Psychometric Properties of the Barthel Index Used at Intensive Care Unit Discharge

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Background The Barthel Index, originally developed and validated to assess activities of daily living in patients with neuromuscular disorders, is commonly used in research and clinical practice involving critically ill patients.
Objectives To evaluate the internal consistency, reliability, measurement error, and construct validity of the Barthel Index used at intensive care unit discharge.
Methods In this observational study, 2 physiotherapists measured the physical functioning of 122 patients at intensive care unit discharge, using the Barthel Index and other measurement instruments.
Results The patients had a median (IQR) age of 56 (47-66) years, and 62 patients (51%) were male. The primary reason for intensive care unit admission was sepsis (28 patients [23%]), and 83 patients (68%) were receiving mechanical ventilation. The Cronbach α value indicating internal consistency was 0.81. For interrater reliability, the intraclass correlation coefficient for the total score was 0.98 (95% CI, 0.97-0.98; $P<.001$) and the κ statistic for the individual items was 0.54 to 0.94. The standard error of measurement was 7.22, the smallest detectable change was 20.01, and the 95% limits of agreement were −10.3 and 11.8. The Barthel Index showed moderate to high correlations with the other physical functioning measurement instruments ($\rho = 0.57$ to 0.88; $P<.001$ for all).
Conclusion The Barthel Index is a reliable and valid instrument for assessing physical functioning at intensive care unit discharge. (*American Journal of Critical Care.* 2022; 31:65-72).

doi:https://doi.org/10.4037/ajcc2022732

A stay in the intensive care unit (ICU) is associated with prolonged immobilization and inactivity, often resulting in reduced muscle strength and endurance as well as loss of balance and motor coordination.[1] This functional decline persists after hospital discharge and can negatively affect the patient's quality of life.[2] Thus, assessing the patient's physical functioning during and after an ICU stay is important.[1]

A review by González-Seguel et al[3] described 60 instruments that have been used to measure physical functioning in the ICU, including the Barthel Index. The Barthel Index was developed to assess the ability of patients with neuromuscular disorders to perform activities of daily living and is considered a measure of functional independence.[4,5] Although the Barthel Index was not specifically designed or validated for use in the ICU,[1] it is commonly used to evaluate physical functioning in the critically ill population in both research and clinical practice.[6-8]

Although some questions remain regarding the use of the Barthel Index in the ICU (a setting with several barriers to performing activities of daily living), the scale is considered a global measure that includes capacity for self-care and thus may provide useful information to treatment providers on the patient's physical functioning throughout the rehabilitation process (ICU, general care areas in the hospital, and outpatient clinics).[9] The Barthel Index is more suitable than another functional measure, the Katz Index, for assessing patients after an ICU stay[10]; in addition, it has good measurement properties in patients with stroke and older people and has been validated for use in outpatient clinics.[5,11,12] The scale comprises the following domains identified by the World Health Organization's International Classification of Functioning, Disability, and Health: *mobility, self-care, other body functions,* and *products and technology for personal use in daily living.* This multidimensionality distinguishes the Barthel Index from the other physical functioning measurement scales used in the ICU, most of which address only the mobility domain.[3] These factors may explain why the Barthel Index is so widely used in different settings, including the ICU.

The Barthel Index has not been validated for use in the ICU.

Although the psychometric properties of the Barthel Index when used in critically ill patients have been evaluated previously,[13] these studies had some limitations: the patients were outside the ICU setting or in a specialized center for weaning from mechanical ventilation, and most of the correlations reported in assessment of construct validity were between respiratory and peripheral muscle strength. Thus, the purpose of this study was to evaluate the internal consistency, reliability, and measurement error of the Barthel Index used at ICU discharge, as well as its construct validity compared with functional scales that have been specifically created for use in the ICU and measures of strength.

Methods

Study Design and Setting

This cross-sectional observational study was performed in a 10-bed general ICU at the University Hospital at Federal University of Santa Catarina, Florianopolis, Brazil, during a consecutive 8-month period beginning in January 2018. The study was approved by the Federal University of Santa Catarina Human Research Ethics Committee (protocol 63173716.0.0000.0121) and followed the Consensus-Based Standards for the Selection of Health Measurement Instruments (COSMIN).[14]

Characteristics of Participants

All patients aged 18 years or older who were consecutively admitted to the ICU were eligible for the study. The inclusion criteria were completion of a 48-hour stay in the ICU and provision of written informed consent by the participant or a family member. The exclusion criteria were clinical evolution to palliative care, brain death, transfer to another hospital during the ICU stay, death in the ICU, inadequate level of consciousness—defined as not being able to follow 3 of 5 orders (open and close your eyes, look at me, open your mouth and put out your tongue, nod your head, and raise your

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eyebrows)[15]—or cognitive impairment, physical dysfunction such as amputation or paralysis, and the decision by a patient or a family member to withdraw from the study.

Data Collection

After patients were enrolled in the study, data on their baseline demographic and clinical characteristics were obtained from the medical records. Data were collected on age, sex, body mass index, Acute Physiology and Chronic Health Evaluation II score, Simplified Acute Physiology Score III, Charlson Comorbidity Index, ICU diagnosis, ICU and hospital length of stay, use of mechanical ventilation, days receiving mechanical ventilation, and hospital outcome after a hospital stay. Each patient was assessed for physical functioning at ICU discharge, if tolerated, or up to 24 hours after discharge by 2 physiotherapists with the same amount of clinical experience.

Instruments

The physical functioning assessment included use of the following instruments:

- Barthel Index: measures the patient's ability to perform 10 basic activities of daily living (feeding, grooming, toilet use, bathing, bowel and bladder control, dressing, transfers, stair-climbing, and ambulation), with the total score ranging from 0 to 100 points[4]
- Perme ICU Mobility Score (Perme Score): measures the mobility status of an ICU patient, with the total score ranging from 0 to 32 points[16,17]
- Functional Status Score for the Intensive Care Unit (FSS-ICU): measures performance of 5 functional tasks, with the total score ranging from 0 to 35 points[18-20]
- Physical Function ICU Test-scored (PFIT-s): measures a patient's ability to perform 4 tasks, with the total score ranging from 0 to 12 points (ordinal scale)[21,22]
- Medical Research Council Sum Score (MRC-SS): tests the patient's peripheral muscle strength, with the total score ranging from 0 to 60 points[23]
- Handgrip dynamometry: measures grip strength in the dominant hand; the current study used a Jamar Plus+ dynamometer (model 12-0604) and followed the recommendations of the American Society of Hand Therapists[24]
- Handheld dynamometry: measures isometric strength; the current study used the Lafayette dynamometer (model 01165) to test knee-extension strength[25]

The dynamometric measures were tested 3 times, with the highest score used. The maximum acceptable variation among these measurements was set at 10%.[24] For all the instruments, a higher score reflected better function or strength.

Some instruments used in this study contain items evaluated in the same way (eg, sit-to-stand transfer). Thus, we created an assessment sequence and a record sheet to avoid requiring the patient to perform the same task more than once. This procedure protected the patient from possible fatigue and allowed several scales to be administered simultaneously. The main rater (who administered the tests) and a second rater (who only observed the procedure) were trained in scale use and acquainted with the assessment sequence. To avoid bias, both raters completed the record sheet immediately after finishing the assessment, without any contact or discussion between them, and the functions of the rater and observer were alternated every 2 patients.[16,17] The same order was used to evaluate all patients, with each evaluation lasting approximately 1 hour.

No criterion standard exists for evaluating physical functioning in the ICU.

To improve understanding, we regarded the Perme Score, FSS-ICU, and PFIT-s as specific ICU functional scales and the MRC-SS, handgrip dynamometry, and handheld dynamometry for knee extension as strength measures.

Data Analysis

Patients' baseline demographic and clinical characteristics were expressed with descriptive statistics, using mean and SD for normally distributed data, median and IQR for non–normally distributed data, and frequency and percentage for categorical data. The Kolmogorov-Smirnov test was used to determine the data's normality.

Internal consistency was determined using the Cronbach α, with a value of 0.70 set as the minimum reliability standard.[26] Interrater reliability was determined using the intraclass correlation coefficient (ICC; 2-way random effects, absolute agreement, single measurement) for the total scores and the κ statistic for the Barthel Index categories (described below) and individually for each domain (items 1 to 10). Values above 0.75 were considered excellent.[27] For analysis of interrater measurement error, the agreement standard error of measurement ($SEM_{agreement}$), the smallest detectable change at the individual and group levels ($SDC_{individual}$ and SDC_{group}, respectively), and the limits of agreement were calculated. Moreover, the Bland-Altman plot was used to determine interrater agreement in the total score for the Barthel Index.[28]

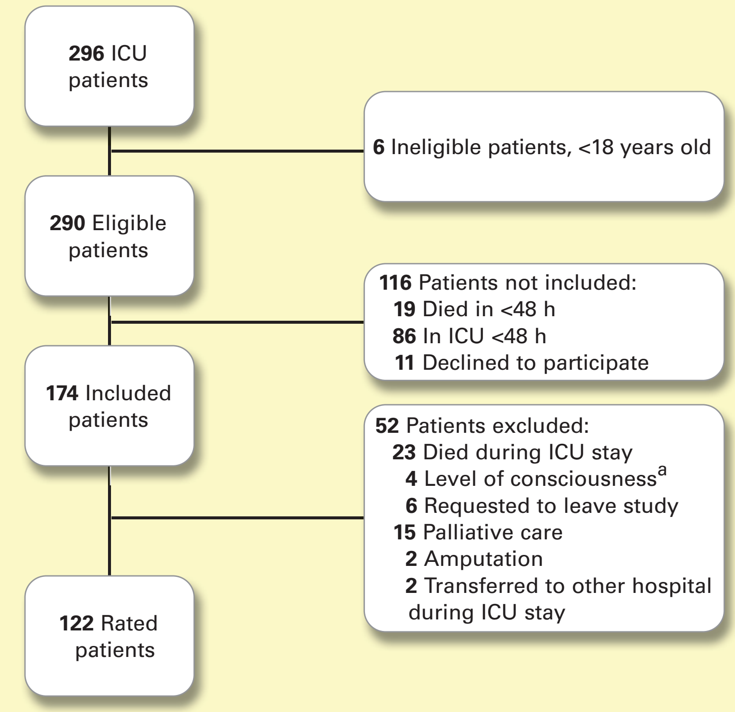

Figure 1 Flow chart of eligibility and inclusion criteria.

Abbreviation: ICU, intensive care unit.

[a] Patient could not follow 3 of 5 orders (open and close your eyes, look at me, open your mouth and put out your tongue, nod your head, and raise your eyebrows).[15]

The Barthel Index incorporated 2 and 5 categories according to different definitions. The 2 categories were moderate to severe disability (≤75 points) and mild to no impairment (>75 points).[29] The 5 categories were total dependence (0-20), severe dependence (21-60), moderate dependence (61-90), slight dependence (91-99), and independence (100).[30]

The proportions of the evaluations with minimum scores (floor effect) and maximum scores (ceiling effect) were calculated. The floor and ceiling effects were considered present if more than 15% of the respondents achieved the lowest or highest possible score. The presence of a floor or ceiling effect indicates that the instrument has limited content validity and the participants with the lowest or highest possible scores could not be distinguished from one another, thus reducing reliability.[26]

A high correlation was found between the Barthel Index and the specific ICU functional scales.

Although several physical functioning scales have been developed in recent years, none has been accepted as the criterion standard for evaluating the physical functioning of critically ill patients. Thus, we evaluated the construct validity of the Barthel Index by comparing it with the Perme Score, the FSS-ICU, the PFIT-s, the MRC-SS, handgrip dynamometry, and handheld dynamometry for knee extension. We adopted the hypothesis that the Barthel Index would have a high and positive correlation with the specific ICU functional scales, with a ρ of at least 0.75,[26] and a positive and moderate correlation with the strength measures.[31] The Spearman correlation was used to test this association.

We aimed for a sample size of at least 100 because this minimum is recommended in the COSMIN checklist for studies of measurement properties and considered excellent.[32] All patients included were considered for the analyses of internal consistency, reliability, measurement error, floor and ceiling effects, and construct validity. There were no missing data in the analyses. Some analyses require only 1 value to perform the calculations; therefore, we used the main rater's scores.

All statistical analyses were performed using IBM SPSS for Windows, version 22.0. For all analyses, *P* values of less than .05 were considered statistically significant.

Results

From January to August 2018, a total of 296 patients were admitted to the ICU. After the exclusion criteria were applied, 122 patients were included in the study (Figure 1).

The participants' baseline characteristics are summarized in Table 1. The median (IQR) age was 56 (47-66) years, and 62 patients (51%) were male. The main reasons for ICU admission were sepsis (28 patients [23%]) and elective postoperative (23 patients [19%]).

The participants' clinical and physical functioning characteristics are described in Table 2. Most patients (83 [68%]) received mechanical ventilation and were discharged to home (107 [88%]). Measurements of physical functioning using the specific ICU functional scales and strength measures showed a trend toward independence and strength, but some patients were diagnosed with ICU-acquired weakness using the MRC-SS (17%) and handgrip dynamometry (20%). Most patients left the ICU setting with moderate to severe disability measured with the Barthel Index, and only 37 patients (30%) were able to walk independently (Table 3).

Values for internal consistency (Cronbach α) and interrater reliability (κ statistic) are shown in Table 4. Interrater reliability for the Barthel Index total score based on the ICC was 0.98 (95% CI, 0.97-0.98) ($P<.001$). The $SEM_{agreement}$ was 7.22, the $SDC_{individual}$ was 20.01, and SDC_{group} was 1.81. The floor and ceiling effects for the Barthel Index (total score) were 11% and 1%, respectively.

The Bland-Altman plot of the total score on the Barthel Index to determine interrater agreement is shown in Figure 2. The mean (SD) interrater bias was 0.74 (5.63), with 95% limits of agreement of −10.3 and 11.8.

The study's hypothesis was confirmed, with a positive and high correlation between the Barthel Index and the specific ICU functional scales. Furthermore, the Barthel Index had moderate correlations with the strength measures (Table 5).

Discussion

To our knowledge, this is the first study to evaluate the Barthel Index's psychometric properties at ICU discharge and to correlate these outcomes with those of other functional scales specifically created for use in the ICU. The results of this study indicate that the Barthel Index is a reliable and valid scale for application at ICU discharge, with excellent internal consistency, moderate to excellent interrater reliability, high correlations with the other functional scales currently used in the ICU, and moderate correlations with the strength measures.

The study's internal consistency had a Cronbach α value (0.81) that was above the intended cutoff value of 0.70, which is considered sufficient,[33] and similar to that found in neurological populations (0.86 and 0.92).[30] The interrater reliability of the Barthel Index was satisfactory, with ICC and κ values higher than 0.70.[33] Individually, most items demonstrated excellent interrater reliability. The items of grooming, bathing, and bowel control had the lowest levels. Collin et al[5] conducted a study in an active rehabilitation center indicating that transfers, feeding, toileting, and dressing were the most difficult items for the raters to agree on. The low levels of interrater reliability in our study may have been due to the inherent subjectivity of these items and their dependence on raters' interpretations.

The $SDC_{individual}$ was 20 points on a scale from 0 to 100 points. However, the interrater measurement error would be rated as indeterminate, because the minimal important change value does not yet exist to enable the classification.[33] The Bland-Altman plot showed good interrater agreement with a low degree of bias and most of the mean differences within the 95% limits of agreement. There is no consensus on what constitute acceptable limits of agreement. Usually, this is a clinical decision that depends on the variable measured.[34] Therefore, because of the Barthel Index score range, we considered the limits of agreement to be acceptable.

The removal of any of the Barthel Index items did not significantly change the internal consistency.

Table 1
Baseline characteristics of 122 patients included in the study

Characteristic	Value
Age, median (IQR), y	56 (47-66)
Male sex, No. (%)	62 (51)
BMI,[a] median (IQR)	25 (21-29)
BMI category, No. (%)	
Underweight (<18.5)	9 (7)
Normal (≥18.5 to <25)	51 (42)
Overweight (≥25 to <30)	36 (30)
Obese (≥30)	26 (21)
SAPS III, mean (SD)	60.1 (14.6)
APACHE II score, mean (SD)	20.9 (8.2)
Charlson Comorbidity Index, median (IQR)	3 (1-4)
ICU diagnosis category, No. (%)	
Sepsis	28 (23)
Elective postoperative	23 (19)
Cardiovascular disorders	17 (14)
Neurological disorders	15 (12)
Emergency postoperative	14 (11)
Respiratory disorders	10 (8)
Gastrointestinal disorders	9 (7)
Other disorders	6 (5)

Abbreviations: APACHE II, Acute Physiology and Chronic Health Evaluation II; BMI, body mass index; ICU, intensive care unit; SAPS III, Simplified Acute Physiology Score III.
[a] Calculated as weight in kilograms divided by height in meters squared.

Table 2
Clinical and physical functioning characteristics of 122 patients included in the study

Variable	Value
Perme ICU Mobility Score, median (IQR)	25.5 (15-30)
FSS-ICU, median (IQR)	23 (11-31)
PFIT-s, median (IQR)	8 (5-10)
MRC-SS, median (IQR)	56 (51-59)
ICU-acquired weakness (<48 points), No. (%)	21 (17)
HGD, mean (SD)	16.4 (9.4)
ICU-acquired weakness (female, <7 kgf; male, <11 kgf), No. (%)	24 (20)
HHD for knee extension, mean (SD)	7.8 (3.5)
Mechanical ventilation, No. (%)	83 (68)
Duration of mechanical ventilation, median (IQR), d	5 (3-8)
ICU LOS, median (IQR), d	7 (5-11)
Hospital LOS, median (IQR), d	22 (14-30)
Hospital outcome, No. (%)	
Home	107 (88)
Death	13 (11)
Other hospital	2 (2)

Abbreviations: FSS-ICU, Functional Status Score for the Intensive Care Unit; HGD, handgrip dynamometry; HHD, handheld dynamometry; ICU, intensive care unit; LOS, length of stay; MRC-SS, Medical Research Council Sum Score; PFIT-s, Physical Function ICU Test-scored.

Table 3
Measurements of Barthel Index in the 122 patients included in the study

Variable	Rater 1	Rater 2
Barthel Index, median (IQR)	25 (10-60)	25 (15-55)
Barthel Index: 2 categories, No. (%)		
Moderate to severe disability (≤75 points)	118 (97)	118 (97)
Mild to no impairment (>75 points)	4 (3)	4 (3)
Barthel Index: 5 categories, No. (%)		
Total dependence (0-20)	55 (45)	55 (45)
Severe dependence (21-60)	44 (36)	51 (42)
Moderate dependence (61-90)	20 (16)	14 (11)
Slight dependence (91-99)	2 (2)	0 (0)
Independent (100)	1 (1)	2 (2)

Table 4
Internal consistency, interrater reliability, and measurement error based on total score and items (1-10) of the Barthel Index[a]

Barthel Index	Cronbach α	κ
Total score	0.81	—
2 categories	—	0.74
5 categories	—	0.77
Item	**Cronbach α if item is excluded**	**κ**
1. Feeding	0.79	0.82
2. Grooming	0.81	0.54
3. Toilet use	0.81	0.83
4. Bathing	0.82	0.65
5. Bowels	0.81	0.68
6. Bladder	0.81	0.81
7. Dressing	0.81	0.89
8. Transfers	0.78	0.88
9. Stairs	0.76	0.92
10. Ambulation	0.76	0.94

[a] *P*<.001 for all rows.

The scale had floor and ceiling effects below 15% and excellent interrater reliability, suggesting that the Barthel Index is suitable and reliable for application at ICU discharge.

The instruments used in this study measured the patient's physical functioning according to different components of the International Classification of Functioning, Disability, and Health, such as body functions and structures, activities and participation, environmental factors, and personal factors. None of the instruments included all 4 components, but the most frequent domain identified among them was mobility,[3] which could explain the strong construct validity of the Barthel Index compared with the specific ICU functional scales.

Previous studies[35,36] have indicated fair to moderate correlations of the Barthel Index with duration of mechanical ventilation, handgrip dynamometry, respiratory and peripheral muscle strength, and the amount of time spent free of mechanical ventilation. In the review by Parry et al,[13] these correlations were considered to indicate construct validity, but these variables mostly pertain to muscle function and respiratory muscle function domains. Notably, these studies[35,36] included some critically ill patients who were outside of the ICU setting. In one of the studies,[35] the patients were assessed in a specialized center for weaning patients off of mechanical ventilation after an ICU stay, and in another study[36] the patient was assessed in a hospital's general care area 3 to 7 days after ICU discharge. In our study, patients were evaluated at the time of ICU discharge or within 24 hours after discharge so that the patient's physical functioning reflected the recent influences of the ICU stay. Moreover, we emphasized the importance of the correlation of the Barthel Index with other scales that assess similar domains, such as mobility.

The Barthel Index was moderately correlated with the strength measures, and similar correlations were found between the MRC-SS and the PFIT-s ($\rho = 0.49$)[21] and the FSS-ICU ($\rho = 0.69$).[37] The strength measures are included in the muscle function domain that constitutes a part of a physical functioning evaluation. Muscle strength assessments are required to diagnose patients with ICU-acquired weakness; moreover, owing to the complexity and multifaceted nature of ICU patients' physical impairments, strength should not be the only component of an assessment of physical functioning, which depends on several variables.[38]

In our study, the specific ICU functional scales yielded higher physical functioning scores, trending toward independence, compared with the Barthel Index. These results could indirectly indicate that these specific ICU functional scales could be suitably administered earlier to compare the patient's recovery at different time points during the ICU stay. However, they may not be the best option for measuring global physical functioning after an ICU stay. Currently there are few robust, validated predictive models for assessing physical functioning impairments within the ICU, and a mix of instruments is probably necessary for a complete evaluation.[3,9]

Limitations

Some limitations of this study should be considered. First, this was a single-center study in a general ICU. Second, if assessment during the patient's ICU stay was not possible, it occurred within 24 hours of

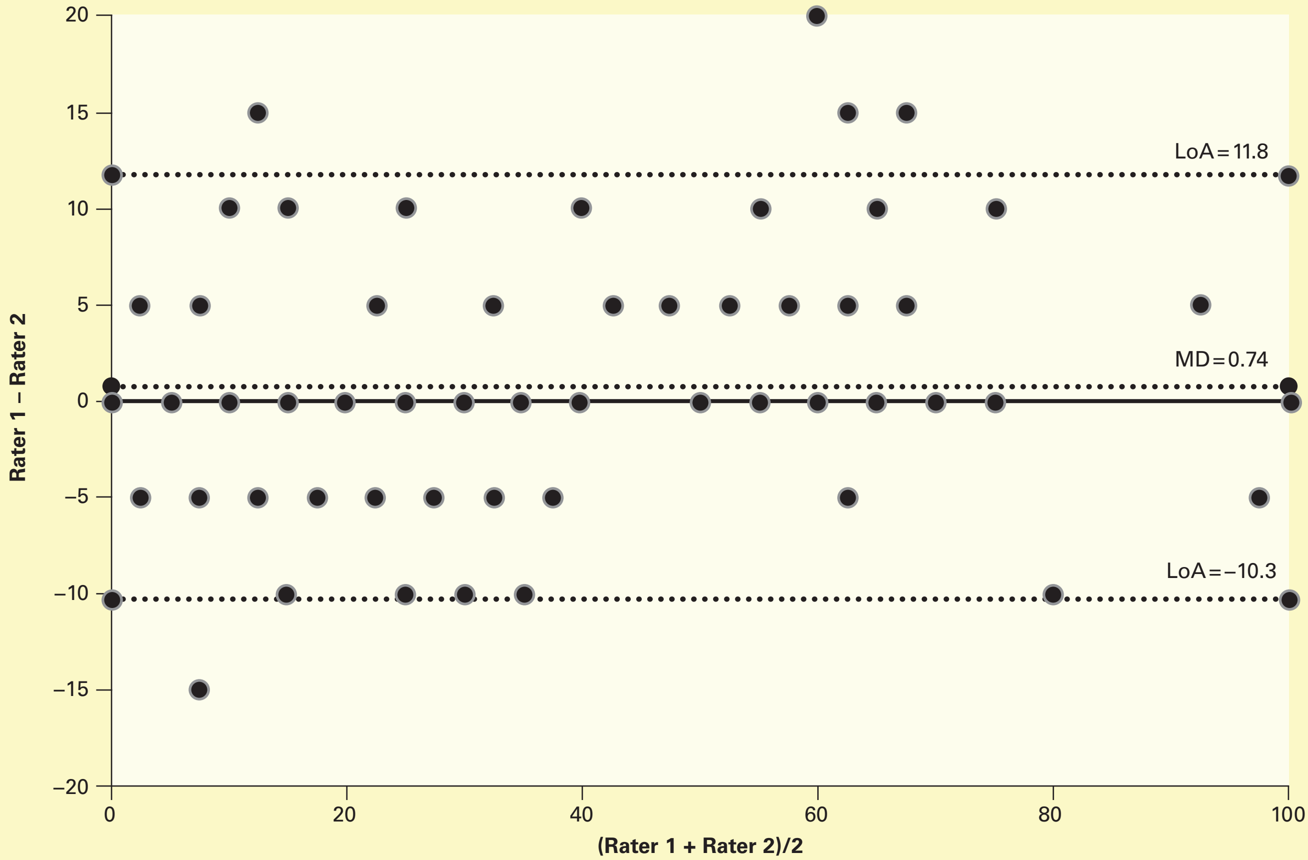

Figure 2 Bland-Altman plot of the total score on the Barthel Index showing interrater agreement.

Abbreviations: LoA, limit of agreement; MD, mean difference.

the patient's discharge from the ICU. Thus, some items were assessed retrospectively. However, in these cases the short interval from discharge to assessment minimized the effect of the delay and the change of location of the evaluation. In future research on use of the Barthel Index in the ICU setting, caution should be used when extrapolating results in an ICU population with different baseline and clinical characteristics and different assessment time points.

In addition, because there is no criterion standard for measuring physical functioning, in this study, construct validity was assessed against other measurement tools that rely on a subjective evaluation of the rater (Perme Score, FSS-ICU, PFIT-s, and MRC-SS). However, objective measurement devices (noninvasive mobility sensors) have been developed and validated to automatically and continuously measure patient mobility in the ICU setting.[39] In future research, such devices might constitute a new resource for evaluating physical functioning and measuring instruments' construct validity.

Table 5
Correlations between the Barthel Index and the specific ICU functional scales and the strength measures

Measure	Correlation (ρ) with Barthel Index[a]
Perme ICU Mobility Score	0.85
FSS-ICU	0.88
PFIT-s	0.86
MRC-SS	0.65
HGD	0.57
HHD for knee extension	0.62

Abbreviations: FSS-ICU, Functional Status Score for the Intensive Care Unit; HGD, handgrip dynamometry; HHD, handheld dynamometry; ICU, intensive care unit; PFIT-s, Physical Function ICU Test-scored; MRC-SS, Medical Research Council Sum Score.

[a] $P<.001$ for all rows.

Conclusion

The results of this study indicate that the Barthel Index is a reliable and valid tool for assessing physical functioning at ICU discharge, with an emphasis on mobility, self-care, and other body function domains. These results support the use of the Barthel Index in research and clinical practice in this patient population. Future research is needed to evaluate the utility of the Barthel Index in assessing clinical outcomes longitudinally throughout the rehabilitation process as well as its ability to predict functional outcomes.

FINANCIAL DISCLOSURES

This study was funded in part by a grant from the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior–Brasil (finance code 001) to Nair Fritzen dos Reis and Fernanda Cabral Xavier Sarmento Figueiredo. Rosemeri Maurici is supported by a grant from the National Council for Scientific and Technological Development (code 309040/2019-1).

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