Estimating the Threshold Value for Change for the Six Dimensions of the Impairment Inventory of the Chedoke-McMaster Stroke Assessment

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ABSTRACT

Purpose: Our purpose was to estimate a threshold value for change for the six dimensions of the Impairment Inventory of the Chedoke-McMaster Stroke Assessment and the confidence in labelling a person as having improved or not. **Method:** Secondary analysis of two data sets, previously reported by two research teams, consisted of two statistical analyses. The first analysis used a multiple of the standard error of measurement to calculate the threshold value for change for the six dimensions. The second analysis used the diagnostic test method to calculate a threshold improvement value and the confidence a clinician had in labelling a person as having improved or not on the leg, foot, and postural control dimensions. **Results:** The threshold value for change was determined to be 1 impairment point (i.e., stage) for the arm, hand, leg, foot, and postural control dimensions and 2 impairment points for the shoulder pain dimension. The positive predictive values associated with the leg, foot, and postural control dimensions were 74%, 59%, and 65%, respectively. **Conclusions:** Clinicians can use a change of 1 impairment point for the arm, hand, leg, foot, and postural control dimensions and a change of 2 impairment points for the shoulder pain dimension to identify true change in a patient's motor recovery.

Key Words: outcome assessment; recovery of function; stroke.

RÉSUMÉ

Objectif : parvenir à une valeur seuil de changement aux six dimensions de l'inventaire des déficiences de l'évaluation Chedoke-McMaster de l'AVC ainsi que de la confiance à déclarer que l'état d'une personne s'est amélioré ou non. **Méthodologie :** l'analyse secondaire de deux ensembles de données, dont deux équipes de recherche avaient déjà rendu compte, s'est déclinée en deux analyses statistiques. La première faisait appel à un multiple de l'écart-type de mesure pour calculer la valeur seuil de changement aux six dimensions. La seconde puisait dans la méthode de test diagnostique pour calculer une valeur d'amélioration du seuil et la confiance du clinicien à déclarer que l'état d'une personne s'est amélioré ou non dans les dimensions du contrôle de la jambe, du pied et de la posture. **Résultats :** les chercheurs ont établi que la valeur seuil de changement correspondait à 1 point de déficience (phase) pour les dimensions du contrôle du bras, de la main, de la jambe, du pied et de la posture et de 2 points de déficience pour la dimension de la douleur de l'épaule. Les valeurs prédictives positives associées aux dimensions de contrôle de la jambe, du pied et de la posture s'élevaient à 74 %, 59 % et 65 %, respectivement. **Conclusions :** les cliniciens peuvent utiliser un changement d'1 point de déficience des dimensions de contrôle du bras, de la main, de la jambe, du pied et de la posture, et un changement de 2 points de déficience pour la dimension de la douleur de l'épaule pour déclarer un véritable changement dans le rétablissement moteur du patient.

The Chedoke-McMaster Stroke Assessment (CMSA) is an internationally used,¹⁻¹² performance-based outcome measure with two parts: the Impairment Inventory (II) and the Activity Inventory (AI).¹³ The CMSA was developed to assess patients who had experienced a stroke and were receiving treatment in a rehabilitation setting.^{1,13,14} Presently, there is no threshold value for change reported for any of the six dimensions of the CMSA-II. Consequently, clinicians are using the dimen-

sions of the CMSA-II to assess motor recovery without knowing the threshold value that represents a true change. By *true change*, we mean that a patient's status has truly changed and is not an artifact of a random fluctuation in a truly unchanged patient. This deficiency prompted our current study.

We performed a search of the literature to identify articles reporting on the CMSA. Our search identified evidence of reliability and validity for both the

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CMSA–II^{1,4,5,9,11,12,15–18} and the CMSA–AI¹ in the context of stroke rehabilitation. In addition, we found evidence of validity for the CMSA–AI in the context of rehabilitation after acute brain injury,¹⁹ rehabilitation for acute neurological conditions,²⁰ and in-patient geriatric care.²¹ Moreover, we found that a minimal clinically important difference existed for the CMSA–AI, reported as 7 when determined by physiotherapists²⁰ and 8 when determined by stroke patients and their caregivers.²²

Clinicians have consistently reported that an identified barrier to the use of standardized measures in clinical practice is that scores may lack meaning.^{23,24} Stokes and O'Neill reported that although clinicians are aware of the purpose of outcome measures, they have low confidence in interpreting scores in a meaningful way and low confidence in their knowledge of measurement properties.²³ In addition, Duncan and Murray reported that clinicians have concerns about the clinical relevance of outcome measures.²⁴ Moreover, Salbach and colleagues conducted a cross-sectional survey from which they determined that 78% of physiotherapist respondents agreed that research findings were useful to their practice, although 55% agreed that there was a divide between research and practice.²⁵

Together, these findings suggest that a gap exists between clinicians' confidence in interpreting scores and how these scores are applied in clinical practice. In this study, we aimed to address this barrier by providing a clinically relevant threshold value for change.

The purpose of this study was to estimate values that would serve as the threshold value for true change for the CMSA–II dimensions in persons undergoing rehabilitation after stroke. The estimate was based on the results of two different approaches applied to data from two prospective cohort studies. The two objectives of our study were to estimate (1) the threshold value for change (both improvement and deterioration) based on a multiple of the standard error of measurement (SEM; Study 1) and (2) the threshold improvement value and increased confidence in labelling an individual as improved using diagnostic test methodology (Study 2). In addition, we present a clinical vignette to describe how the results of this study could be used by a clinician.

METHODS

Our investigation consisted of performing secondary analyses of two data sets using different participant samples, reported previously by separate research teams.^{1,13,26} In this article, we use information from both data sets to estimate a threshold value for change using two statistical methods. Study 1 used data reported in the CMSA manual,¹³ and Study 2 used data from Dang and colleagues.²⁶

Chedoke-McMaster Stroke Assessment

The CMSA–II has six dimensions – arm, hand, shoulder pain, leg, foot, and postural control – and is scored on a 7-point (1–7) scale^{1,13} that corresponds to the Brunnstrom stages of motor recovery.¹³ Higher scores represent a higher stage of motor recovery, with the exception of shoulder pain, which is scored on the basis of severity.¹³ The CMSA–AI measures functional outcomes and is composed of a gross motor function index and a walking index.¹³ The gross motor function index consists of 10 items related to the activities of bed mobility, sitting, standing, and transfers, and the walking index consists of 5 items that score walking indoors and walking outdoors.¹³ The items from both indices are scored on a 7-point scale that corresponds to the adult FIM, with higher scores representing higher functional independence.¹³

Study 1

The goal of Study 1 was to estimate a threshold value for change for the six dimensions of the CMSA–II based on a multiple of the SEM.

Participants

The original investigators recruited patients admitted to the stroke unit of the Chedoke-McMaster Rehabilitation Centre, a regional, tertiary care institution.^{1,13} Over 9 months, the investigators recruited 32 participants (16 men, 16 women).¹³ Of these participants, 18 had hemiplegia involving the left side and 14 had hemiplegia involving the right side.¹ On admission, the mean (range: min–max) for the following we reported: participants' age, 70 (54–85) years; time after onset, 9 (1–24) weeks; length of hospital stay, 9 (2–21) weeks; CMSA–II score on admission, 23 (14–34); and CMSA–AI score on admission, 52 (14–98).¹³ Further information about participants' characteristics and data collection can be found in the CMSA manual.¹³

Data analysis

We used the CMSA manual to perform the following calculations: SEM and minimal detectable change (MDC) at 90% CI (MDC₉₀) for the six dimensions of the CMSA using the type 2,1 intraclass correlation coefficient (ICC) values (reported in the manual's Table 4–5); number of clients at each recovery stage on admission for the impairment dimensions, and SD for the CMSA impairment dimensions using the stage of impairment frequency data (Table 4–4).¹³ Specifically, the values from the frequency distribution reported in Table 4–4 were applied to calculate the mean and SD for this sample. The SEM was calculated using the equation

$$SEM = SD \times \sqrt{1 - ICC}^{27},$$

and the 95% CI was obtained by adapting the method reported by Stratford and Goldsmith.²⁸

We obtained an estimate for the MDC₉₀ value by multiplying the SEM by the square root of 2 and the *z* value

associated with a 90% CI ($z = 1.65$). MDC_{90} represents a range of difference values between test and retest owing to random fluctuations in truly unchanged participants.²⁷ From the standpoint of a clinician, if a change greater than the MDC_{90} – either improvement or deterioration – is observed, a patient would be labelled as changed.²⁷ However, the exact certainty of, or confidence in, this inference is unknown.²⁹

Study 2

The three goals of Study 2 were to obtain estimates of (1) a threshold improvement value, (2) a CI for the threshold improvement value, and (3) the extent to which valid inferences could be drawn when using the identified threshold improvement values to differentiate among patients who had improved and those who had not.

Participants

We obtained data from a pre-existing database containing de-identified and anonymized data, previously reported by Dang and colleagues.²⁶ Ethics approval was obtained from the Hamilton Integrated Research Ethics Board; permission to use the data set was granted by the senior investigator of the Dang and colleagues study.²⁶

The database contained information obtained by chart review for patients admitted to a stroke rehabilitation unit between July 1996 and July 1998.²⁶ This data set consisted of 74 participants (48 men, 26 women), who were assessed using the CMSA at an average of 15.6 (SD 8.6) days post-stroke.²⁶ The sample had a mean age of 65.3 (SD 12.4) years.²⁶ A total of 41 participants had had left-sided cerebral vascular accidents, and 33 had had right-sided cerebral vascular accidents.²⁶ The average length of stay in the stroke rehabilitation unit was 44.8 (SD 24.4) days.²⁶ Further information related to the sample's characteristics and data collection can be found in the original publication.²⁶

Data analysis

We analyzed the data using STATA, version 14.2 (Stata-Corp LP, College Station, TX). We used diagnostic test methodology to estimate the threshold improvement value for the leg, foot, and postural control dimensions of the CMSA.³⁰ Diagnostic test methodology requires a dichotomized reference standard to classify participants as improved or not improved.³⁰ On the basis of the work of Huijbregts and colleagues,²² we used CMSA–AI scores, dichotomized at an improvement of 8 points, as a reference standard: improved (≥ 8 points) or not improved (< 8 points).²² We used the 8-point reference standard because it represents a conservative improvement in lower extremity function from the patient's perspective.²² We excluded participants with scores of 7 on the individual CMSA–II dimensions at admission because 7 is the

highest score on the measure, and the measure could not quantify further improvement.

We were not able to apply diagnostic test methodology to the arm, hand, or shoulder pain dimensions because we could not access any data from a prospective cohort study that included both scores for these CMSA–AI dimensions and scores for important improvement; these data would have given us a reference measure of upper extremity function.

Using the STATA software, we applied non-parametric receiver operating characteristic (ROC) curve analysis to identify the threshold improvement value. An ROC curve plots sensitivity against 1-specificity.³⁰ The area under the curve (AUC) can be interpreted as a validity index.²² The AUCs range from 0 to 1, with an area of 0.5, indicating that a measure does no better than chance at labelling a patient as improved or not.³⁰ We considered misclassification errors in either direction to be equally important (i.e., labelling a truly improved patient as not improved would carry the same weight as labelling a truly unimproved patient as improved). Accordingly, our approach was to identify the threshold improvement value that jointly maximized sensitivity and specificity. We applied the STATA add-on bootstrap program *roc-mic*.ado to identify the 95% CI for the threshold improvement value.³¹ To do this, we obtained 500 bootstrap samples, with replacement, for each impairment scale estimate.

RESULTS

Study 1

Table 1 reports the Type 2,1 ICCs, SEM and 95% CI, and MDC_{90} values for the arm, hand, shoulder pain, leg, foot, and postural control dimensions of the CMSA–II. Point estimates of the MDC_{90} for the arm, hand, shoulder pain, leg, foot, and postural control dimensions of the CMSA–II were 1.39, 1.25, 1.80, 1.01, 1.25, and 1.31 impairment points (i.e., stages), respectively.

Study 2

Of the 74 participants in the study by Dang and colleagues,²⁶ 71 had CMSA–II stage scores of less than 7 and

Table 1 Reliability and Minimal Detectable Change Estimates: Study 1

Impairment category	ICC(2,1) (95% CI)	SEM (95% CI)	MDC_{90}
Arm	0.84 (0.72, 0.92)	0.60 (0.48, 0.80)	1.39
Hand	0.85 (0.72, 0.92)	0.54 (0.43, 0.72)	1.25
Shoulder pain	0.75 (0.55, 0.87)	0.77 (0.63, 1.05)	1.80
Leg	0.92 (0.85, 0.96)	0.43 (0.34, 0.57)	1.01
Foot	0.85 (0.71, 0.92)	0.54 (0.43, 0.72)	1.25
Postural control	0.80 (0.63, 0.90)	0.56 (0.45, 0.74)	1.31

ICC = intra-class correlation coefficient; SEM = standard error of measurement; MDC = minimal detectable change.

Figure 1 Receiver operating characteristic curve for the leg dimension, with improvement threshold values labelled: Study 2.

Figure 2 Receiver operating characteristic curve for the foot dimension, with improvement threshold values labelled: Study 2.

were eligible for analysis in our study. Another 12 patients had CMSA-AI improvement scores of less than 8 points, and 59 participants had change scores of 8 points or more.²⁶

The ROC curves are shown in Figures 1–3. The AUCs were 0.77 (95% CI: 0.66, 0.89) for the leg dimension, 0.62 (95% CI: 0.44, 0.81) for the foot dimension, and 0.70 (95% CI: 0.56, 0.83) for the postural control dimension. For all impairment dimensions, the threshold improvement value that jointly maximized sensitivity and specificity was 1 impairment point: 1.0 (95% CI: 0.85, 1.15) for the leg dimension, 1.0 (95% CI: 0.09, 1.91) for the foot dimen-

sion, and 1.0 (95% CI: 0.70, 1.30) for the postural control dimension. Table 2 provides the sensitivity and specificity for the improvement score of each impairment dimension.

DISCUSSION

Two questions to consider when appraising the extent to which valid inferences can be drawn from a measured-change score are as follows: (1) What is the threshold change or improvement value and (2) how confident can a clinician be if the threshold value is applied to inform a decision concerning a patient's change status? To our knowledge, a threshold value for the CMSA-II

Figure 3 Receiver operating characteristic curve for postural control, with improvement threshold values labelled: Study 2.

Table 2 Sensitivity and Specificity for Improvement Scores (Study 2)

Dimension and threshold improvement value	Sensitivity, %	Specificity, %
Leg		
0	100.00	0.00
1	72.88	75.00
2	27.12	100.00
3	6.78	100.00
>3	0.00	100.00
Foot		
0	98.31	16.67
1	61.02	58.33
2	22.03	83.33
3	5.08	100.00
>3	0.00	100.00
Postural control		
0	100.00	0.00
1	66.67	63.64
2	25.00	100.00
3	5.00	100.00
>3	0.00	100.00

dimensions has not been reported in the literature. Our study applied two discrete samples and methods to estimate a threshold change value for the CMSA-II dimensions. The first method produced a threshold change value (MDC₉₀) of approximately 1 impairment point for the arm, hand, leg, foot, and postural control dimensions and 2 impairment points for the shoulder pain dimension. Although MDC₉₀ provides an estimate for a threshold change value, it does not provide information about

the confidence a clinician has in applying this value. The interpretation of MDC₉₀ in our study is that 90% of the unchanged patients demonstrated random fluctuations of approximately 1 point between test and retest.

Our second validation method applied an anchor-based approach that used diagnostic test methodology to identify a threshold improvement change value. In addition to estimating a threshold improvement value, the anchor-based method allows one to calculate the confidence in applying the threshold value. Both methods produced a similar threshold value for change or improvement for the leg, foot, and postural control dimensions, supporting a threshold value of 1 point.

We recognize that the CI for the AUC of the foot dimension presented in Study 2, reported as 0.62 (95% CI: 0.44, 0.81), contains the null value of 0.5. A value of 0.5 indicates that the measure does no better than chance at correctly labelling a person as improved or not.³⁰ We speculate that this finding may be the result of an increased variability due to a lack of consistency in how therapists administer and score the foot dimension of the CMSA-II. Therefore, the threshold improvement value of 1 impairment point for the foot dimension identified in Study 2 should be interpreted with caution.

This study had a few limitations. First, the MDC estimate was based on a secondary analysis of data gathered more than 2 decades ago, and we are uncertain of the impact this timeline might have on our results.^{1,13,26} However, we speculate that the estimate of MDC would be primarily affected by the clinicians' experience with the measure and the distribution of motor impairment present in the patient sample. To the extent that the clinicians in the historical study had between 4 months and

Figure 4 Information gain curves for leg improvement change values of 1 and 2 impairment points.

5 years experience, we suspect that our results would generalize to contemporary clinicians with similar levels of experience. Second, the information used in our analysis was limited to the data reported by the original authors in terms of sample size, patient characteristics, and recruitment procedures.^{1,13,26}

A third limitation of our study was that the CMSA-AI cutoff score of 8 was based on a sample size of 7 patients from the Huijbregts and colleagues' study.²² This cutoff score was identified in a study by Barclay-Goddard²⁰ that included a sample of 22 participants, 12 of whom had experienced a stroke. However, a sensitivity analysis using a cutoff score of 7 yielded the same threshold improvement value of 1 impairment point for each measure. Despite these limitations, we believe that our estimated change threshold value of approximately 1 point is supported by the fact that two estimation methods applied to two separate samples obtained from two geographical locations converged on the same estimated value.

Clinical vignette

Mr. Smith is a 70-year-old man admitted to the stroke rehabilitation unit of a regional tertiary care hospital after experiencing a right anterior cerebral artery stroke 2 weeks ago. On admission, the physiotherapist assessed him using the CMSA and determined that he had a score of Stage 3 on the leg dimension of the CMSA-II. The therapist constructed the following measurable goal: to increase Mr. Smith's leg function by at least one stage in 4 weeks. The improvement value of 1 point, or stage, comes from this study's change estimates; the time frame for scheduling the reassessment comes from the physiotherapist's experience (e.g., a chart review of similar

patients). Specifically, the reassessment interval is scheduled for a point at which the therapist anticipates that approximately 50% of patients with a prognosis similar to Mr. Smith's would be expected to improve by at least 1 point.³²

Using the method described by Stratford and Riddle,²⁹ and to graph the relationship between the pre- and post-intervention measure chance of improvement, we applied the sensitivity and specificity values reported in Table 2 for the leg threshold values of 1 (sensitivity 73, specificity 75) and 2 points (sensitivity 27, specificity 100). Figure 4 shows the estimated chance of improvement before interpreting a patient's leg-change score against the estimated chance of improvement afterward by applying the patient's measured-change score to the improvement scores of 1 (thin, arcing line) and 2 points (thick, angled line). The dashed, diagonal line represents no increase in confidence in making a decision about a patient's improvement status. The thin and thick lines represent the chance that a patient has improved given a change of more than 1 or 2 points, respectively.

If, on reassessment, Mr. Smith's leg score improved by 1 point, the physiotherapist's confidence that this apparent improvement represented a true improvement, rather than a random fluctuation in a truly unchanged patient, would increase from 50% to 75%. This is shown by the arrow in Figure 4. If Mr. Smith improved by 2 or more points, the physiotherapist could rule in an improvement with absolute certainty (i.e., post-leg score chance of improvement = 100%).

In this vignette, the physiotherapist scheduled the reassessment when he or she estimated a 50% chance that this patient would achieve at least a 1-point

improvement. A feature of Figure 4 is that it illustrates the potential information gain for a spectrum of pre-assessment estimates of improvement, ranging from 0 to 100. For example, suppose the patient in this scenario was unable to be reassessed at the time the therapist anticipated a 50% change, hypothetically at 4 weeks, and that the assessment actually occurred at 8 weeks. This increase would likely affect the therapist's pre-measure estimate of this patient's chance of improvement. Rather than assigning a 50% chance of improvement, the therapist would likely assign a greater chance of improvement, say 75%. Figure 4 shows that an improvement of 1 point, combined with a pre-measure chance of 75% improvement, now yields a post-measure chance of improvement of approximately 88%.

CONCLUSION

The CMSA is a widely used, performance-based outcome measure that has demonstrated evidence of both reliability and validity.^{1,4,5,9,11,12,13,15–18} Previously, there was no threshold value for change reported for dimensions of the CMSA–II. Our study identified a threshold value-for-change score of 1 impairment point for the arm, hand, leg, foot, and postural control dimensions and 2 impairment points for the shoulder pain dimension. Having these values, clinicians can better determine whether their patients have experienced a clinically relevant change. In addition, using the threshold change value of 1 impairment point for the leg, foot, and postural control dimensions gives clinicians increased confidence in labelling a patient as improved or not.

Future research could focus on cross-validating the threshold values for change estimated in Study 1 for the arm, hand, and shoulder pain dimensions of the CMSA–II. Moreover, it may be valuable to conduct a prospective cohort study to estimate a threshold value for change for the CMSA–II dimensions. In doing so, researchers would continue to help bridge the gap between research and clinical practice by providing information that supports clinicians in making decisions reflective of the best available evidence, clinical expertise, and patient values.

KEY MESSAGES

What is already known on this topic

The Chedoke-McMaster Stroke Assessment Impairment Inventory is frequently used by rehabilitation personnel to categorize the motor recovery of persons with stroke. However, no threshold value for change has been reported for any of its six dimensions.

What this study adds

Clinicians can use a change of 1 impairment point (i.e., stage) for the arm, hand, leg, foot, and postural control dimensions and a change of 2 impairment points for

the shoulder pain dimension to identify true change in a patient's motor recovery.

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