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## Assessment of Mobility in Older People Hospitalized for Medical Illness Using the de Morton Mobility Index and Cumulated Ambulation Score-Validity and Minimal Clinical Important Difference

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### ABSTRACT

**Background and Purpose:** Older adults acutely hospitalized for medical illness typically have comorbidity and disability, and in-hospital physical inactivity greatly increases the likelihood of developing new disability. Thus, assessment of the patients' mobility status is crucial for planning and carrying out targeted interventions that ensure mobilization during hospital admission. The aim of this study was to determine convergent validity, known group validity, floor and ceiling effects, and anchor-based minimal clinically important difference (MCID) of the more time-consuming de Morton Mobility Index (DEMMI) and the less time-consuming Cumulated Ambulation Score (CAS) in older adults acutely hospitalized for medical illness.

**Methods:** In this multicenter cohort study, 235 older hospitalized adults, with a mean (standard deviation) age of 84.8 (7.1) years, were consecutively included. Assessments of mobility using the DEMMI (score range 0-100), the CAS (score range 0-6), and the Barthel Index (BI, score range 0-100) were performed by physical or occupational therapists at hospital admission and discharge. In addition, at discharge patients and therapists were independently asked to assess the patients' current mobility status compared with their mobility status at hospital admission using the Global Rating of Change scale.

**Results and Discussion:** Complete data sets were obtained for 155 patients. Baseline characteristics of those with complete data sets did not differ from those with incomplete data sets, except for the number of secondary diagnoses, which was lower in the latter. Significant and moderate relationships existed both at admission and at discharge between scores in the DEMMI and the BI ( $r_s = 0.68$ ,  $P < .0001$ , and  $r_s = 0.71$ ,  $P < .0001$ ), and between scores in the CAS and the BI ( $r_s = 0.60$ ,  $P < .0001$ , and  $r_s = 0.57$ ,  $P < .0001$ ). Use of a gait aid and discharge to inpatient rehabilitation or nursing home were associated with significantly lower DEMMI and CAS scores. No floor or ceiling effects were present in the DEMMI, while a ceiling effect was present in the CAS. The MCID scores based on patients' assessments were 10.7 points for the DEMMI and 0.67 for the CAS.

**Conclusions:** These data show that the DEMMI is valid and responsive to changes in mobility and can be considered to have the required properties for measuring mobility in older adults who are hospitalized in medical and geriatric wards. In contrast, the CAS appears to be appropriate to identify whether a patient is independently mobile or needs assistance, while the measure is less suitable for measuring improvements in mobility.

**Key Words:** aged, mobility limitation, outcome assessment, rehabilitation, validity

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among older persons.<sup>1-6</sup> Even when illness is successfully treated, disability following hospitalization is common in older adults hospitalized for medical illness<sup>4,5</sup> and more so in adults who are physically frail.<sup>6</sup>

Older adults are particularly vulnerable to disuse muscle atrophy.<sup>7</sup> Just by reducing the steps taken for 14 days, a measurable reduction in muscle mass of the lower extremities has been documented in healthy older adults.<sup>8</sup> Furthermore, hospitalization totaling 8 days or more during a 1-year span appears to be associated with a clinically important loss of muscle mass and quadriceps strength even in initially well-functioning older adults.<sup>9</sup> These effects could partly be a result of low mobility and bed rest,<sup>10,11</sup> which is very common in older adults who are hospitalized.<sup>12-14</sup> Indeed, available data suggest that the incidence of iatrogenic disability between the time of hospital admission and discharge may be as high as 12%, and that the vast majority of the cases can be attributed to low mobilization including excessive bed rest and lack of exercise.<sup>15</sup> A decline in mobility following hospitalization is related to an increased mortality risk, new institutionalization, and a decline in activities of daily living (ADL) 1 month after discharge.<sup>16-19</sup> Therefore, it is important to assess mobility as part of the functional status assessment at admission to ensure initiation of an early and targeted mobilization program during the hospitalization.<sup>4</sup>

The Barthel Index (BI), a performance-based measure, is routinely used for assessing mobility and functional status in older adults admitted to an acute medical ward. However, the BI is a multidimensional instrument that measures feeding and continence in addition to domains of mobility, and this makes it difficult to interpret the total score. A 1-dimensional instrument that accurately measures mobility and that can be applied to all patients, including those who are unable to get out of bed and those with a high level of independence, would help to identify the individual patient's rehabilitation needs and facilitate goal setting. These criteria are met by the de Morton Mobility Index (DEMMI), which was developed for assessing mobility in patients in the acute hospital setting.<sup>20</sup> The DEMMI has been validated against the BI in several studies, and the measure has been reported to be reliable in older adults who are hospitalized across a broad spectrum of abilities, including adults with cognitive impairment.<sup>21-25</sup>

The time to administer a test is important in the acute care setting, where there is typically time constraint. The time to administer the DEMMI has been reported to be around 10 minutes,<sup>22</sup> but it often takes longer when administered to older adults acutely admitted to a medical or geriatric ward. The Cumulated Ambulation Score (CAS),<sup>26</sup> which also assesses basic mobility (the ability to independently get out of bed, rise from a chair, and walk),<sup>27</sup> is less time-consuming. The feasibility of the CAS has been reported to be good in older adults admitted for acute medical illness, but the validity of the CAS during hospitalization in this group of patients has not previously been investigated. The CAS provides less information regarding mobility problems

than the DEMMI. Thus, while the CAS is appropriate for drawing attention to patients who need interdisciplinary action to become more mobile, the CAS may be less suitable for planning an individualized physical therapy intervention.

The purpose of this multicenter study was to examine (1) convergent validity between the DEMMI and the BI and the CAS; (2) known group validity (ie, whether the test can discriminate between adults known to have a particular trait and adults who do not have the trait) of the DEMMI and the CAS in regard to use of a gait aid and discharge destination; (3) whether floor and ceiling effects were present in the DEMMI and the CAS; and (4) the anchor-based minimal clinically important difference (MCID) of the Danish version of the DEMMI and the CAS in older adults who are hospitalized in medical and geriatric wards.

## METHODS

### Participants

In this pragmatic multicenter cohort study, patients 65 years and older were consecutively recruited in the geriatric and medical wards of the University Hospitals Bispebjerg, Frederiksberg, Hvidovre, Herlev, Gentofte, and Glostrup in the Region of Copenhagen, Denmark, from June to December 2011. Exclusion criteria were a planned hospital stay of less than 3 days, documented contraindication to mobilization, isolation for infection, or terminal disease. The study was approved by The Research Ethics Committees for The Capital Region (H-2-2011-FSP12), the Danish Data Protection Agency, and the National Board of Health (j.nr. 7-604-04-2/315/KWH).

### Outcome Measures

The DEMMI is a freely available, 1-dimensional measure of mobility<sup>22</sup> (available for download from [https://static-content.springer.com/esm/art%3A10.1186%2F1477-7525-6-63/MediaObjects/12955\\_2008\\_465\\_MOESM1\\_ESM.pdf](https://static-content.springer.com/esm/art%3A10.1186%2F1477-7525-6-63/MediaObjects/12955_2008_465_MOESM1_ESM.pdf)). The DEMMI has 15 items covering 5 clinically relevant subscales: bed mobility, transferring into and out of a chair, static and dynamic balance, and walking. The test is administered by observation of physical performance and provides Rasch-converted interval level total scores, ranging from 0 to 100.<sup>22</sup> A score of 100 indicates independent mobility.<sup>25</sup> The interrater reliability and agreement of the DEMMI in older adults who are hospitalized is reported to be good.<sup>23</sup> The original version of the DEMMI was translated to Danish using gold standard recommendations for translation and cross-cultural validation<sup>28</sup> and was approved by the author.

The CAS is a unidimensional Danish mobility measure with 3 items. The CAS assesses a person's independence in getting in and out of bed, sit to stand from a chair, and ambulation.<sup>27</sup> Each activity is assessed on a 3-point ordinal scale (0 = unable, despite human assistance and verbal cueing; 1 = able to, with human assistance and/or verbal cueing from one or more persons; 2 = able to safely, without human assistance or verbal cueing). The total score ranges

from 0 to 6, with 6 representing independent mobility.<sup>29</sup> The CAS has been shown to have a high interrater reliability and agreement in older adults hospitalized for medical illness.<sup>26</sup>

The BI is a multidimensional measure with 10 items. The BI examines feeding, bowel and bladder control, mobility, and independence in ADL, including chair/bed transfer, personal hygiene, toilet, bathing self, dressing, ambulation, and stair climbing. The total score ranges from 0 to 100, with 100 indicating no problems with feeding and continence, normal mobility, and ADL independence.<sup>30</sup> The BI is routinely carried out on all older adults admitted to an acute medical department, and the results are reported to the Danish National Geriatric Database.

The Global Rating of Change scale<sup>30</sup> served as the anchor to assess whether the mobility level had changed from admission to discharge. Patients and therapists were independently asked to assess the patients' current mobility status compared with their mobility status at hospital admission on a 5-level ordinal scale: much worse, a bit worse, the same, a bit better, and much better.

### Descriptive Variables

Descriptive variables included (1) diagnosis; (2) cognitive function assessed with the Mini-Mental State Examination (MMSE, score ranges from 0 to 30, with scores  $\geq 24$  considered to be within the normal range)<sup>31</sup>; (3) use of a gait aid; (4) prior residence (apartment/house, sheltered housing, nursing home); (5) receiving home care; and (6) discharge destination.

### Testing Procedure

Consecutively, eligible patients were assessed on weekdays (Monday to Friday) within 3 days of hospital admission and again the day before hospital discharge, or on the day of discharge. Assessments of the DEMMI, the CAS, and the MMSE were carried out by staff physical therapists ( $n = 19$ ) and staff occupational therapists ( $n = 4$ ), who had to complete a 1-day course to ensure that they followed the same testing protocol, and that test procedures and recording of results were standardized. Ward nurses or nursing assistants undertook the BI assessment of all patients as part of the routines in the department, and they were blinded to the DEMMI, CAS and MMSE scores. In addition, at hospital discharge the assessors were blinded to the results of the previous measurements. Descriptive variables were collected from medical records and interviews with the patient, family, or caregiver.

### Sample Size

The data collection period of this pragmatic study was determined to ensure a sufficient sample size based on (1) the study published on the development of the DEMMI<sup>22</sup> and (2) a sample size of 100 or more for determining criterion validity and responsiveness of a measurement according to the recommendations from Consensus-based Standards for the selection of health Measurement Instruments (COSMIN).<sup>32</sup>

### Statistical Methods

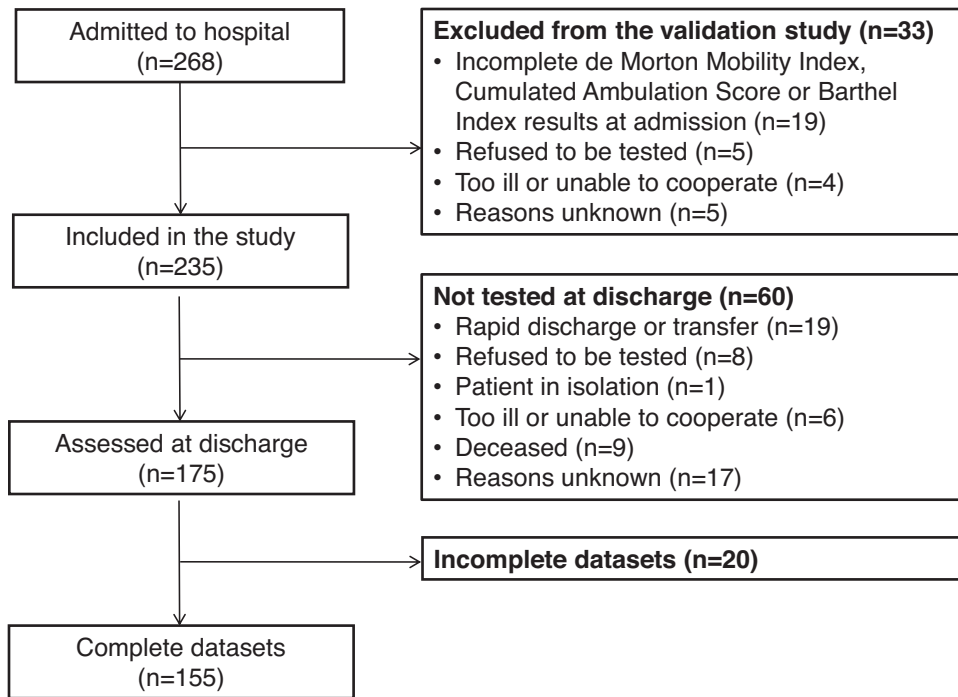
Descriptive data are presented as mean (standard deviation), median (interquartile range), or percentage. Incomplete data sets, which existed for 80 patients, were not included in the data analyses. Only the 155 complete data sets were used for the statistical analyses of convergent validity, known-groups validity, and anchor-based MCID. The Shapiro-Wilk test was used to test whether the data were normally distributed. Because the CAS results were not normally distributed, the Spearman  $\rho$  (bivariate) was used to determine the correlations between the BI, the DEMMI, and the CAS (convergent validity), and the size of correlation was interpreted as  $r = 0.30$  to  $0.50$  (low);  $r = 0.50$  to  $0.70$  (moderate);  $r = 0.70$  to  $0.90$  (high); and  $r = 0.90$  to  $1.00$  (very high).<sup>33</sup> The known-groups validity was assessed in regard to use of a gait aid and discharge destination using the Mann-Whitney  $U$  test.

Floor and ceiling effects were investigated by calculating the proportion of patients who scored the lowest or highest possible score on the DEMMI and the CAS. The Wilcoxon signed rank test was used to determine significant changes in scores of each of the items in the DEMMI and the CAS from hospital admission to discharge. The Global Rating of Change scale answer was used to calculate the anchor-based MCID (ie, the smallest difference in scores which patients perceive as beneficial or not beneficial)<sup>34</sup> for the DEMMI and the CAS. The rating "much better" was classified as "improved" and "much worse" was classified as "deteriorated," while "a bit better," "the same," and "a bit worse" were classified as "unchanged" because these ratings are unlikely to represent a clinically meaningful change.<sup>35</sup> The anchor-based MCID was calculated as the average change in the mobility instruments for the "improved group".<sup>34</sup> Both therapists and patients reported the Global Rating of Change for the DEMMI and the CAS. All tests were 2-tailed, and  $P$  values of less than .05 were considered significant. Data analyses were performed using SPSS version 19.0 (SPSS Inc, Chicago, Illinois).

### RESULTS

Of the 268 patients admitted to the hospitals, complete data sets on the DEMMI, the CAS, and the BI existed in 235 patients at hospital admission (Figure 1). Baseline characteristics of the study sample are shown in Table 1. Most patients had multimorbidity, and the majority used a gait aid and were dependent on home care (ie, various health professionals making home visits) (Table 1). Length of stay in the medical department was 15.3 (10.4) days. An MMSE score existed for 76% of the patients, and of those, 41% had cognitive dysfunction (MMSE  $< 24$ ) (Table 1). The DEMMI, the CAS, and the BI could be carried out in patients with cognitive impairment, even in those who had moderate or severe impairment (MMSE score  $< 18$ ).

Complete data sets at hospital discharge were missing for 80 patients (Figure 1). However, baseline characteristics for the 155 patients with complete data sets did not differ



**Figure 1.** Flowchart of the study. BI indicates Barthel Index; CAS, Cumulated Ambulation Score; DEMMI, de Morton Mobility Index.

from those with incomplete data sets, except for the number of secondary diagnoses (Table 1).

In general, mobility improved during hospitalization (Table 2). Significant improvements ( $P < .05$ ) were found for 11 of the 15 DEMMI items while results for 4 items remained unchanged from admission to discharge. The unchanged items included bridge from supine position (item 1) and sit unsupported (item 4), which almost all patients could perform; and tandem stand with eyes closed (item 10) and jump (item 15), which almost none of the patients could perform. Significant improvements were also found for all 3 items in the CAS ( $P < .05$ ).

At hospital admission and discharge, moderate to high correlations were found between DEMMI and CAS scores ( $r_s = 0.797, P < .0001$ , and  $r_s = 0.557, P < .0001$ ), between DEMMI and BI scores ( $r_s = 0.675, P < .0001$ , and  $r_s = 0.701, P < .0001$ ), and between CAS and BI scores ( $r_s = 0.597, P < .0001$ , and  $r_s = 0.565, P < .0001$ ) (Figure 2). Patients who used a gait aid had lower DEMMI and CAS scores at admission compared with those who walked without any aid (DEMMI score: 42.8 [15.3],  $n = 114$  vs 54.5 [21.0],  $n = 39, P < .0001$ ); CAS 5.0 [1.2],  $n = 114$  vs 5.2 [1.1],  $n = 39, P = .045$ ). Patients who were discharged to their own home had higher scores in the DEMMI and the CAS at admission compared with those who were discharged to inpatient rehabilitation or a nursing home (DEMMI: 55.6 [15.3],  $n = 101$  vs 45.2 [14.5],  $n = 54, P < .05$ ; CAS: 5.8 [0.4],  $n = 101$  vs 5.3 [1.1],  $n = 54, P < .05$ ).

Histograms of the score distributions in the DEMMI and the CAS at admission and discharge are shown in Figure 3.

No patients obtained the highest possible DEMMI score, while 2 patients obtained the lowest score at admission and 1 at discharge. The highest possible CAS was obtained by 79 patients at admission and 119 at discharge, and 1 patient obtained the lowest score at discharge.

The anchor-based MCID for the DEMMI was 18.8 when reported by therapists and 10.7 when reported by patients. The anchor-based MCID for the CAS was 1.3 when reported by therapists and 0.7 when reported by patients (Table 3).

## DISCUSSION

This study showed convergent and known-groups validity for the DEMMI (Danish version) and the CAS. The DEMMI showed no ceiling or floor effects in contrast to the CAS, which showed a ceiling effect. The anchor-based MCID scores of the DEMMI, which were calculated on the basis of the patients' and the therapist's ratings, were 10.7 and 18.8 points, respectively. The corresponding anchor-based MCID scores of the CAS were 0.7 and 1.3 points. Importantly, patients with cognitive impairment, including those with severe cognitive impairment, could perform both the DEMMI and the CAS.

The BI admission scores of the studies on acutely hospitalized older adults with medical illness by de Morton et al<sup>20,22</sup> were higher than in our study (81.3 [22.7] vs 59.4 [24.1]). Even so, the convergent validity of the DEMMI and the BI was similar to that reported by de Morton and colleagues,<sup>20</sup> indicating that the translation and cross-cultural adaptation was successful. The known-groups

**Table 1. Comparison of Baseline Characteristics for Patients With Full and Incomplete Data Sets**

Variables	All Patients (N = 235)	Patients With Full Data Sets (N = 155)	Patients With Incomplete Data Sets (N = 80)
Age, mean (SD), y	84.8 (7.1)	84.5 (7.1)	85.5 (7.1)
Gender, female, n (%)	162 (69)	110 (71)	52 (65)
Body mass index, mean (SD), kg/m <sup>2</sup>	23.6 (5.1)	23.9 (5.1)	22.7 (4.8)
Primary diagnosis, n (%)			
Cardiovascular diseases	19 (8)	11 (7)	8 (5)
Respiratory diseases	29 (12)	21 (14)	8 (5)
Endocrine diseases	17 (7)	12 (8)	5 (3)
Genitourinary diseases	31 (13)	19 (12)	12 (8)
Digestive diseases	13 (6)	9 (6)	4 (3)
Hematological diseases	12 (5)	7 (5)	5 (3)
Neurological diseases	20 (9)	17 (11)	3 (2)
Musculoskeletal diseases	15 (6)	9 (6)	6 (4)
Cancer	3 (1)	2 (1)	1 (1)
Fall and dizziness	10 (4)	6 (4)	4 (3)
Other diseases	64 (28)	42 (27)	22 (14)
Number of secondary diagnoses, mean (SD)	4.1 (3.4)	4.3 (1.7)	3.8 (2.1) <sup>a</sup>
MMSE, mean (SD)	23.3 (5.1)	23.3 (5.1)	23.0 (4.7)
Use of a gait aid, n (%)	171 (73)	114 (74)	57 (71)
Prior residence, n (%)			
Own home	215 (92)	146 (94)	69 (90)
Sheltered housing	13 (6)	7 (5)	6 (8)
Nursing home	4 (2)	2 (1)	2 (3)
Home care, n (%)	173 (78)	121 (78)	52 (76)

Abbreviations: BMI, body mass index; MMSE, Mini-Mental State Examination (score range 0-30); SD, standard deviation.  
<sup>a</sup>Significant ( $P = .039$ ) difference in numbers of secondary diagnoses between patients with complete data sets and those with incomplete data sets. For patients with complete data sets (de Morton Mobility Index [DEMMI], Cumulated Ambulation Score [CAS], and Barthel Index [BI]), data on BMI ( $n = 2$ ) and MMSE ( $n = 17$ ) were missing. For patients with incomplete data sets (DEMMI, CAS, and BI), data on BMI ( $n = 22$ ), MMSE ( $n = 39$ ), prior residence ( $n = 3$ ), and home care ( $n = 12$ ) were missing.

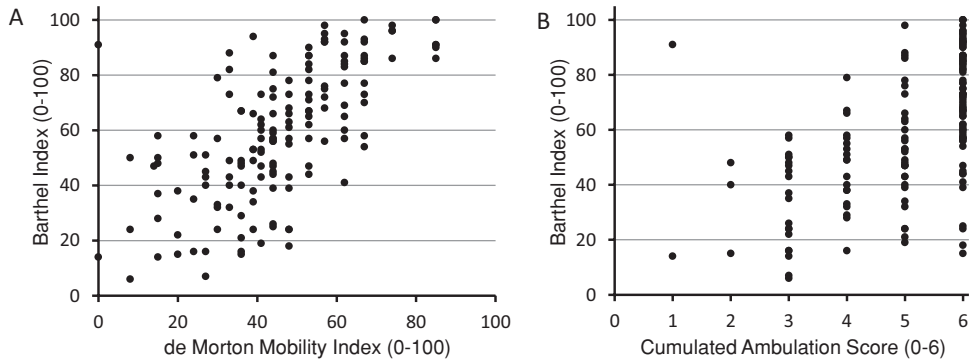
validity of the DEMMI in our study was evident with regard to the use of a gait aid and discharge destination, as was also reported by de Morton et al.<sup>23</sup> Floor and ceiling

**Table 2. Test Results at Admission and Discharge (N = 155)**

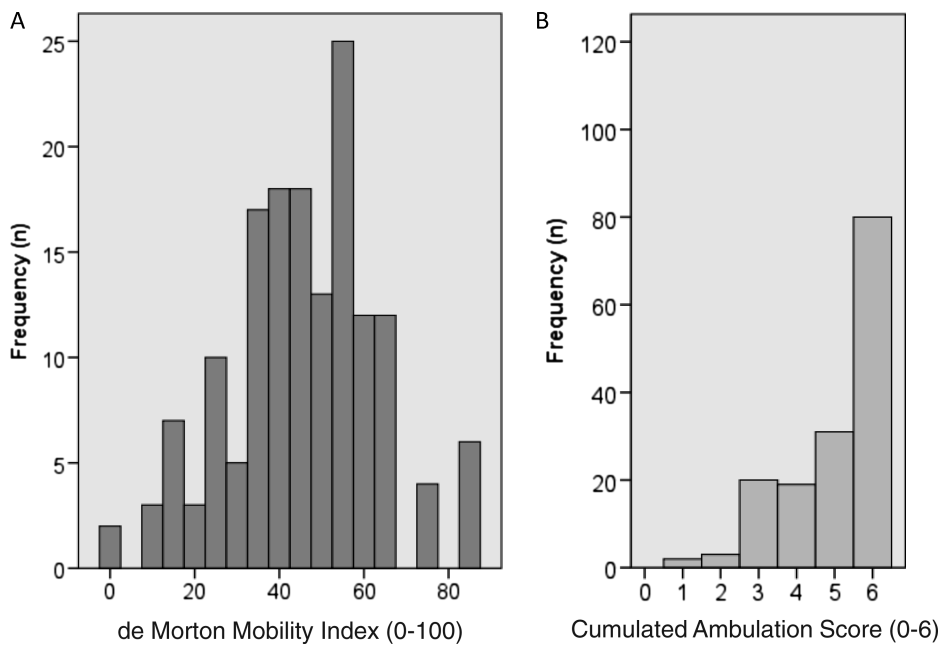
Mobility Measure	Scores		P Value
	Admission	Discharge	
de Morton Mobility Index			
Mean (SD)	45.4 (17.7)	51.9 (15.8)	$P < .0001$
Median (IQR)	44 (21)	53 (18)	
Cumulated Ambulation Score			
Mean (SD)	5.0 (1.2)	5.6 (0.8)	$P < .0001$
Median (IQR)	6 (2)	6 (0)	
Barthel Index			
Mean (SD)	59.4 (24.1)	73.6 (22.6)	$P < .0001$
Median (IQR)	58 (38)	80 (34)	

Abbreviations: IQR, interquartile range; SD, standard deviation.

effects were clearly not present in our patient population since few obtained minimum or maximum DEMMI scores at admission or at discharge. These results indicate that it is possible to document changes over time, which is important if the purpose is to identify the effect of a physical activity intervention. Our results show that a change score needs to be 10.7 points for an assessor to be confident that a change meaningful to the patient has occurred. It could be argued that recall bias may limit the reliability of the results and that giving a reliable and accurate report places considerable cognitive demand on the patient.<sup>36</sup> Since many of the patients had cognitive dysfunction, this may hamper the validity of the criterion-based MCID estimate. However, the MCID estimate of 10.7 points on the DEMMI in our study is similar to that reported by de Morton et al.<sup>23</sup> Because the Global Rating of Change question was an open question, the patients decided what factors they considered important in determining change in mobility status. This could be a contributing factor to the discrepancy between the patients' and therapists' perceptions of an important change in mobility status.<sup>36-38</sup>



**Figure 2.** Relationship between measures of mobility at admission. (A) Relationship between results in the Barthel Index and the de Morton Mobility Index. (B) Relationship between results in the Barthel Index and the Cumulated Ambulation Score.



**Figure 3.** Distribution of DEMMI and CAS scores at admission. (A) Distribution of DEMMI scores. (B) Distribution of CAS scores. CAS indicates Cumulated Ambulation Score; DEMMI, de Morton Mobility Index.

Similar to the DEMMI, we found a moderate relationship between CAS and BI scores (convergent validity), and CASs were significantly greater in patients who did not use a gait aid compared with those who did. Likewise,

those who were discharged to their home had higher CASs compared with those who were discharged to inpatient rehabilitation or a nursing home. Similar to the DEMMI, the criterion-based MCID estimates based on therapist ratings were higher compared with that based on patient ratings. The MCID estimate of 0.7 points on the CAS based on the patients' ratings is consistent with results in patients with hip fractures where a change of more than 0.6 CAS points indicates a real change in basic mobility.<sup>29</sup> However, the ceiling effect at admission makes the CAS inappropriate for measuring changes in mobility in patients across a broad spectrum of abilities. Our findings are in agreement with a recent study on older adults hospitalized for medical diseases (median age 77.9 years)<sup>39</sup> that also showed a ceiling effect at admission for the CAS (median [IQR]: 6.0 [6.0-6.0]). The median CAS was 6, even in the patients who

**Table 3. Criterion-Based Minimal Clinical Important Difference**

Method	Instrument	n	Estimate Mean (SD)
Criterion-based MCID-therapist	DEMMI	142	18.8 (13.1)
	CAS	142	1.3 (1.3)
Criterion-based MCID-patient	DEMMI	146	10.7 (14.9)
	CAS	146	0.7 (1.2)

Abbreviations: CAS, Cumulated Ambulation Score; DEMMI, de Morton Mobility Index; MCID, Minimal Clinical Important Difference; SD, standard deviation.

had limited mobility at 30 days postdischarge follow-up. On the other hand, this study found that a CAS of less than 6 at admission increased the risk of mobility limitations after discharge. The importance of assessing the patients' mobility on a daily basis has been suggested because mobility impairment is strongly associated with an increased risk of hospitalization-associated disability.<sup>4</sup> Thus, since the CAS is a quick and easy measure, it may be especially relevant as an interdisciplinary tool to ensure that patients who are dependent in basic mobility at admission receive sufficient attention to achieve independence. This is most relevant because of the adverse events related to in-hospital physical inactivity.<sup>15-19</sup>

### Strengths and Limitations of the Study

The strengths of the study were that (1) almost all eligible patients were included, (2) it was carried out in a very heterogeneous group of older adults acutely admitted to a medical or geriatric ward, (3) the therapists were blinded to the admission results when they performed the DEMMI and the CAS at discharge, and (4) the therapists were blinded to the patient-reported change ratings.

The limitations to the study include the large dropout rate and the proportion of incomplete data, which may have influenced the validity of our results. However, the patients with incomplete data sets did not differ from those with complete data sets, except that the number of secondary diagnoses was significantly lower. The validation sample (n = 155) was recruited from geriatric and medical wards in the Region of Copenhagen, the capital of Denmark, and might not be representative for greater Denmark, which also includes rural areas. However, the proportion of patients discharged to their own home was similar in our study (66%) compared with that reported in the Danish nationwide geriatric database (64%).

### CONCLUSIONS

The present study showed that the Danish version of the DEMMI is valid and responsive to changes in mobility and thus has the required properties for measuring mobility in older adults acutely admitted to medical and geriatric wards. In contrast to the DEMMI, the CAS appears to be appropriate to identify whether a patient is independently mobile or needs assistance, but the measure is less suitable for measuring improvements in mobility.

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