recovery from hip fracture in eight areas of function. *J Gerontol A Biol Sci Med Sci*. 2000;55: M498-M507.
4. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001;56:M146-M156.
5. Volpato S, Cavalieri M, Guerra G, et al. Performance-based functional assessment in older hospitalized patients: feasibility and clinical correlates. *J Gerontol A Biol Sci Med Sci*. 2008;63:1393-1398.
6. Rantanen T, Masaki K, He Q, et al. Midlife muscle strength and human longevity up to age 100 years: a 44-year prospective study among a decedent cohort. *Age*. 2012;34:563-570.
7. Rantanen T, Guralnik JM, Foley D, et al. Midlife hand grip strength as a predictor of old age disability. *JAMA*. 1999;281:558-560.
8. Goodpaster BH, Park SW, Harris TB, et al. The loss of skeletal muscle strength, mass, and quality in older adults: The Health, Aging and Body Composition study. *J Gerontol A Biol Sci Med Sci*. 2006;61A: 1059-1064.
9. Auyeung TW, Lee JS, Kwok T, Woo J. Physical frailty predicts future cognitive decline—a four-year prospective study in 2737 cognitively normal older adults. *J Nutr Health Aging*. 2011;15:690-694.
10. Giampaoli S, Ferrucci L, Cecchi F, et al. Handgrip strength predicts incident disability in non-disabled older men. *Age Ageing*. 1999;28:283-288.
11. Cawthon P, Fox KM, Gandra SR, et al. Health, Aging and Body Composition Study. Do muscle mass, muscle density, strength, and physical function similarly influence risk of hospitalization in older adults? *J Am Geriatr Soc*. 2009;57:1411-1419.
12. Rantanen T, Volpato S, Ferrucci L, et al. Handgrip strength and cause specific and total mortality in older disabled women: exploring the mechanism. *J Am Geriatr Soc*. 2003;51:636-641.
13. Lauretani F, Russo CR, Bandinelli S, et al. Age-associated changes in skeletal muscles and their effect on mobility: an operational diagnosis of sarcopenia. *J Appl Physiol*. 2003;95:1851-1860.
14. Norman K, Stobäus N, Gonzalez MC, et al. Hand grip strength: outcome predictor and marker of nutritional status. *Clin Nutr*. 2011;30: 135-142.
15. Cruz-Jentoft AJ, Baeyens JP, Bauer JM, et al. Sarcopenia: European consensus on definition and diagnosis: Report of the European Working Group on Sarcopenia in Older People. *Age Ageing*. 2010;39: 412-423.
16. Savino E, Sioulis F, Guerra G, et al. Potential prognostic value of handgrip strength in older hospitalized patients. *J Frailty Aging*. 2012;1:32-38.
17. Maguire PA, Taylor IC, Stout RW. Elderly patients in acute medical wards: factors predicting length of stay in hospital. *Br Med J*. 1986;292:1251-1253.
18. Cooper R, Kuh D. Objectively measured physical capability levels and mortality: systematic review and meta-analysis. *BMJ*. 2010;341:c4467.
19. Pioli G, Frondini C, Lauretani F, et al. Time to surgery and rehabilitation resources affect outcomes in orthogeriatric units. *Arch Gerontol Geriatr*. 2012;55:316-322.
20. Pioli G, Lauretani F, Davoli ML, et al. Older people with hip fracture and IADL disability require earlier surgery. *J Gerontol A Biol Sci Med Sci*. 2012;67:1272-1277.
21. Hillman TE, Nunes QM, Hornby ST, et al. A practical posture for hand grip dynamometry in the clinical setting. *Clin Nutr*. 2005;24:224-228.
22. Richards LG. Posture effects on grip strength. *Arch Phys Med Rehabil*. 1997;78:1154-1156.
23. Katz S, Ford AB, Moskowitz R, et al. Studies of illness in the aged: the Index of ADL: a standardized measure of biological and psychosocial function. *JAMA*. 1963;185:914-919.
24. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. *Gerontologist*. 1969;9: 179-186.
25. Parker MJ, Currie CT, Thorngren KG. Standardised Audit of Hip Fractures in Europe (SAHFE). *Hip Int*. 1998;8:10-15.
26. Pfeiffer E. A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. *J Am Geriatr Soc*. 1975;23:433-441.
27. Hoyl MT, Alessi CA, Harker JO, et al. development and testing of a five-item version of the Geriatric Depression Scale. *J Am Geriatr Soc*. 1999;47:873-878.
28. Charlson ME, Pompei P, Ales KL, MacKenzie CR. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40:373-383.
29. Lauretani F, Frondini C, Davoli ML, et al. Vitamin D supplementation is required to normalize serum level of 25OH-Vitamin D in older adults: an observational study of 974 hip fracture inpatients. *J Endocrinol Invest*. 2012;35:921-924.
30. Visser M, Deeg DJ, Lips P, et al. Skeletal muscle mass and muscle strength in relation to lower-extremity performance in older men and women. *J Am Geriatr Soc*. 2000;48:381-386.
31. Bean N, Bennett KM, Lehmann AB. Habitus and hip fracture revisited: skeletal size, strength and cognition rather than thinness? *Age Ageing*. 1995;24:481-484.
32. Visser M, Harris TB, Fox KM, et al. Change in muscle mass and muscle strength after a hip fracture: relationship to mobility recovery. *J Gerontol A Biol Sci Med Sci*. 2000;55:M434-M440.
33. Beloosesky Y, Weiss A, Manasian M, Salai M. Handgrip strength of the elderly after hip fracture repair correlates with functional outcome. *Disabil Rehabil*. 2010;32:367-373.

34. Rantanen T, Era P, Kauppinen M, et al. Maximal isometric muscle strength and socio-economic status, health, and physical activity in 75-year-old persons. *J Aging Phys Act*. 1994;2:206-220.
35. Rantanen T, Masaki K, Foley D, et al. Grip strength changes over 27 years in Japanese-American men. *J Appl Physiol*. 1998;85: 2047-2053.
36. Reed T, Fabsitz RR, Selby JV, et al. Genetic influences and grip strength norms in the NHLBI twin study males aged 59-69. *Ann Hum Biol*. 1991;18:425-432.
37. Bauer DC, Browner WS, Cauley JA, et al. Factors associated with appendicular bone mass in older women. The Study of Osteoporotic Fractures Research Group. *Ann Intern Med*. 1993;118: 657-665.
38. Dixon WG, Lunt M, Pye SR, et al. Low grip strength is associated with bone mineral density and vertebral fracture in women. *Rheumatology*. 2005;44:642-646.
39. Sirola J, Rikkonen T, Tuppurainen M, et al. Grip strength may facilitate fracture prediction in perimenopausal women with normal BMD: a 15-year population-based study. *Calcif Tissue Int*. 2008;83:93-100.
40. Volpato S, Cavalieri M, Sioulis F, et al. Predictive value of the short physical performance battery following hospitalization in older patients. *J Gerontol A Biol Sci Med Sci*. 2011;66A:89-96.
41. Ip EH, Church T, Marshall SA, et al. Physical activity increases gains in and prevents loss of physical function: results from the Lifestyle Interventions and Independence for Elders Pilot Study. *J Gerontol A Biol Sci Med Sci*. 2013;68:426-432.

Supplemental Table 1 Cox Proportional Hazard Models (95% Confidence Intervals) of All-Cause Mortality by Grip Strength at Baseline

	Hazard Ratio (95% CI)			
Tertiles	No. of Events (%)	Model 1	Model 2	Model 3
Lowest	44 (25.6)	1	1	1
Intermediate	34 (19.6)	0.74 (0.46-1.20)	0.96 (0.57-1.59)	1.15 (0.67-1.97)
Highest	25 (15.7)	0.59 (0.33-1.07)	0.95 (0.50-1.78)	1.00 (0.52-1.90)
P value of test for trend		0.074	0.858	0.999
Grip strength continuous variable	103 (20.4)	0.97 (0.93-1.00)	0.99 (0.96-1.04)	1.00 (0.97-1.04)

CI = confidence interval.

Model 1 includes age, gender, and medical center. Model 2 includes age, gender, medical center, difficulty in at least 1 Activity of Daily Living 2 weeks before hip fracture, cognitive decline, and depressive symptoms. Model 3 includes age, gender, medical center, Basic Activities of Daily Living difficulty, cognitive decline, depressive symptoms, Charlson Index, caregiver assistance, time before surgery, type of surgery, early rehabilitation, and vitamin D levels.