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Development of a cluster-based linkage framework between hospital mobility scales and international and Brazilian functional classifications

Desenvolvimento de uma estrutura de linkage baseada em clusters entre escalas de mobilidade hospitalar e classificações funcionais internacionais e brasileiras

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ABSTRACT | INTRODUCTION: The diversity of instruments for assessing hospital mobility creates fragmentation in care and hinders interprofessional communication. The lack of systematic correspondence between clinical scales and established functional classifications limits care standardization and comparability across studies. **OBJECTIVE:** To establish systematic linkages between the ICU Mobility Scale (IMS), Johns Hopkins Highest Level of Mobility Scale (JH-HLM), International Classification of Functioning (ICF), and Brazilian Classification of Physiotherapeutic Diagnoses (BCPD) through cluster analysis, aiming to create a unified framework for assessing hospital mobility. **METHODS:** This methodological study used ten detailed clinical scenarios, independently evaluated by three experts. Hierarchical cluster analysis (Ward's method) was applied to identify natural functional profiles. Reliability was assessed using the weighted Kappa coefficient, and cluster stability was assessed using bootstrap validation. **RESULTS:** Four distinct functional clusters with excellent stability were identified: Critical Mobility, Assisted Mobility, Partially Independent Mobility and Independent Mobility. Inter-rater agreement was substantial to excellent. **CONCLUSIONS:** The established linkage offers a framework for translation between different mobility instruments, facilitating interprofessional communication, continuity of care, and standardization of functional assessment in the hospital *continuum*.

KEYWORDS: Multidimensional Scaling Analysis. International Classification of Functioning, Disability and Health. Moving and Lifting Patients. Health Care Quality, Access, and Evaluation. Classification Algorithms.

RESUMO | INTRODUÇÃO: A diversidade de instrumentos para avaliação da mobilidade hospitalar cria fragmentação no cuidado e dificulta a comunicação interprofissional. A falta de correspondência sistemática entre escalas clínicas e classificações funcionais estabelecidas limita a padronização assistencial e a comparabilidade entre estudos. **OBJETIVO:** Estabelecer *linkage* sistemático entre a Escala de Mobilidade em UTI (EMU), Escala de Maior Nível de Mobilidade de Johns Hopkins (EMNM-JH), Classificação Internacional de Funcionalidade (CIF) e Classificação Brasileira de Diagnósticos Fisioterapêuticos (CBDF) por meio de análise de *clusters*, visando criar *framework* unificado para avaliação da mobilidade hospitalar. **MÉTODOS:** Estudo metodológico utilizando dez cenários clínicos detalhados, avaliados independentemente por três especialistas. Aplicou-se análise de clusters hierárquica (método de Ward) para identificar perfis funcionais naturais. A confiabilidade foi avaliada pelo coeficiente Kappa ponderado e a estabilidade dos clusters por validação *bootstrap*. **RESULTADOS:** Identificaram-se quatro clusters funcionais distintos com excelente estabilidade: Mobilidade Crítica, Mobilidade Assistida, Mobilidade Parcialmente Independente e Mobilidade Independente. A concordância interavaliador foi de substancial a excelente. **CONCLUSÕES:** O linkage estabelecido oferece um framework para tradução entre diferentes instrumentos de mobilidade, facilitando a comunicação interprofissional, continuidade do cuidado e padronização da avaliação funcional no *continuum* hospitalar.

PALAVRAS-CHAVE: Análise de Escalonamento Multidimensional. Classificação Internacional de Funcionalidade, Incapacidade e Saúde. Movimentação e Reposicionamento de Pacientes. Qualidade da Assistência à Saúde. Algoritmos de Classificação.

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1. Introduction

Functional mobility assessment in hospitalized patients constitutes a fundamental element of contemporary clinical care, representing a critical predictor of outcomes such as length of hospital stay, incidence of immobility-associated complications, post-discharge quality of life, and readmission rates[1]. This evaluative dimension has become increasingly relevant in the current context of evidence-based medicine, where therapeutic decisions and efficient resource allocation demand objective and standardized quantification of patients' functional capacities[2].

Early mobilization in hospital settings, particularly in intensive care units (ICUs), demonstrates unequivocal benefits in preventing post-intensive care syndrome (PICS), reducing mechanical ventilation duration, and improving long-term functionality[3]. Multicenter studies show that structured mobilization protocols result in 20-30% reductions in mechanical ventilation time, 15-25% decreases in hospital length of stay, and 40-50% lower incidence of ICU-acquired weakness[4].

However, the field of functional mobility assessment is characterized by a multiplicity of measurement instruments, each with specific methodological features, distinct scoring scales, and varied application contexts[5]. This heterogeneity, while enriching evaluative perspectives, creates significant barriers to interprofessional communication, continuity of care across clinical units, comparative research, and development of evidence-based clinical guidelines[6].

In the Brazilian hospital context, the ICU Mobility Scale (IMS) and the Johns Hopkins Highest Level of Mobility Scale (JH-HLM) stand out as predominant instruments. The IMS, developed specifically for intensive care environments by Hodgson et al.[7], features an 11-level hierarchical grading system (0-10) encompassing progressive milestones from complete immobility to independent ambulation outside the unit. This scale demonstrates excellent inter-rater reliability (κ=0.91) and established construct validity across multiple international studies[8].

The JH-HLM, developed by Hoyer et al.[9] for general inpatient units, employs an 8-level scale (1-8) focused on the patient's highest achieved mobility level during hospitalization, distinguishing itself from the IMS by prioritizing maximum functional capacity rather than current capacity. This instrument shows adequate sensitivity for detecting functional changes in hospitalized patients and significant correlation with outcomes such as length of stay and discharge destination[10].

Concurrently, the International Classification of Functioning, Disability and Health (ICF), established by the World Health Organization, provides a comprehensive conceptual framework for describing health and related states, offering a universally recognized standardized language[2]. The ICF is structured into components of Body Functions and Structures, Activities and Participation, and Environmental Factors, each domain qualified on a scale from 0 (no difficulty) to 4 (complete difficulty), enabling detailed and specific coding.

Within the Brazilian national context, the Classificação Brasileira de Diagnósticos Fisioterapêuticos – CBDF (Brazilian Classification of Physiotherapy Diagnoses), developed by the Conselho Federal de Fisioterapia e Terapia Ocupacional - COFFITO (Brazilian Federal Council of Physiotherapy and Occupational Therapy), offers a specific classification system for physiotherapeutic diagnoses, including a dedicated category for mobility activities (CBDF-M)[11]. This system establishes a national conceptual framework that complements international classifications while providing cultural and linguistic specificity appropriate to the Brazilian healthcare environment.

The absence of systematic correspondence between these instruments leads healthcare professionals to frequently perform informal and approximate conversions between different scales, introducing potential inaccuracies in functional assessment, therapeutic planning, and interprofessional communication[12]. This fragmentation proves particularly problematic during transitions between care units, where discontinuity in functional assessment correlates with poorer clinical outcomes and extended hospitalization[2].

The concept of linkage between assessment instruments and functional classifications — a methodology established and recommended by the World Health Organization — offers a systematic approach to connecting different measurement systems[13]. The linkage process enables evidence-based conceptual correspondence, facilitating integration of information from diverse instruments and allowing comparability across different clinical and cultural contexts.

Previous linkage studies have predominantly focused on direct linear correlations between raw scale scores, an approach that, while useful, fails to adequately capture the complexity of functional profiles and clinical variability among patients[14]. Cluster analysis emerges as a promising analytical methodology grounded in robust statistical principles, aiming to identify underlying patterns in complex datasets by grouping elements with similar characteristics into distinct clusters[15].

Applying cluster analysis to mobility scales enables the creation of natural functional profiles that transcend discrete scores, establishing categories with intuitive clinical meaning and direct applicability. The hierarchical clustering method, particularly when implemented using Ward's algorithm to minimize intra-cluster variance, transforms scores into clinically relevant functional categories[14].

This methodological approach offers significant advantages over traditional linkage methods by simultaneously incorporating multiple evaluative dimensions and identifying complex patterns not evident through simple bivariate analyses. Additionally, cluster analysis enables validation of cluster consistency and stability through specific statistical techniques like bootstrap resampling and cross-validation[16].

The hypothesis of this study is that cluster analysis applied to the IMS and JH-HLM scales, integrated with ICF qualifiers and CBDF categories, will identify natural functional profiles serving as a "translation dictionary" between different instruments. This integrative framework will facilitate interprofessional communication, promote care continuity across clinical units, and establish a solid foundation for standardizing functional assessment throughout the hospital *continuum*.

The scientific and practical relevance of this study lies in its potential to overcome current fragmentation in hospital functional assessment, promote a common language across specialties and care contexts, and establish foundations for future development of care protocols based on integrated, standardized functional profiles.

2. Methods

The study was conducted between June and August 2025 at Salvus Tecnologia (Salvus Technology), in Recife, Pernambuco, Brazil, where the expert assessment panel was developed and executed. The panel was implemented digitally. The sample size (ten clinical scenarios) was intentionally defined to encompass the full spectrum of hospital mobility, from complete dependence to full functional independence.

A methodological, cross sectional, and analytical study was carried out, structured into four sequential phases: (1) initial conceptual mapping of mobility scales to functional classifications; (2) development and evaluation of simulated clinical scenarios; (3) cluster analysis and establishment of linkage; and (4) statistical and clinical validation of results.

A preliminary systematic mapping of the IMS and JH HLM items to specific ICF codes and CBDF categories was conducted, following the methodology established by Cieza et al.[16] for linking health assessment instruments. This process was performed by a multidisciplinary panel of six professionals with specific training in ICF and a minimum of ten years of experience in hospital physiotherapy.

Table 1 below corroborates this correspondence, illustrating the relationship between mobility levels, functional domains, and the associated degree of dysfunction.

Table 1. Correspondence between IMS levels, ICF codes, and CBDF categories

IMS Level	ICF Code	ICF Description	CBDF Category	CBDF Description
0–1	d410.0 – d410.3	Changing basic body positions	IV	Complete dysfunction
2–3	d415.0 – d415.2	Maintaining a body position	III	Severe dysfunction
4–6	d420.0 – d420.2	Transferring oneself	II	Moderate dysfunction
7–8	d460.0 – d460.2	Moving around in different locations	I	Mild dysfunction
9–10	d450.0 – d450.4	Walking	0	No dysfunction

Source: the authors (2025).
IMS - ICU Mobility Scale; ICF - International Classification of Functioning, Disability and Health; CBDF - Classificação Brasileira de Diagnósticos Fisioterapêuticos (Brazilian Classification of Physiotherapy Diagnoses).

The following table presents the correspondence between the Johns Hopkins Highest Level of Mobility (JH HLM) scale levels, the respective ICF codes, and CBDF categories, illustrating the relationship between walking ability, functional domains, and the degree of dysfunction.

Table 2. Correspondence between JH HLM levels, ICF codes, and CBDF categories

JH HLM Level	ICF Code	ICF Description	CBDF Category	CBDF Description
1	d410.0	Changing basic body positions	IV	Complete dysfunction
2–3	d415.0 – d415.1	Maintaining a body position	III	Severe dysfunction
4	d420.0	Transferring oneself	II	Moderate dysfunction
5	d460.0	Moving around in different locations	I–II	Mild to moderate dysfunction
6–7	d450.1 – d450.2	Walking short distances	I	Mild dysfunction
8	d450.4	Walking long distances	0	No dysfunction

Source: the authors (2025).
JH-HLM - Johns Hopkins Highest Level of Mobility; ICF - International Classification of Functioning, Disability and Health; CBDF - Classificação Brasileira de Diagnósticos Fisioterapêuticos (Brazilian Classification of Physiotherapy Diagnoses).

To replace primary data collection with real patients, a methodology of structured clinical scenarios was adopted — an approach validated in international linkage studies[16]. Ten detailed clinical scenarios were developed using generative artificial intelligence (Claude 4 Sonnet Thinking) and subsequently reviewed and refined by the clinician with the most extensive experience to ensure clinical realism and representativeness.

The use of the generative AI tool was restricted to the initial stage of textual elaboration of the clinical scenarios. All generated content was subsequently reviewed and adjusted by the researchers to ensure clinical accuracy, conceptual coherence, and neutrality. The tool did not influence analytical decisions, result interpretation, or scientific writing.

The scenarios were stratified to ensure adequate coverage of the full spectrum of hospital mobility: scenarios representing critically compromised mobility, moderately compromised mobility, mildly compromised mobility, and preserved mobility. Each scenario included standardized information on demographic data, primary diagnosis, relevant comorbidities, detailed description of current functional status, specific mobility capabilities, use of assistive or support devices, required level of assistance, specific contraindications, and relevant contextual factors.

An expert panel consisting of three physiotherapists with a minimum of ten years of experience in ICU and inpatient physiotherapy independently evaluated all ten clinical scenarios. The evaluators were instructed to assign scores on the IMS and JH-HLM scales and to indicate the most appropriate ICF qualifiers and CBDF categories for each scenario.

The evaluations were conducted through an electronic platform that presented the scenarios in randomized order to minimize order bias. The evaluators had access to the complete operational definitions of all scales and classifications used but were unaware of the other panel members' assessments.

For scenarios showing high variability between evaluators (Kappa coefficient <0.4), a second evaluation round was conducted following structured discussion of points of divergence, aiming to establish adequate consensus for subsequent analyses.

The data were analyzed using R software version 4.3.0 with specific packages: "cluster" for clustering analysis, "factoextra" for visualization, "NbClust" for determining the optimal number of clusters, "irr" for agreement analysis, and "corrplot" for correlation analysis.

Inter-rater reliability was assessed using the weighted Kappa coefficient (with quadratic weights) for the IMS and JH-HLM scales and simple Kappa for ICF qualifiers and CBDF categories. The Krippendorff's alpha coefficient was also calculated to evaluate overall agreement among all evaluators.

For each scenario, consensus scores were established as the median of the evaluations when inter-rater agreement was adequate (κ>0.6). The correlation between consensus scores of the IMS and JH-HLM scales was assessed using Spearman's correlation coefficient.

The consensus scores were normalized to a 0-1 scale to enable direct comparability between instruments. The optimal number of clusters was determined through the convergence of three statistical methods: the elbow method, the Calinski-Harabasz index, and average silhouette analysis.

Hierarchical agglomerative cluster analysis was applied using Ward's method with squared Euclidean distance as the dissimilarity measure, simultaneously considering the normalized scores from the IMS and JH-HLM scales and the derived ICF qualifiers and CBDF categories.

Cluster stability was rigorously validated through two complementary approaches: leave-one-out cross-validation and bootstrap analysis with 1,000 resamples. The quality of the cluster solution was assessed using the average silhouette and adjusted Rand index.

Each identified cluster was characterized in detail in terms of descriptive statistics (median, interquartile range, minimum and maximum values) for IMS, JH-HLM, ICF qualifiers, and CBDF categories, as well as the predominant clinical characteristics described in the corresponding scenarios.

Statistical significance was established at $p<0.05$ for all analyses, and 95% confidence intervals were calculated for agreement and correlation measures.

This study was conducted in accordance with the ethical and scientific principles outlined in national and international health research guidelines. As a methodological study involving no direct patient participation or collection of personally identifiable data, limited to the participation of three specialist professionals in evaluating hypothetical clinical scenarios, submission to the Research Ethics Committee (REC) was not required, pursuant to the criteria established by Resolution No. 510/2016 of the National Health Council (NHC), which exempts ethical review for research that does not involve human subjects directly or indirectly.

The study fully respected the principles of autonomy, beneficence, non-maleficence, and justice, ensuring confidentiality and anonymity of the participating professionals. No sensitive information, personal identification, or real patient data was used or stored at any stage of the research.

3. Results

The reliability analysis demonstrated substantial to excellent agreement among evaluators for all instruments assessed. The panel showed a weighted Kappa coefficient of 0.83 (95% CI: 0.78-0.88) for the IMS and 0.80 (95% CI: 0.75-0.85) for the JH-HLM. For ICF qualifiers, agreement was 0.77 (95% CI: 0.71-0.83), and for CBDF categories, it was 0.79 (95% CI: 0.73-0.85).

Krippendorff's alpha coefficient for overall agreement among all evaluators was 0.82, indicating strong general agreement. Greater variability was observed in evaluations of scenarios with intermediate mobility levels (IMS 4-7 or JH-HLM 3-6), where agreement was moderate ($\kappa=0.64$), while scenarios at the functional spectrum extremes showed near-perfect agreement ($\kappa>0.90$).

The correlation analysis between consensus scores of the IMS and JH-HLM scales revealed a strong positive correlation (Spearman's coefficient $\rho=0.91$; $p<0.001$; 95% CI: 0.86-0.95), confirming a robust association between the instruments while indicating they are not perfectly interchangeable.

The correlation between IMS and ICF qualifiers was $\rho=-0.88$ ($p<0.001$), representing the expected negative correlation since higher IMS scores correspond to lower ICF qualifiers (less dysfunction). Similarly, the correlation between JH-HLM and ICF qualifiers was $\rho=-0.84$ ($p<0.001$).

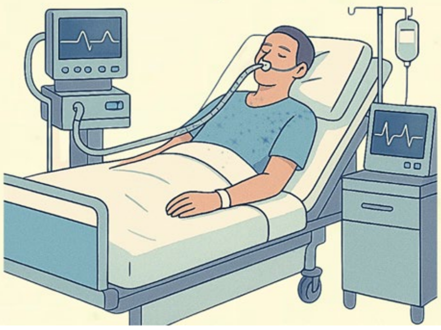
The analysis consistently converged on a four-cluster solution as the most appropriate and stable. The elbow method identified a pronounced inflection at $k=4$, the Calinski-Harabasz index showed a maximum value for four clusters (CH=187.3), and the average silhouette analysis confirmed an optimal value of 0.72 for the four-cluster solution, indicating good separation and internal cohesion of the groupings.

Thus, the representative cards for the four identified clusters are presented below, organized according to complexity level and associated with patient mobility. Each cluster was named according to its predominant characteristics: critical mobility, assisted mobility, partially independent mobility, and independent mobility. This categorization aims to facilitate understanding of the grouped profiles and highlight nuances between different levels of observed autonomy.

Figure 1. Representative cards of the four identified clusters, organized according to their degree of complexity and associated with the mobility of individuals

CLUSTER A
Critical Mobility

Functional Correspondence and Equivalence	Functional Status and Care Implications
IMS: median 1 (0–2; IQR: 0–2) EMNM-JH: median 1 (1–2; IQR: 1–1)	Extremely limited mobility; total dependence for positional changes; exclusively passive mobilization.
ICF: median qualifier 4 (predominance 3–4) Correspondence: d410.0–d410.4	Severe to complete functional impairment; bed confinement; high risk of immobility-related complications.
CBDF: median IV (complete functional dysfunction) Correspondence: Category IV and III	Critically ill ICU patient; continuous sedation, mechanical ventilation, and vasoactive drug support; care focused on prevention of pressure injuries and joint contractures.



CLUSTER B
Assisted Mobility

Functional Correspondence and Equivalence	Functional Status and Care Implications
IMS: median 4 (3–5; IQR: 3–5) EMNM-JH: median 3 (3–4; IQR: 3–4)	Partial mobility with assistance; performs positional changes under supervision or with light physical support.
ICF: median qualifier 2 Correspondence: d415.0–d415.2 / d420.0–d420.1	Moderate functional capacity; assisted sitting and transfers; requires supervision to ensure postural safety.
CBDF: median II (moderate functional dysfunction) Correspondence: Category II	Awake and cooperative patient; impaired muscle strength (MRC 36–48); able to perform supported standing and bedside sitting.

CLUSTER C
Partially Independent Mobility

Functional Correspondence and Equivalence	Functional Status and Care Implications
IMS: median 7 (6–8; IQR: 6–8) EMNM-JH: median 5 (4–6; IQR: 4–6)	Preserved functional mobility with mild impairment; able to perform positional changes and ambulation with minimal assistance.
ICF: median qualifier 1 (predominance 1–2) Correspondence: d410.0–d410.1 / d415.1 / d450.1–d450.2 / d460.1–d460.2	Mild to moderate difficulty in changing position, maintaining posture, and ambulating; performs activities under supervision or with light support.
CBDF: median II (moderate functional dysfunction) Correspondence: Category II	Patient in a ward or step-down unit; undergoing ventilatory weaning or extubated; ambulates with assistive devices; mildly reduced muscle strength (MRC 48–54).

CLUSTER D
Independent Mobility

Functional Correspondence and Equivalence	Functional Status and Care Implications
IMS: median 9 (8–10; IQR: 8–10) EMNM-JH: median 7 (6–8; IQR: 6–8)	Preserved mobility; independently and safely performs positional changes and ambulation.
CIF: qualificador mediana 0 (predomínio 0–1) Correspondência: d410.0 / d415.0 / d450.0–d450.1 / d460.0	No to minimal difficulty in maintaining posture, changing position, and ambulating; functionally independent.
CBDF: median 0 (no functional dysfunction) Correspondence: Category 0 and ICBDF: median 0 (no functional dysfunction) Correspondence: Category 0 and I	Patient in a ward setting, suitable for hospital discharge; normal or mildly reduced muscle strength (MRC >54); no assistance required for mobility.

Source: the authors (2025).

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Table 3. Functional Equivalence Matrix between Scales and Classifications

Cluster	IMS	JH-HLM	Main ICF	CBDF	Functional Correspondence
A - Critical	0-2	1-2	d410.3-d410.4	III-IV	Passive mobility, positioning
B - Assisted	3-5	2-4	d415.2-d450.3	II	Sitting, assisted standing
C - Partially Independent	6-8	4-6	d450.1-d460.2	I-II	Assisted ambulation, supervision
D - Independent	8-10	6-8	d450.0-d460.0	0-I	Preserved functional mobility

Source: the authors (2025).
IMS - ICU Mobility Scale; JH-HLM - Johns Hopkins Highest Level of Mobility; ICF - International Classification of Functioning, Disability and Health; CBDF - Classificação Brasileira de Diagnósticos Fisioterapêuticos (Brazilian Classification of Physiotherapy Diagnoses).

The Spearman correlation between the IMS and JH-HLM scales was ρ=0.92 (p<0.001), confirming a strong linear association. The cluster analysis showed an average silhouette of 0.74, indicating a well-defined structure. The adjusted Rand index was 0.89 in bootstrap validation, demonstrating high stability.

Agreement among evaluators in classifying scenarios by cluster was substantial, validating the consistency of the proposed framework. The unit transition index (ICU ↔ Ward) showed 84% classificatory continuity, 93% construct preservation, and 88% direct comparability.

4. Discussion

The development of a cluster-based linkage system represents a significant advancement in harmonizing hospital mobility assessment instruments. Unlike approaches based on simple linear correlations, the proposed methodology identifies natural groupings of patients with similar functional profiles, creating clinically interpretable categories that transcend the limitations of isolated scores.

The identification of four distinct clusters — Critical Mobility, Assisted Mobility, Partially Independent Mobility, and Independent Mobility — offers a common language that can be understood and applied by different specialties, regardless of the originally used scale. This standardization is particularly valuable in complex hospital environments where multiple teams interact in the care of the same patient[1].

The systematic mapping of the identified clusters to ICF domains represents an important methodological contribution. The ICF, as a universally recognized classification system, provides a solid conceptual foundation for interpreting the identified functional profiles. Aligning clusters with specific ICF domains enables not only comparison across different studies and populations but also integration with health information systems based on international standards[2].

The incorporation of the CBDF adds a relevant national dimension, considering the specificities of the Brazilian healthcare system and local clinical practices. This dual anchoring — international (ICF) and national (CBDF) — strengthens the framework's applicability across different contexts[3].

The choice of hierarchical cluster analysis with Ward's method proved appropriate for the study's objectives. This method, by minimizing intra-cluster variance, ensures that groupings identify true functional differences rather than mere statistical proximities. Validation through bootstrap and leave-one-out methods confirmed the stability of the four-cluster solution, indicating that this structure is robust and not dependent on sample particularities[6].

The average silhouette of 0.74 and adjusted Rand index of 0.89 are clustering quality indicators considered excellent in the specialized literature, suggesting that the identified groupings represent natural and well-differentiated categories[11].

The developed framework has the potential to transform various aspects of clinical practice into hospital mobility, such as interprofessional communication, since the common language based on clusters facilitates communication between physiotherapists, intensivists, nurses, and occupational therapists. A transfer from the ICU to the ward can be communicated as "patient progressing from Cluster B to C", conveying precise information about functional capacities and therapeutic needs; Therapeutic Planning, since each cluster implies specific therapeutic strategies. Patients in Cluster A require protocols for preventing complications of immobility, while those in Cluster C benefit from programs to strengthen and gain independence and continuity of care, because the system allows longitudinal tracking of the patient's functional evolution, regardless of the scales used in different units or moments of hospitalization.

Previous studies attempted to establish equivalences between mobility scales through direct correlations or linear regressions[2,4]. While useful, these approaches fail to capture the categorical nature of human functionality and may introduce inaccuracies in borderline cases.

The present study advances by recognizing that functional mobility is best represented by discrete categories with clinical meaning, rather than a linear continuum. This perspective aligns with established theoretical milestones in rehabilitation that emphasize the importance of specific functional landmarks[2].

Some limitations must be acknowledged. First, validation was conducted with detailed but artificial clinical scenarios. Although this approach allowed rigorous variable control and ensured representativeness of different functional profiles, prospective application in real cohorts is necessary to confirm external validity.

Second, the study primarily focused on motor aspects of mobility. Cognitive, motivational, and contextual factors, although partially addressed in the ICF, warrant more in-depth investigation in future studies.

Third, generalization to other populations (pediatrics, palliative care, and rehabilitation) requires specific studies, as mobility patterns may differ significantly.

Implementation of this framework in clinical practice can follow a staged approach: Phase 1 - Team training in interpretation and application of functional clusters; Phase 2 - Pilot implementation in selected units with usability monitoring; Phase 3 - Integration with hospital information systems for automatic documentation; Phase 4 - Institutional expansion with development of cluster-specific protocols.

5. Conclusion

This study successfully achieved its objective of developing a cluster-based linkage system that integrates different hospital mobility assessment instruments. Four functional clusters were identified, serving as a common language across distinct scales. These clusters were systematically mapped to the ICF and CBDF categories, creating a conceptual framework that harmonizes international and national classifications, enabling cross-study comparisons and integration with health information systems. The hierarchical cluster analysis methodology demonstrated statistical robustness, supporting the framework's viability as a standardized tool for functional mobility assessment and communication in hospital settings.

Declaration on Artificial Intelligence Use

AI tools (Claude 4 Sonnet Thinking) were used exclusively to assist in the development of simulated clinical scenarios. No AI tool was listed as an author, and the authors assume full responsibility for the content and interpretation presented in this manuscript, in accordance with ICMJE and COPE guidelines.

Authors' contributions

The authors declared that they have made substantial contributions to the work in terms of the conception or design of the research; the acquisition, analysis or interpretation of data for the work; and the writing or critical review for relevant intellectual content. All authors approved the final version to be published and agreed to take public responsibility for all aspects of the study.

Competing interests

No financial, legal, or political conflicts involving third parties (government, private companies, and foundations, etc.) were declared for any aspect of the submitted work (including but not limited to grants and funding, advisory board participation, study design, manuscript preparation, statistical analysis, etc.).

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Appendix

Appendix 1. Clinical Scenarios

Agreement between Mobility Tools

For each scenario, you must calculate scores for the ICF, IMS, JH-HLM, SOMS, PFIT, CPAx, and Perme tools.

Scenario 1: Critical Mobility - Patient on Mechanical Ventilation

Demographic Data: Male, 72 years old, BMI 27.5 kg/m².

Primary Diagnosis: Severe SARS-CoV-2 pneumonia with acute respiratory distress syndrome (ARDS).

Comorbidities: Systemic arterial hypertension, type 2 diabetes mellitus, chronic obstructive pulmonary disease.
Length of Stay: 7 days in ICU.

Devices and Supports:

- Invasive mechanical ventilation in volume-controlled mode (FiO_2 60%, PEEP 12 cmH_2O)
- Central venous catheter in right subclavian vein
- Arterial line in left radial artery
- Indwelling urinary catheter
- Nasointestinal tube for nutrition
- Continuous cardiac monitoring

Current Clinical Status:

- Mild sedation (RASS -2)
- Responsive to simple commands (hand squeeze, eye opening)
- Hemodynamically stable with low-dose norepinephrine (0.05 mcg/kg/min)
- Intermittent fever (37.8°C)

Mobility Capacity:

- Able to open eyes and move head on command
- Capable of actively moving upper limbs against gravity, but with rapid fatigue
- Active lower limb movement limited, partially overcoming gravity
- Unable to perform bed rotation without maximum assistance
- Unable to sit up due to extreme fatigue and respiratory instability
- Very limited tolerance to activities, with desaturation (SpO_2 drops to 88%) during simple movements

Required Level of Assistance:

- Requires maximum assistance (3 people) for position changes
- Needs total assistance for any mobilization beyond active limb movement in bed

Specific Limitations:

- Severe fatigue
- Desaturation during minimal efforts
- Ineffective cough
- Presence of catheters limiting range of motion

Scenario 2: Critical Mobility with Initiation of Verticalization

Demographic Data: Female, 58 years old, BMI 31 kg/m².

Primary Diagnosis: Immediate postoperative period (3 days) of cardiac surgery (myocardial revascularization).

Comorbidities: Coronary artery disease, hypertension, dyslipidemia, obesity.

Length of Stay: 3 days in cardiovascular ICU.

Devices and Supports:

- Airway: Extubated 24 hours ago, on nasal cannula oxygen therapy (2 L/min)
- Right anterior and posterior thoracic drains
- Temporary epicardial pacemaker (on standby)
- Central venous catheter in right internal jugular vein
- Indwelling urinary catheter

Current Clinical Status:

- Conscious and oriented (RASS 0)
- Pain controlled at rest (VAS 3/10), worsening with movement (VAS 6/10)
- Hemodynamically stable without vasopressor drugs
- Controlled heart rate (85-95 bpm)

Mobility Capacity:

- Able to perform active movement of all segments in bed
- Can perform bed rotation with moderate assistance (1 person)
- Able to elevate head of bed to 60° without symptoms
- Attempt at bedside sitting resulted in mild orthostatic hypotension (15 mmHg drop) and dizziness
- Can maintain bedside sitting for 2 minutes with moderate assistance (2 people) before reporting fatigue
- Preserved muscle strength (grade 4/5 in upper and lower limbs)
- Unable to perform standing due to dizziness and insecurity

Required Level of Assistance:

- Requires moderate assistance (1 person) for position changes
- Needs significant assistance (2 people) for bedside sitting
- Unable to perform standing at this time

Specific Limitations:

- Pain on mobilization (especially in sternotomy area)
- Orthostatic hypotension
- Presence of thoracic drains limiting movement
- Fear of displacing drains and devices

Scenario 3: Patient with Limited Mobility in ICU

Demographic Data: Male, 65 years old, BMI 24 kg/m².

Primary Diagnosis: Severe acute pancreatitis with resolution, in recovery phase.

Comorbidities: Chronic alcoholism, hypertension, history of gastric ulcer.

Length of Stay: 15 days (12 in ICU, 3 in semi-intensive care).

Devices and Supports:

- Spontaneous breathing on room air
- Peripheral venous catheter in left upper limb
- Nasointestinal tube for nutritional supplementation

Current Clinical Status:

- Conscious, oriented (RASS 0)
- No pain at rest, mild pain on mobilization (VAS 2/10)
- Hemodynamically stable
- Partial independence for bed mobilization

Mobility Capacity:

- Able to perform independent position changes in bed
- Can sit up with minimal assistance (1 person)
- Maintains bedside sitting for up to 15 minutes without significant fatigue
- Able to perform standing with moderate assistance (2 people)
- Can maintain standing for 1 minute with support
- Attempt at stationary marching resulted in fatigue and insecurity
- Moderate muscle weakness (MRC score 48/60)
- Unable to transfer from bed to chair without significant assistance

Required Level of Assistance:

- Independent for bed mobilization
- Requires minimal assistance for sitting
- Needs moderate assistance for standing
- Unable to perform marching at this time

Specific Limitations:

- Generalized muscle weakness (more pronounced in lower limbs)
- Cardiopulmonary deconditioning
- Fatigue with moderate effort
- Visible quadriceps atrophy

Scenario 4: Assisted Mobility in Semi-Intensive Care

Demographic Data: Female, 45 years old, BMI 22 kg/m².

Primary Diagnosis: Postoperative period (5 days) of extensive abdominal surgery for gastric neoplasia.

Comorbidities: Anemia, mild malnutrition secondary to neoplasia.

Length of Stay: 8 days (3 in ICU, 5 in semi-intensive care).

Devices and Supports:

- Spontaneous breathing on room air
- Peripheral venous catheter
- Patient-controlled analgesia (PCA)
- Abdominal drain in right lower quadrant

Current Clinical Status:

- Conscious, oriented
- Pain controlled at rest (VAS 1/10), moderate on movement (VAS 4/10)
- Hemodynamically stable
- Normal respiratory rate at rest, with mild tachypnea on effort

Mobility Capacity:

- Independent for bed mobilization
- Able to sit at bedside without assistance
- Performs bed-to-chair transfer with minimal assistance (1 person, supervision)
- Can maintain standing for 3-5 minutes
- Able to perform stationary marching at bedside for 30 seconds
- Walks 5-7 meters with walker and minimal assistance (1 person)
- Requires frequent pauses during walking due to fatigue
- Mildly reduced muscle strength (MRC score 52/60)

Required Level of Assistance:

- Independent in bed and sitting
- Supervision for transfers
- Minimal assistance for short walking

Specific Limitations:

- Incisional pain limiting range of motion
- Presence of abdominal drain
- Fear of walking alone
- Fatigue after moderate efforts

Scenario 5: Mobility with Minimal Assistance in Ward

Demographic Data: Male, 52 years old, BMI 29 kg/m².

Primary Diagnosis: Community-acquired pneumonia, treated with antibiotic therapy.

Comorbidities: Asthma, smoking (20 pack-years), dyslipidemia.

Length of Stay: 7 days in ward.

Devices and Supports:

- Spontaneous breathing with intermittent oxygen therapy (nasal cannula 1 L/min during activity)
- Peripheral venous catheter
- Inhaled medication

Current Clinical Status:

- Conscious, oriented
- No pain
- Resolved fever
- Occasional productive cough
- Saturation 93-94% on room air, dropping to 91-92% during activity

Mobility Capacity:

- Fully independent in bed
- Independent for sitting and transfers
- Independent standing maintained indefinitely
- Walks without assistance up to 30 meters using cane
- Requires rest pause after 30 meters due to dyspnea (Borg 4/10)
- Can climb 4-5 steps with handrail before needing a pause
- Presents dyspnea with moderate activities (changing clothes, personal hygiene)
- Preserved muscle strength, but reduced endurance

Required Level of Assistance:

- Independent for basic mobility
- Supervision for prolonged walking
- Minimal assistance for stairs and endurance-demanding activities

Specific Limitations:

- Dyspnea with moderate efforts
- Mild desaturation during activity
- Fatigue after short periods of activity
- Need for supplemental oxygen during more intense activities

Scenario 6: Partially Independent Mobility in Ward

Demographic Data: Female, 78 years old, BMI 21 kg/m².

Primary Diagnosis: Right proximal femur fracture, surgically treated (partial hip arthroplasty) 5 days ago.

Comorbidities: Osteoporosis, arterial hypertension, controlled hypothyroidism.

Length of Stay: 7 days in orthopedic ward.

Devices and Supports:

- No respiratory support
- Peripheral venous catheter for analgesia
- Suction drain already removed
- Use of walker as mobility aid

Current Clinical Status:

- Conscious, oriented
- Mild pain at rest (VAS 3/10), moderate on movement (VAS 5/10)
- Stable vital signs

Mobility Capacity:

- Independent for bed mobilization, including position changes
- Performs independent bedside sitting
- Bed-to-chair transfer with supervision
- Standing maintained without time limitation
- Walks with walker for 50 meters independently, respecting partial weight-bearing on right lower limb
- Requires minimal assistance for complex maneuvers (turns during walking)
- Climbs and descends one flight of stairs with moderate assistance (1 person)
- Fatigue after endurance-demanding activities
- Preserved strength in non-operated limb, reduced in right quadriceps (grade 3+/5)

Required Level of Assistance:

- Independent for basic mobility with assistive device
- Supervision for longer walking
- Minimal assistance for stairs and uneven surfaces

Specific Limitations:

- Total weight-bearing restriction on operated limb
- Fear of falls
- Pain on mobilization
- Difficulty with coordination-demanding maneuvers
- Limited range of motion in operated hip (maximum flexion 70°)

Scenario 7: Nearly Independent Mobility in Ward

Demographic Data: Male, 43 years old, BMI 25 kg/m².

Primary Diagnosis: Complicated acute appendicitis with localized peritonitis, surgically treated 7 days ago.

Comorbidities: No significant comorbidities.

Length of Stay: 8 days in surgical ward.

Devices and Supports:

- No invasive devices
- Surgical scar in normal healing process
- No need for walking aids

Current Clinical Status:

- Conscious, oriented
- Mild pain (VAS 2/10) only with intense effort
- Normal vital signs
- Normalized physiological eliminations

Mobility Capacity:

- Completely independent in bed
- Sitting and transfers without difficulty
- Standing maintained without limitation
- Walks independently for at least 100 meters without fatigue
- Able to climb and descend stairs using handrail at slower pace
- Can walk at moderate speed, but avoids running
- Fully preserved muscle strength (MRC 60/60)
- Avoids only intense efforts (running, jumping, abdominal exercises)

Required Level of Assistance:

- Independent for all basic mobility activities
- Supervision only for high-intensity exercises (not recommended at this time)

Specific Limitations:

- Mild pain in surgical wound area during sudden movement or coughing
- Avoids exercises that increase intra-abdominal pressure
- Medical restriction for lifting weights >5 kg
- Mild discomfort when sitting for prolonged periods

Scenario 8: Neurological Patient with Mixed Mobility

Demographic Data: Male, 67 years old, BMI 27 kg/m².

Primary Diagnosis: Ischemic stroke in left middle cerebral artery territory, occurred 10 days ago.

Comorbidities: Arterial hypertension, atrial fibrillation, type 2 diabetes mellitus.

Length of Stay: 12 days (4 in ICU, 8 in neurological ward).

Devices and Supports:

- No invasive devices
- Ankle-foot orthosis (AFO) on right lower limb
- Four-point cane for walking assistance

Current Clinical Status:

- Conscious, oriented (mild attention deficit)
- Mild dysarthria
- Hemodynamically stable
- Glasgow 15

Mobility Capacity:

- Independent for bed mobilization, with mild difficulty moving right hemibody
- Independent bedside sitting
- Transfers with minimal assistance due to balance deficit
- Standing maintained with supervision for indefinite time
- Proportional right hemiparesis (brachial G3/5, crural G4/5)
- Walks with cane and supervision for 40-50 meters
- Presents hemiparetic gait pattern with mild right circumduction
- Able to climb/descend one flight of stairs with minimal assistance
- Compromised dynamic balance (Berg 40/56)
- Mild right foot dragging during walking

Required Level of Assistance:

- Independent in bed
- Supervision for transfers and standing
- Minimal assistance for longer walking and stairs
- Requires continuous supervision due to fall risk (Morse 55)

Specific Limitations:

- Motor deficit in right hemibody
- Altered deep sensation on right
- Dynamic balance deficit
- Post-stroke fatigue
- Need for orthosis to stabilize right ankle

Scenario 9: Preserved Mobility in Cardiac Patient

Demographic Data: Female, 62 years old, BMI 28 kg/m².

Primary Diagnosis: Unstable angina, underwent cardiac catheterization with angioplasty and stent implantation in right coronary artery 3 days ago.

Comorbidities: Arterial hypertension, type 2 diabetes mellitus, dyslipidemia.

Length of Stay: 4 days in cardiology ward.

Devices and Supports:

- No invasive devices
- Dressing on right inguinal area (femoral puncture site)
- No need for walking aids

Current Clinical Status:

- Conscious, oriented
- No chest pain since procedure
- Stable vital signs
- No electrocardiographic changes

Mobility Capacity:

- Fully independent for bed mobilization
- Performs transfers without any assistance
- Standing without limitations
- Walks independently through ward corridor (approximately 100 meters) without limitations
- Climbs and descends one flight of stairs without assistance, though at slower pace
- Preserved muscle strength in all segments
- No balance alterations
- Reports mild fatigue after continuous 100-meter walking (Borg 2/10)

Required Level of Assistance:

- Independent for all mobility activities
- Supervision only for more intense physical activities

Specific Limitations:

- Medical restriction to avoid intense effort for 10 days
- Guidance to avoid marked right hip flexion in first 48 hours post-catheterization
- Cardiac monitoring during more intense exercises
- Avoid blood pressure elevation with maximum heart rate limitation (120 bpm)

Scenario 10: Fully Independent Mobility

Demographic Data: Male, 35 years old, BMI 23 kg/m².

Primary Diagnosis: Cellulitis in left lower limb, under intravenous antibiotic treatment.

Comorbidities: No comorbidities.

Length of Stay: 3 days in ward.

Devices and Supports:

- Peripheral venous catheter for antibiotic therapy
- No other devices or supports

Current Clinical Status:

- Conscious, oriented
- Mild localized pain in cellulitis area (VAS 2/10)
- Normal vital signs
- Afebrile for 24 hours
- Cellulitis area regressing

Mobility Capacity:

- Completely independent for all bed activities
- Transfers performed without any difficulty
- Standing maintained without limitations
- Walks independently for long distances (>250 meters) without fatigue
- Climbs and descends multiple flights of stairs without difficulty
- Able to walk at various speeds, including light jogging
- Fully preserved strength, balance, and coordination
- No dyspnea even with more intense activities
- Performs all activities of daily living independently

Required Level of Assistance:

- Completely independent for all mobility activities
- No need for supervision

Specific Limitations:

- Guidance to avoid trauma to affected area
- Periodic elevation of affected limb when at prolonged rest
- Monitoring of inflammatory signs during more intense physical activity

Source: the authors (2025).