Converting Functional Autonomy Measurement System Scores of Patients Post-Stroke to FIM Scores

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ABSTRACT

Purpose: The Functional Independence Measure (FIM) is widely used to assess persons post-stroke. The Quebec government has selected the Functional Autonomy Measurement System (SMAF) for use in all care settings. In this article, we propose simple equations to convert SMAF scores to FIM scores for persons undergoing post-stroke rehabilitation. **Method:** Persons post-stroke ($n = 143$) from three rehabilitation centres were assessed at admission and discharge using the FIM and SMAF. The sample was randomly split into derivation and validation data sets. Regression analysis was performed on the first data set to derive a conversion equation at each time point. The validity of the equations was measured using correlation coefficients, and differences between the observed and predicted FIM scores were computed from the second data set. **Results:** The relationship between the SMAF and FIM scores was linear at admission but quadratic at discharge. The proposed equations are, at admission, $FIM = 139 - 1.5 \times SMAF$ and, at discharge, $FIM = 118 - 0.018 \times SMAF^2$. The observed and predicted FIM scores were highly correlated in the validation data set ($r_s = 0.92$ and 0.93 at admission and discharge, respectively). Furthermore, the equations performed well in classifying stroke severity compared with a classification based on the observed FIM scores. **Conclusions:** SMAF scores can be reliably converted to FIM scores using the proposed equations, thus facilitating international trials in stroke rehabilitation.

Key Words: functional autonomy measurement; rehabilitation; stroke.

RÉSUMÉ

Objectif : la mesure de l'indépendance fonctionnelle (MIF) est largement utilisée lors de l'évaluation après un accident vasculaire cérébral (AVC). Le gouvernement du Québec a retenu l'utilisation du système de mesure de l'autonomie fonctionnelle (SMAF) dans tous les établissements de soins. Le présent article présente des équations simples pour convertir les scores du SMAF en scores de MIF chez les personnes en réadaptation après un AVC.

Méthodologie : les chercheurs ont évalué les personnes qui avaient subi un AVC ($n = 143$) de trois centres de réadaptation à l'aide de la MIF et du SMAF à l'admission et au congé. Ils ont divisé l'échantillon aléatoirement en ensembles de données de dérivation et de validation. Ils ont procédé à une analyse de régression du premier ensemble de données pour dériver une équation de conversion à chaque point dans le temps. Ils ont mesuré la validité des équations au moyen de coefficients de corrélation et calculé les différences entre les scores de MIF observés et prédits à partir du deuxième ensemble de données.

Résultats : la relation entre les scores du SMAF et de MIF était linéaire à l'admission, mais quadratique au congé. À l'admission, l'équation proposée est $MIF = 139 - 1,5 \times SMAF$ et, au congé, $MIF = 118 - 0,018 \times SMAF^2$. Les scores de MIF observés et prédits étaient hautement corrélés dans l'ensemble de données de validation ($r = 0,92$ et $0,93$ à l'admission et au congé, respectivement). De plus, les équations donnaient de bons résultats dans le classement de la gravité des AVC par rapport au classement reposant sur les scores de MIF observés.

Conclusions : on peut convertir les scores de SMAF en toute fiabilité à l'aide des équations proposées, facilitant ainsi les essais internationaux sur la réadaptation après un AVC.

Every year, an estimated 17 million people around the world have a first stroke.¹ Stroke affects primarily older adults, and it remains a leading cause of disability among survivors, although rates of burden vary greatly

across countries.^{2,3} The prevalence of stroke is expected to rise significantly around the world, mostly in people aged 65 years and older.⁴ Health care providers and clinical researchers value the availability of standardised,

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psychometrically sound instruments for assessing care-induced changes in patients or the efficacy of promising interventions. Such tools are also useful for cost-effectiveness analyses that guide decision makers in allocating often-scarce health care resources.

In post-stroke rehabilitation, performance of functional activities is widely recognized as one of the most important outcomes to assess, given its known influence on stroke survivors' capacity for community reintegration.⁵ Researchers have developed several measurement instruments, and extensively validated some of them, to assess functional autonomy in patients post-stroke. Of those, the Functional Independence Measure (FIM) is one of the most commonly used in rehabilitation programmes and research.⁵⁻⁷

The FIM was developed by a joint task force appointed by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation.^{8,9} It consists of 18 items related to self-care (6 items), sphincter control (2 items), mobility (3 items), locomotion (2 items), communication (2 items), and social cognition (3 items). The FIM has no item related to instrumental activities of daily living (IADLs). The first 13 items are commonly combined to form the FIM Motor sub-scale, and the last 5 are grouped into the Cognitive sub-scale. Each item is scored on a 7-point scale (1 = *complete dependence*; 7 = *independence*). Summing the scores across all items generates a total score that ranges from 18 to 126, with lower scores reflecting greater disability. The FIM assesses what a patient really does and not what he or she could do in other circumstances or in a different setting. Alexander¹⁰ defined four degrees of severity of the FIM total score: very severe (<40), severe (40–60), moderate (61–80), and mild (>80).

The FIM has been shown to be reliable, valid, and responsive in diverse populations.^{7,11-13} The minimal clinically important difference has been established at 22 points for patients with stroke undergoing rehabilitation, using physicians' assessments of change as the external criterion.¹⁴ The FIM, however, has been found to be prone to ceiling effects;^{6,15,16} thus, in an attempt to overcome this problem and extend its range, 12 items related to cognition and speech taken from the Functional Assessment Measure (FAM) have been added to the FIM, leading to the so-called FIM + FAM.¹⁷ However, ceiling effects remain, and the FIM + FAM does not surpass the FIM alone in use.^{12,18} We used only the FIM in the current study.

In Quebec, the Ministry of Health and Social Services chose to use the *Système de mesure de l'autonomie fonctionnelle*, or SMAF (in English, Functional Autonomy Measurement System) to assess health-related needs and planning services across the continuum of care. The SMAF is a 29-item scale developed according to the World Health Organization's *International Classification of Impairments, Disabilities and Handicaps*.^{19,20} It mea-

sures functional ability in five areas: activities of daily living (ADLs; seven items), mobility (six items), communication (three items), mental functions (five items), and IADLs (eight items). Each function is rated on an ordinal scale (ranging from 0 = *independent* to 3 = *dependent*) using information obtained through interviews with and observation of a patient or by questioning a knowledgeable informant. Summing the ratings assigned to each function generates a total score out of 87; unlike the FIM, higher scores reflect greater disability. Like the FIM, the SMAF assesses what a patient does rather than what he or she could do under more favourable conditions.

The SMAF has been shown to be reliable, valid, and sensitive to change in older adults but also, more generally, in rehabilitation patient groups.²⁰⁻²³ The minimal detectable change on the SMAF has been established at 5 points for community-dwelling people aged older than 75 years.²⁴ Pinsonnault and colleagues²⁵ added six items to the SMAF to assess social functioning; we did not use these additional items in the current study.

Users of the SMAF, whether based in Quebec or elsewhere,²⁶⁻³² could benefit from a simple equation to convert SMAF scores to FIM scores—that is, to derive a FIM score from an observed SMAF score. Such a conversion would facilitate comparisons of findings across studies that use either of these scales and increase the likelihood that findings based on the SMAF would be considered for inclusion in systematic reviews and meta-analyses. Conversion equations would also facilitate multi-centre collaborative studies without disrupting normal clinical practice. Several articles have reported predictive equations or algorithms for converting stroke scales,³³⁻³⁶ but none has yet proposed a conversion equation from the SMAF to the FIM. We aim to fill this gap. This article reports on the development and validation of two simple equations for converting SMAF total scores to FIM total scores over the rehabilitation period.

METHODS

The current study was part of a larger initiative to create a clinical databank that would facilitate knowledge exchange between rehabilitation teams and researchers, with the ultimate goal of providing patients with state-of-the-art rehabilitation care.³⁷ For the current study, we used a data set involving 143 patients with stroke admitted consecutively between January 2015 and January 2016 to one of three academic rehabilitation centres in Quebec. Eligible patients were aged 18 years or older and were clinically diagnosed as having had a stroke. At study entry, we obtained socio-demographic and clinical data from the patients, their next of kin, and medical records. We assessed the patients' functional autonomy using the FIM and the SMAF, in that order, within 72 hours of admission to the stroke rehabilitation unit and at discharge.

For any given patient, all assessments were made by the same rehabilitation professional, trained in using the two measurement instruments. Data acquisition procedures were approved by the research ethics boards of each participating rehabilitation centre. At study enrolment, participants provided written, informed consent when able. Authorisation to enrol patients who were unable to give consent on their own was provided by their legal representative, usually a close family member.

Statistical analysis

We summarized participants' baseline socio-demographic and clinical characteristics using the mean (SD) for continuous variables and using frequency and proportion for categorical variables. Seven participants had missing data on at most four items of the FIM or SMAF for either admission or discharge. A rating of 1 was substituted for missing data on the FIM, as one data guide has recommended.³⁸ There is no such recommendation for the SMAF. To take a coherent approach, we also replaced missing data on the SMAF with the worst score (i.e., 3). To ensure that this imputation approach did not have a significant effect on the proposed equations, we reran the analyses, ignoring patients with missing data. The resulting equations were identical, so we report only those derived from the entire sample of patients.

For analysis purposes, the data set was split randomly into two equal-sized data sets, with prior stratification by rehabilitation centre. The first set ($n = 72$) was used to develop the conversion equations, and the second ($n = 71$) served to validate the resulting equations. We compared participants' characteristics between the derivation and validation data sets using t tests and χ^2 . Using the first data set, we generated scatter plots at both time points to identify the functional form that would best capture the relationship between the SMAF and the FIM. We then carried out linear regression analyses at each time point to derive an equation for predicting a FIM total score from a SMAF total score. Residual analyses were conducted afterward to check the distributional assumptions underlying the linear regression and to detect influential observations. Conversion equations derived from the first data set were then tested on the validation data set by estimating Pearson's product-moment correlations between the observed and predicted FIM scores. Differences between the observed and predicted scores were also scrutinized. Data were analyzed using IBM SPSS Statistics version 24.0 (IBM Corp., Armonk, NY).

Sample size considerations

Because the study objectives were pursued using an existing data set, the sample size was not determined a priori. Nonetheless, it was worth checking whether a sample of 143 patients split in half would provide sufficient statistical power for the planned analyses—that is,

for deriving the conversion equations and estimating the correlations and mean prediction errors between the observed and predicted FIM scores at admission and discharge. Because the equations were to include a single predictor (i.e., the SMAF total score), a sample of 72 patients was largely sufficient. Using nQuery version 7.0 (Statistical Solutions Ltd., Boston, MA) and setting the desired power at 90% and the significance level at 0.05, a sample of 65 participants was required to test the hypotheses H_0 , with $\rho = 0.8$, and H_1 , with $\rho > 0.8$, where ρ denoted the correlation between the observed and predicted FIM scores and the true correlation in the population was assumed to be 0.9.

Last, to estimate mean prediction errors between the observed and predicted FIM scores with 95% confidence, nQuery suggested a sample of 56 participants when the desired precision was set at 5 points, ρ at 0.80, and SD at 30, based on a systematic review of validation studies conducted with the FIM.³⁹ Combined, these considerations suggested that splitting a sample of 143 patients into equal-sized data sets for deriving and validating conversion equations would provide sufficient power for the planned analyses.

RESULTS

The baseline characteristics of the 143 study participants are reported in Table 1. They had a mean age of 68 years, ranging from 19 to 96. The sample included similar proportions of men and women and of right and left hemiparesis. Ischemic strokes were more prevalent. According to the SMAF, patients were quite impaired in IADLs and mental functioning. Scores on the FIM suggested considerable impairment in both the motor and the cognitive domains. Given the relatively large sample size, the random procedure was effective, and no difference was found between patients assigned to the derivation or the validation data sets on any of the variables available (smallest p -value = 0.188).

Deriving the conversion equations using the derivation data set ($n = 72$)

The scatter plots shown in Figure 1 clearly suggest a linear relationship at admission but a quadratic one at discharge. Strong inverse relationships between SMAF and FIM total scores were observed at both time points, with Pearson's r s = -0.89 and -0.95 , respectively. At admission, the best equation for converting the SMAF total score into a FIM total score was

$$\text{Predicted FIM} = 138.88 - 1.526 \times \text{SMAF} (R^2 = 80\%; \\ F_{1,70} = 278.7, p < 0.001),$$

and at discharge the best equation was

$$\text{Predicted FIM} = 117.81 - 0.018 \times \text{SMAF}^2 (R^2 = 90\%; \\ F_{1,70} = 597.9, p < 0.001).$$

Table 1 Baseline Characteristics of Study Participants ($n = 143$)

Characteristic	No. (%)	Mean (SD), range
Age, y		68 (15.2), 19–96
Gender (female)	67 (46.9)	
Side of stroke ($n = 142$)		
Right	67 (47.2)	
Left	63 (44.4)	
Bilateral	12 (8.4)	
Type of stroke ($n = 141$)		
Hemorrhagic	38 (27.0)	
Ischemic	103 (73.0)	
Time from stroke onset to admission to rehabilitation centre, d		27 (20), 5–111
Length of stay in rehabilitation centre, d		56 (32), 9–162
SMAF total score at admission (out of 87)*†		37.8 (14.0), 2.5–70
ADL		1.1 (0.7), 0–3
Mobility		0.02 (0.7), 0–2.5
Communication		0.4 (0.4), 0–1.7
Mental functions		1.6 (0.6), 0–2.4
IADL		2.2 (0.6), 0.2–3
FIM total score at admission (out of 126)*§		81.6 (23.4), 24–125
Motor sub-scale		4.3 (1.6), 1–7
Cognitive sub-scale		5.2 (1.3), 2–7

*A higher score reflects greater disability.

†To facilitate comparison across domains, descriptive statistics are expressed on a common scale of 0–3.

‡A lower score reflects greater disability.

§To facilitate comparison across sub-scales, descriptive statistics are expressed on a common scale of 1–7.

FIM = Functional Independence Measure; SMAF = Functional Autonomy Measurement System; ADL = activities of daily living; IADL = instrumental activities of daily living.

When using the conversion equations, any prediction falling outside the theoretical range of the FIM (i.e., 18–126) was brought back within that range by resetting the prediction to either the lowest or the highest possible value. At admission, one patient with a SMAF score of 2.5 had a predicted FIM score of more than 126, which was reset to 126. Differences between the predicted and observed FIM scores ranged from –36 to +24. Of the differences, 85% were within 15 points; 67% were within 10 points. At discharge, no patient had a predicted FIM score outside its theoretical range. Differences between the predicted and observed FIM scores were smaller, ranging from –16 to +14; 90% of the differences lay within 10 points of each other.

Validating the conversion equations using the validation data set ($n = 71$)

The two derived equations were applied to participants randomly assigned to the validation data set to predict their FIM scores from their SMAF scores. Two of these participants, with SMAF scores of 3 and 7, respectively, had predicted FIM scores of more than 126 at admission. The two values were reset to 126. In the validation data set, we found strong correlations between the observed and predicted FIM scores, both at admission ($r = 0.92$; 95% CI: 0.88, 0.94) and at discharge ($r = 0.93$; 95% CI: 0.90, 0.95). Prediction errors averaged –0.89 (95% CI: –3.1, 1.3) at admission and –0.91 (95% CI: –2.2, 0.4) at discharge. At admission, 92% of the differences were within 15 points; 70% were within 10 points. Corresponding values at discharge were 99% and 93%, respectively.

Next, we focused on the participants for whom the equations had yielded greater prediction errors, either at admission or at discharge, and tested whether any of the

Figure 1 Scatter plots linking SMAF and FIM total scores from the derivation data set at admission (left) and discharge (right), with 95% prediction bands.

FIM = Functional Independence Measure; SMAF = Functional Autonomy Measurement System.

Table 2 Cross-Tabulation of the Observed and Predicted FIM Scores, Categorized by Stroke Severity, at Admission and Discharge

Stroke severity based on observed FIM score	Stroke severity based on predicted FIM score				Total
	Very severe (<40)	Severe (40–60)	Moderate (61–80)	Mild (>80)	
Stroke severity at admission					
Very severe (<40)	1	1	0	0	2
Severe (40–60)	0	8	4	0	12
Moderate (61–80)	0	5	11	1	17
Mild (>80)	0	0	6	34	40
Total	1	14	21	35	71
Stroke severity at discharge					
Very severe (<40)	0	0	0	0	0
Severe (40–60)	0	2	0	0	2
Moderate (61–80)	0	0	2	0	2
Mild (>80)	0	0	2	65	67
Total	0	2	4	65	71

Note: Cells report the number of people classified in the corresponding categories.
FIM = Functional Independence Measure.

variables listed in Table 1 could identify those whose predicted FIM scores were not within 10 points of their observed FIM scores. At admission, participants were more likely to satisfy this criterion if they had sustained a left hemiparesis (76% vs. 24% for right or bilateral hemiparesis; Fisher's exact test, $p = 0.009$). They also showed somewhat greater disability in ADLs and mobility, according to the SMAF (difference of 2 points, on average; $ps = 0.037$ and 0.033 , respectively), and in motor functions, according to the FIM (difference of 10 points, on average; $p = 0.043$). At discharge, participants for whom the predicted FIM score was not within 10 points of their observed score were older, on average, than those for whom the prediction error was less than 10 (83 vs. 67 y; $p = 0.005$). As we observed at admission, participants also had lower performance in ADLs, mobility, and motor tasks ($ps = 0.037$, 0.008 , and 0.002 , respectively), but also in IADLs ($p = 0.035$). However, adding side of stroke, age, or both into the two regression models did not modify the predictive power of the two equations.

To further judge the value of the two equations, we examined their ability to accurately classify stroke severity, using the cutoff scores for the FIM proposed by Alexander.¹⁰ Results are shown in Table 2. At admission, 54 of the 71 patients (76%) were correctly classified; stroke severity was underestimated by one category for 6 patients and overestimated for the 11 others. At discharge, 69 of the 71 patients (97%) were correctly classified. The two remaining participants were classified in the moderate category, whereas their observed FIM score would have classified them in the mild category.

Having concluded that the two derived equations performed well on the validation data set, they were re-estimated using the entire sample of 143 patients, as research has recommended.⁴⁰ The resulting equations were very similar to the previous ones, with parameter

estimates differing only in the second decimals. After rounding numbers for ease of use, the final equations were

$$\text{At admission: FIM} = 139 - 1.5 \times \text{SMAF} (r = 0.90),$$

$$\text{At discharge: FIM} = 118 - 0.018 \times \text{SMAF}^2 (r = 0.94).$$

DISCUSSION

In this study, we developed two simple equations for converting a SMAF total score into a FIM total score for patients undergoing post-stroke rehabilitation. The equations performed well on the validation data set, with acceptable prediction errors and high coefficients of determination. These findings suggest that the equations may be reliably used in clinical and research settings. The equations should be of broad applicability in Quebec because they were derived from data collected in three of the largest teaching rehabilitation centres that provide post-stroke care to diverse patients aged 18 years and older from both rural and urban areas. The proposed equations should also be useful outside Quebec. Although the SMAF is less well known than the FIM, its use is expanding rapidly, as evidenced by recent articles from a variety of countries, including France, Switzerland, Taiwan, and Africa.^{26–32}

Ideally, a single equation would have been found to be valid for use at both admission to and discharge from in-patient rehabilitation. However, the scatter plots clearly suggest the need for two equations: one to be used at admission, which would link SMAF and FIM total scores linearly, and the other for use at discharge, which would include a quadratic rather than a linear term. In our opinion, the need for two distinct equations can be partly explained by IADL items that only the SMAF

includes. At admission, rating these items had little effect because most study participants were too impaired to perform instrumental tasks. At discharge, though, many participants had regained the capacity to accomplish some IADLs, which the FIM could not detect. The right panel of Figure 1 confirms the ceiling effect of the FIM for patients with mild residual impairments. The FIM thus appears to be less responsive than the SMAF to the clinically meaningful improvement that patients with stroke can achieve by the end of the rehabilitation period.

Some years ago, Desrosiers and colleagues⁴¹ found the SMAF total score to be more sensitive to change than the FIM total score in a similar population of stroke patients, with standardised response means of 1.20 and 0.97, respectively ($p < 0.001$). Although the present study examined those findings from a different perspective, it supports the claim that the SMAF outperforms the FIM in detecting improvement in patients with stroke. Nonetheless, because use of the FIM will likely continue, it is important to be able to convert one scoring system to the other.

Some limitations of this study are as follows. The proposed equations should be validated using external data sets from both academic rehabilitation centres and community hospitals. Although these were derived from a relatively large sample, a larger sample would provide more power to characterize the small proportion of patients for whom the equations yield slightly greater prediction errors. Such patients could be the focus of future investigations. The equations should also be validated in other Canadian provinces and countries in which the SMAF is used to assess patients post-stroke.

CONCLUSION

The SMAF and FIM were found to be highly correlated, despite assessing a slightly different set of functions. We have provided methods to convert the first to the second, using simple equations that we found to be reliable. The proposed equations provide a useful means of comparing samples of participants post-stroke with findings across published observational studies and therapeutic trials that have been conducted in various countries around the world using either the SMAF or the FIM to measure functional independence. These proposed equations could also facilitate the conduct of future studies by allowing participating sites to use the assessment tool already in use in their own settings.

KEY MESSAGES

What is already known on this topic

The FIM is widely used in rehabilitation programmes and research to measure functional autonomy in patients undergoing post-stroke rehabilitation. In Quebec, the Functional Autonomy Measurement System (SMAF), initially developed for measuring functional autonomy in older adults, is used by the Ministry of Health and

Social Services with all patient populations and in all care settings. Both tools have good measurement properties. A means of converting one scoring system to the other would facilitate communication between clinicians and researchers who work with patients post-stroke in different Canadian provinces and in other countries.

What this study adds

This study proposes two simple equations for converting SMAF total scores to FIM total scores, one for use at admission and the other for use at discharge. Evidence suggests that the proposed equations are reliable, although further validation is warranted.

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