

# Handgrip Strength Thresholds for Predicting Independent Walking Ability After Hip Fracture Surgery in Mexican Elderly: A Prospective Cohort Study

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## Abstract

**Objective:** Hip fractures are commonly associated with disability, and muscle strength is an independent prognostic factor for functionality and walking ability. Handgrip strength (HGS) measurement represents an easy and economical strategy for estimating muscle strength and establishing a functional prognosis in elderly patients with hip fractures. Currently, there are no HGS thresholds in the Mexican population to ascertain functional outcomes, such as independent walking ability. The objective was to determine a cut-off point associated with independent walking ability.

**Materials and Methods:** Prospective cohort study that included hospitalized patients older than 60 years for hip fracture. HGS was measured next day of surgery. Cognitive, functional, and nutritional status were also assessed, as well as comorbidities and walking ability. Logistic regression was employed to confirm the association with independent walking.

**Results:** We included 185 patients, 61 men and 124 women, with 34 individuals (18.3%) capable of independent walking. Participants with high HGS were younger, had lower comorbidity scores, and displayed higher functional pre-fracture scores. The thresholds for predicting independent walking were  $\geq 12$  kg for women and  $\geq 19$  kg for men. High HGS and lower comorbidity scores were independently associated with independent walking.

**Conclusion:** HGS in the Mexican population predicts independent walking after hip fracture surgery.

**Keywords:** Clinical geriatrics, elderly, falls, frailty, gait, geriatric trauma, handgrip strength, hip fracture, sarcopenia

## Introduction

Hip fractures in older adults represent a significant public health issue owing to a marked increase in incidence over the past two decades, resulting from aging populations, increased longevity, and a higher prevalence of osteoporosis (1). This trend is expected to continue globally in the coming years, placing pressure on healthcare systems and families due to the challenges of demographic shifts and resource limitations, thereby imposing a substantial economic burden (2). Hip fractures significantly

impair patients' functional status. For instance, up to 80% of patients who survive an initial hospitalization for a hip fracture experience permanent disability (3), and 40% do not regain the ability to walk independently (4).

Several factors influence functional outcomes following a hip fracture (2,5), with muscle strength being one of the most critical for physical recovery (6). Handgrip strength (HGS) is a measurable indicator of overall muscular strength and physical capability and has prognostic value for survival (7) and for functionality (8–13).

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However, there are notable ethnic differences in HGS (14), suggesting that prognostic cut-off points may vary depending on the population investigated. In Mexico, studies have examined the associations among HGS, functionality, and complications in hospitalized elderly patients (15,16). Although evidence suggests that higher HGS is associated with independent walking, no specific cut-off points have been established in the Mexican population because of a lack of prognostic studies. Therefore, this study aimed to determine an HGS cut-off point associated with independent walking recovery in Mexican subjects with hip fracture.

## Materials and Methods

### Study Design

The current cohort study was conducted in the Hip and Pelvic Surgery Department at the Unidad Médica de Alta Especialidad Hospital de Traumatología y Ortopedia No. 21, from the Mexican Institute of Social Security (IMSS), located in Monterrey, Mexico. Ambulatory adults aged  $\geq 60$  years who were hospitalized for hip fracture surgery between February and June 2022 were invited to participate; those who accepted and signed informed consent were included in the study. Patients with pathological fractures and those lost to follow-up were excluded. The study was reviewed and approved by the Local Health Research Committee No. 1903 of the IMSS (institutional registration number: R-2022-1903-001, date: 01.03.2022).

### Variables

Data pertaining to social and demographic characteristics, such as age and sex, were extracted from medical records. Functional capacity before the fracture, mental status, and nutritional status were evaluated using the Barthel index (17), the short portable mental status questionnaire (18), and the mini nutritional assessment (MNA) scale, respectively (19). Finally, Charlson's comorbidity index (20), the FRAIL (21), and SARCF (22) scales were employed to measure comorbidity, frailty, and probable sarcopenia risk. The body mass index (BMI) was calculated from self-reported weight and height.

### Handgrip Strength

HGS assessments were performed by a qualified physician on the first day following hip fracture surgery, with measurements documented for both hands while the patient was in bed and the elbow flexed at 90 degrees. The evaluation utilized a Jamar® Electronic Hand Dynamometer, following the method outlined by Gumieiro et al. (23). For the analysis, the maximum grip strength value was used, as indicated by the Asian Working Group for sarcopenia (24).

### Walking Recovery

Walking recovery was assessed primarily via standardized telephone interviews with participants or caregivers. When telephone contact was unsuccessful after three attempts, electronic medical records were reviewed. Independent walking was defined as the ability to ambulate without personal assistance, six months after discharge (11). The same operational definition was applied to both telephone- and record-based assessments. Patients lost to follow-up were excluded from the analysis.

### Statistical Analysis

Descriptive statistics were employed to characterize the study population. Qualitative variables were summarized as absolute frequencies and percentages, whereas quantitative variables were expressed as medians and interquartile ranges, because most did not follow a normal distribution (Kolmogorov–Smirnov and Shapiro–Wilk tests,  $p < 0.05$ ). Group comparisons were performed using the Mann–Whitney U test for quantitative variables and the chi-square test or Fisher's exact test, as appropriate, for categorical variables. Receiver operating characteristic (ROC) curve analysis was used to evaluate the ability of HGS to predict recovery of independent walking. The Youden index was used to determine the optimal cut-off point. We conducted a binary logistic regression analysis, incorporating predictors such as age, gender, BMI, nutritional status, frailty, multimorbidity, and probable sarcopenia. These predictors were selected a priori based on their clinical relevance and were entered simultaneously into the multivariable logistic regression using the ENTER method. Goodness-of-fit was assessed with the Hosmer–Lemeshow test and pseudo- $R^2$  indices. Multicollinearity was assessed using the variance inflation factor (VIF) and the condition index. VIF values  $< 2.5$  and condition index values  $< 30$  were considered acceptable thresholds. All predictors met these criteria, indicating no relevant collinearity. Associations between HGS and other variables were reported as odds ratios derived from logistic regression models.

The sample size was calculated assuming an alpha level of 0.05, statistical power of 0.80, proportion one of 0.10, and proportion two of 0.40, yielding a minimum of 32 participants per group. A  $p$ -value  $< 0.05$  was considered statistically significant. All analyses were conducted using Stata/SE version 18 (Stata Corporation, College Station, TX, USA).

## Results

### Results of the Receiver Operating Characteristic Area Analysis

The study included 185 participants (61 men and 124 women), with 34 individuals (18.3%) capable of independent walking. ROC analysis demonstrated that maximal HGS had significant

discriminatory power in identifying individuals capable of independent ambulation in both male and female participants (Figure 1 and Table 1). The optimal cut-off values, as determined by the Youden index, were 19.5 kg for men and 12.05 kg for women. For practical application in clinical settings, these values were rounded to 19 kg and 12 kg, respectively, as fractional thresholds are not typically used at the bedside. This rounding did not significantly impact sensitivity, specificity, or likelihood ratios, which remained consistent with the Youden-derived cut-offs. In this cohort, the optimal thresholds derived from the Youden Index effectively distinguished participants who regained independent walking ability. When these values were applied, men with higher HGS exhibited excellent sensitivity and acceptable specificity, while women demonstrated moderate sensitivity and specificity. The likelihood ratios indicated a clinically meaningful increase in the probability of independent walking for those exceeding the cut-off, with consistent performance observed across both sexes.

**General Characteristics and Grip Strength Measures**

Individuals with lower HGS tended to be older and to have higher Charlson’s Comorbidity Index scores and lower pre-fracture Barthel Index scores. These individuals also exhibited

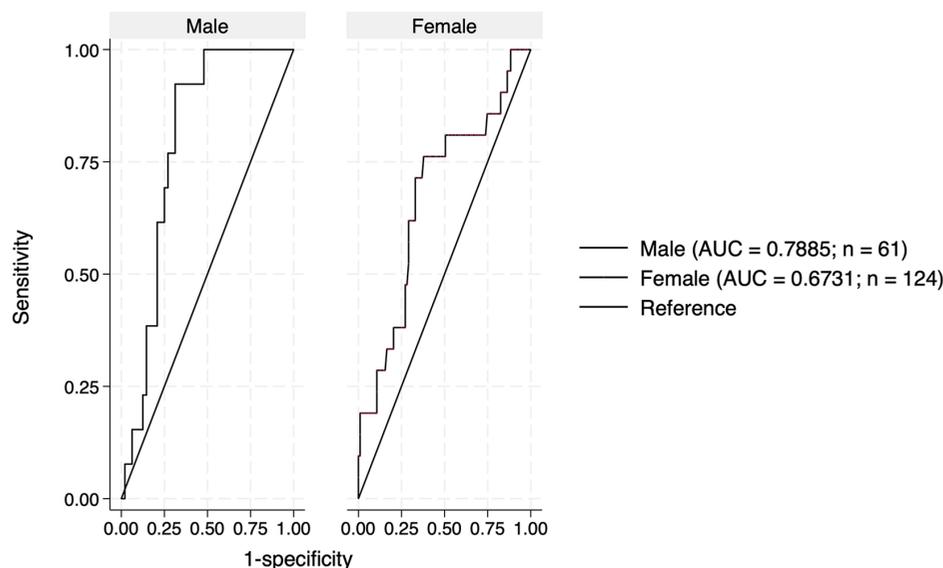
poorer cognitive and nutritional status, and a higher prevalence of probable sarcopenia and frailty (Table 2).

**Factors Associated with Independent Walking**

At six months following surgery, participants exhibiting high HGS demonstrated a significantly greater likelihood of regaining independent ambulation (Table 3). Multivariate analysis identified high HGS and lower scores on the Charlson’s comorbidity index as independent predictors of walking ability. The Hosmer–Lemeshow test confirmed an adequate model fit ( $\chi^2 = 8.322$ ,  $df = 8$ ,  $p = 0.403$ ), and the Nagelkerke  $R^2$  was 0.314. Multicollinearity diagnostics revealed variance inflation factor (VIF) values <2.5 and a condition index <30, indicating the absence of problematic collinearity.

**Discussion**

This study aimed to establish HGS thresholds associated with independent walking. As anticipated, grip strength was correlated with age, comorbidities, and functional, cognitive, and nutritional status, all of which are associated with sarcopenia, frailty, and muscle strength. These results align with findings from previous studies (1,9,11–13).



**Figure 1.** Sex-stratified ROC curves for maximal postoperative HGS predicting independent walking at 6 months after hip fracture surgery. AUC values and sample sizes for each sex are displayed within the figure.

ROC: Receiver operating characteristic, HGS: Handgrip strength, AUC: Area under the curve.

Group	Cut-off (kg)	AUC (95% CI)	Sensitivity (%)	Specificity (%)	LR+	LR-
Male	19.50	0.785 (0.683–0.886)	92.31	64.58	2.606	0.119
Female	12.05	0.682 (0.573–0.792)	71.43	65.05	2.044	0.439

Cut-off values are the Youden-optimal thresholds estimated from the continuous maximal handgrip strength analysis. Sensitivity, specificity, and AUC shown here correspond to the dichotomous predictor defined by those thresholds. For operational use in models and prospective estimates, integer thresholds were applied (19 kg in men; 12 kg in women). AUC: Area under the curve, CI: Confidence interval; LR+: Positive likelihood ratio, LR-: Negative likelihood ratio.

**Table 2. Clinical characteristics of participants according to grip strength values by sex.**

Variable	Male		p	Female		p
	Low HGS n = 32	High HGS n = 29		Low HGS n = 73	High HGS n = 51	
Age in years	79 (76–84)	77 (65–79)	0.024	81 (75–87)	78 (68–83)	0.005
Type of fracture			1.0			0.552
Intracapsular	12 (37.5%)	10 (34.5%)		24 (32.9%)	13 (25.5%)	
Trochanteric	18 (56.3%)	17 (58.6%)		46 (63%)	34 (66.7%)	
Subtrochanteric	2 (6.3%)	2 (6.9%)		3 (4.1%)	4 (7.8%)	
Type of surgery			0.972			0.232
Hip replacement	12 (37.5%)	11 (37.9%)		26 (35.6%)	13 (25.5%)	
Open reduction with internal fixation	20 (62.5%)	18 (62.1%)		47 (64.4%)	38 (74.5%)	
Length of stay (days)	12 (10–16)	12 (10–14)	0.983	12 (9–14)	10 (8–14)	0.222
Days before surgery	10 (8–13)	9 (8–12)	0.954	9 (7–12)	8 (6–11)	0.189
Body mass index	24.1 (22.1–26.0)	24.3 (22.6–27.7)	0.618	23.8 (21.1–27.2)	25.8 (24.0–28.9)	0.004
Mini Nutrition Assessment (score)	22.8 (18.3–24.0)	22.5 (19.5–24.5)	0.591	21.0 (17.0–23.5)	22.5 (19.5–24.0)	0.017
Short portable mental status questionnaire	6 (3–8)	3 (1–4)	<0.001	4 (3–7)	2 (1–5)	<0.001
Pre-fracture Barthel index	90 (78–95)	95 (85–100)	0.021	80 (65–90)	95 (85–100)	<0.001
Charlson comorbidity index (score)	3 (3–4)	3 (2–3)	0.002	3 (3–4)	3 (3–4)	0.096
Sarcopenia	14 (43.8%)	7 (24.1%)	0.107 0.177	51 (69.9%)	19 (37.3%)	<0.001
Frailty status			0.012			<0.001
Frail	7 (21.9%)	1 (3.4%)		26 (35.6%)	6 (11.8%)	
Prefrail	17 (53.1%)	11 (37.9%)		43 (58.9%)	30 (58.8%)	
Robust	8 (25%)	17 (58.6%)		4 (5.5%)	15 (29.4%)	
Death	7 (21.9%)	2 (6.9%)	0.151	10 (13.7%)	2 (3.9%)	0.120
Walk without help	1 (3.1%)	12 (41.4%)	<0.001	6 (8.2%)	15 (29.4%)	0.002

Data are presented as median (interquartile range) or absolute frequencies (%). Comparisons were performed using the Mann–Whitney U test for continuous variables and the chi-square or Fisher’s exact test for categorical variables. Low handgrip strength was defined as <19 kg in men and <12 kg in women; high handgrip strength as ≥19 kg in men and ≥12 kg in women. HGS: Handgrip strength.

**Table 3. Logistic regression analysis for independent walking.**

Variable	p-value	OR (95% CI)
High handgrip strength (ref = low HGS)	0.003	5.236 (1.788–15.331)
Age (years)	0.158	0.971 (0.933–1.011)
Female sex (ref = male)	0.774	1.152 (0.438–3.032)
Mini nutritional assessment (score)	0.135	0.896 (0.775–1.035)
Body mass index	0.158	0.922 (0.824–1.032)
Charlson Comorbidity Index (score)	0.034	0.541 (0.306–0.955)
Short portable mental status (score)	0.901	1.013 (0.821–1.251)
Pre-fracture Barthel index (score)	0.496	1.017 (0.968–1.069)
Frailty status		
-Prefrail (ref = frail)	0.630	1.544 (0.264–9.025)
-Robust (ref = frail)	0.905	1.143 (0.129–10.150)
Not sarcopenic (ref = sarcopenia)	0.325	1.906 (0.528–6.889)

All p-values were obtained through logistic regression analysis. Scores are shown as continuous variables for mini nutritional assessment, Charlson comorbidity index, short portable mental status questionnaire, and pre-fracture Barthel index. Reference categories: frail for frailty status; sarcopenia for sarcopenia status; male for sex; low HGS for handgrip strength. OR: Odds ratio, CI: Confidence interval, HGS: Handgrip strength.

The results indicated that high HGS was positively correlated with independent walking recovery. Consistent with Savino et al. (11), our results suggest that functional capacity, measurable through HGS, has predictive value for walking outcomes. While the methodology differed—Savino et al. (11) used terciles—our thresholds closely resemble those reported by Chang et al. (20.5 kg for men and 11.5 kg for women) (13). Similarly, Hashida et al. (25) reported a cut-off of 13.2 kg in a Japanese population, supporting the robustness of our findings. According to the results obtained by Pérez-Rodríguez et al. (12), thresholds of 23 kg for men and 13 kg for women yielded comparable outcomes, albeit with slight variations attributable to population differences. García-Peña et al. (15) identified a cut-off of 20.65 kg for men in the Mexican population, consistent with our findings.

Evidence from other settings further reinforces our results. In Colombia, Toro et al. (26) demonstrated that HGS was a strong predictor of one-year mortality after hip fracture, underscoring its prognostic value in Latin American populations exposed to similar socioeconomic and healthcare constraints. Selakovic et al. (6) showed that early postoperative HGS strongly predicted functional recovery at 3 and 6 months, supporting the validity of our methodological choice to measure HGS soon after surgery. Conversely, Steihaug et al. (27) found that sarcopenia defined using combined criteria did not predict changes in mobility after hip fracture, suggesting that HGS may provide a more robust and clinically actionable indicator. Likewise, Milman et al. (28) reported that HGS independently predicted successful rehabilitation, confirming its clinical utility as a simple, low-cost tool in hip fracture care.

In contrast, the thresholds for diagnosing sarcopenia (27 kg for men and 16 kg for women) (29) are higher than our cut-off points, which reflects the frailty of our cohort, in which 75% were frail or pre-frail and 49% were sarcopenic. This vulnerability is consistent with observations made by Menéndez et al. (30). Despite numerous known predictors of functional recovery (5), this study found that only high HGS and lower comorbidity scores were significantly associated with independent walking. Although age, nutritional status (MNA), and frailty are recognized predictors of recovery after hip fracture, they did not remain independent predictors in our multivariable model (Table 3). This should be interpreted in light of methodological constraints: the limited number of outcome events reduced statistical power and widened confidence intervals, and conceptual overlap among geriatric constructs (e.g., MNA includes BMI; frailty intersects with comorbidity and functional status) may have attenuated their apparent effects when modeled simultaneously. Importantly, HGS may act as an integrative marker of overall physiological reserve, thereby capturing variance otherwise attributable to age, nutrition, or frailty. Accordingly, the absence of statistical significance for these domains likely reflects limited precision rather than a lack of clinical relevance.

Measuring HGS early post-surgery may enhance its predictive utility, as noted by Savino et al. (11). In our study, HGS was measured postoperatively, allowing the exclusion of strength loss due to bed rest (6,11) and reflecting real-world rehabilitation conditions. It is noteworthy that the cut-off values identified in this cohort were lower than those proposed by international sarcopenia criteria (27 kg for men and 16 kg for women) (29). This likely reflects the clinical vulnerability of our population—characterized by high rates of frailty and probable sarcopenia—and highlights the importance of developing population-specific thresholds. From a clinical perspective, using locally validated cut-offs may improve the identification of patients at risk of poor functional recovery, guiding earlier physiotherapy, tailored nutritional interventions, and optimized discharge planning.

HGS has proven useful for the early identification of older adults at risk of adverse outcomes, including mortality (7), functional decline (6), and pressure ulcers (1) and is a trustworthy and cost-effective tool (9,11).

This study has several strengths. First, it provides sex-specific cut-off values for HGS associated with independent walking recovery in a Mexican cohort, addressing a critical gap in evidence from Latin America. Second, it is among the few studies that combine HGS thresholds with comprehensive geriatric variables (nutritional status, cognition, comorbidity, and frailty). Third, standardized and validated tools were used for key constructs, enhancing methodological rigor. Finally, the study provides actionable thresholds that can be directly implemented during bedside assessments to support rehabilitation planning in routine clinical practice.

### Study Limitations

This study has several limitations. First, the self-reported nature of height and weight data may have introduced non-differential measurement error in the calculation of BMI, potentially attenuating the effect estimates. In addition, comorbidities and health status were self-reported; however, previous research supports the reliability of these self-reports (31). Second, occupational history, which could influence grip strength, was not considered (32). Third, HGS measurement depends on participant cooperation and on proper positioning of the shoulder, elbow, and wrist (23,32). Although delirium was not systematically assessed with a dedicated tool, cognitive status was evaluated with the Pfeiffer (18) short portable mental status Questionnaire to ensure adequate participation. Nonetheless, results may still have been influenced by acute postoperative factors such as pain or sedation. While this could attenuate the accuracy of HGS as a pure measure of muscle strength, its predictive validity in this real-world context supports its role as a pragmatic, clinically applicable tool. Fourth, independent walking outcomes were assessed primarily via standardized telephone interviews and, when participants could not be reached, through review of

medical records; the same operational definition (independent ambulation without personal assistance) was applied. Although this approach was consistent, the lack of a formal validation study between telephone-based and record-based classifications introduces the possibility of misclassification bias. Fifth, five participants (2.7%) were lost to follow-up. This relatively small attrition could still introduce bias (33), particularly if losses occurred disproportionately among frailer or less-mobile patients, although this could not be formally assessed. Sixth, some confidence intervals were wide, reflecting the relatively small sample size in certain subgroups; this limits the precision of the estimates and warrants cautious interpretation. In particular, sex-specific ROC analyses were based on a limited number of positive outcomes, resulting in less stable AUC estimates and wider confidence intervals; therefore, these thresholds should be regarded as exploratory until they are validated in larger cohorts. Another important limitation is the relatively low number of events (independent walkers) compared to the number of predictors included in the logistic regression model, yielding an events-per-variable ratio below the recommended threshold. Although predictors were pre-specified based on clinical relevance and collinearity diagnostics supported model stability, limited EPV may have led to model overfitting, inflated odds ratios, and wide confidence intervals. Additionally, sarcopenia was assessed only with the SARC-F screening tool, without objective measures of muscle mass or physical performance, and thus, results should be interpreted as indicating probable sarcopenia risk rather than confirmed sarcopenia. Finally, this single-center study, conducted in Monterrey, Mexico, had local rehabilitation resources and social support structures, which may limit the generalizability of our findings to other populations and healthcare systems. Therefore, new multicenter studies are warranted to validate the proposed cut-off points and to adapt them to diverse clinical contexts.

## Conclusion

HGS obtained shortly after hip-fracture surgery provides a practical indicator of 6-month independent ambulation. Using simple, sex-specific thresholds, clinicians can flag patients who may benefit from earlier, more intensive rehabilitation, potentially reducing the substantial burden of persistent mobility loss on patients, families, and the healthcare system. Future work should validate these thresholds and assess their impact on care pathways.

## Ethics

**Ethics Committee Approval:** The study was reviewed and approved by the Local Health Research Committee No. 1903 of the Mexican Social Security Institute (IMSS) (institutional registration number: R-2022-1903-001, date: 01.03.2022).

**Informed Consent:** Informed consent was obtained from all participants prior to their inclusion in the study.

## Footnotes

### Authorship Contributions

Surgical and Medical Practices: A.M.F.S., H.E.G.C., M.R.M., H.G.H., E.D.d.L.G., Concept: A.M.F.S., W.V.S., H.E.G.C., M.R.M., Design: A.M.F.S., W.V.S., H.E.G.C., M.R.M., E.D.d.L.G., Data Collection or Processing: H.E.G.C., M.R.M., Analysis or Interpretation: A.M.F.S., W.V.S., H.E.G.C., M.R.M., H.G.H., E.D.d.L.G., Literature Search: A.M.F.S., W.V.S., H.E.G.C., M.R.M., H.G.H., Writing: A.M.F.S., W.V.S., H.E.G.C., M.R.M., H.G.H., E.D.d.L.G.

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