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## Structural Validity of the Short Musculoskeletal Function Assessment in Patients With Injuries

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**Background.** The Short Musculoskeletal Function Assessment (SMFA) is a widely used patient-reported outcome measure, originally having 2 elements of outcome: the function index and the bother index. In multiple studies, it has been argued that the SMFA should be scored using 3, 4, or 6 subscales instead. Hence, there is inconsistency about the number of underlying dimensions of the SMFA.

**Objective.** The aim of this study was to evaluate the structural validity of the various proposed subscale configurations of the SMFA in a broad range of Dutch patients with injuries.

**Design.** This study used a prospective cohort design.

**Methods.** Participants with injuries were asked to complete the Dutch SMFA (SMFA-NL) at 5 to 8 weeks postinjury. The structural validity of the 6 different factor structures that have been proposed in other studies was evaluated using confirmatory factor analyses. Internal consistency was analyzed using Cronbach alpha.

**Results.** A total of 491 patients participated (response rate = 74%). A 4-factor structure showed an acceptable fit (root-mean-square error of approximation [RMSEA] = 0.070, comparative fit index = 0.973, Tucker-Lewis index = 0.971). Other models, including the original 2-index structure, showed insufficient structural validity in Dutch patients with injuries. The 4-factor structure showed sufficient discriminant validity and good internal consistency (Cronbach alpha  $\geq$  0.83).

**Limitations.** It is unclear whether conclusions are generalizable across different countries, people who are elderly, and people without injuries.

**Conclusion.** In a broad range of patients with injuries, the SMFA-NL may be best scored and interpreted using a 4-factor structure. Other factor structures showed insufficient structural validity.

Injuries are a large contributor to the international burden of disease.<sup>1-3</sup> In the treatment of patients with injuries, traditional outcome measures such as x-ray recordings and range of motion do not accurately reflect the patients' perspective on their functioning.<sup>4,5</sup> Patient Reported Outcome Measures (PROMs) have increasingly gained attention: PROMs have been incorporated in clinical trial guidelines<sup>6</sup> and regular care procedures that require PROMs as quality control.<sup>7</sup>

When a heterogeneous group of patients with injuries is evaluated, a general musculoskeletal outcome measure may be used. In 1999, Swiontkowski et al<sup>8</sup> developed the Short Musculoskeletal Function Assessment (SMFA) as an outcome measure to evaluate physical function of patients with a broad range of musculoskeletal disorders, including patients with injuries. The SMFA was originally designed to evaluate 2 latent constructs: patients' physical status, and how bothered they are by functional problems due to the musculoskeletal conditions. Hence it was originally divided into 2 basic elements of outcome: the function index and the bother index. Later, the SMFA was translated and cross-culturally adapted into multiple languages.<sup>9-16</sup> In some cross-cultural validation studies, it was argued that the SMFA may be interpreted by 3,<sup>14,15</sup> 4<sup>10,11</sup> or 6<sup>9</sup> subscales instead of the original 2.<sup>8</sup> The validity of the different configurations of subscales (ie, structural validity) has rarely been studied, resulting in inconsistency about the number and nature of the latent constructs that are evaluated with the SMFA.

Structural validity is an important aspect of validity that concerns the validity of a factor structure of a PROM.<sup>17</sup> The factor structure defines the number of latent constructs (ie, number of subscales) that may be evaluated and the configuration of items that represent these constructs (Figure). Therefore structural validity guides how a PROM should be scored and interpreted.

The aim of this study was (1) to investigate the structural validity and internal consistency of the various proposed subscale configurations of the SMFA in Dutch patients with a broad range of acute injuries and (2) to identify the factor structure that showed best structural validity.

## **Methods**

### **Participants**

Participants were recruited at the Trauma Department of the University Medical Center Groningen (The Netherlands), a level-1 trauma center. Patients that presented with 1 or more acute injuries and required a follow-up treatment for at least 5 weeks at the trauma surgery outpatient clinic were prompted for inclusion. Exclusion criteria were as follows: age under 18 or above 67 years, not able to read or write Dutch, severe neurological deficits, severe traumatic brain injury, pathologic fractures, and severe psychiatric conditions.

Patients received the standard Dutch translation of the SMFA<sup>11</sup> (SMFA-NL) questionnaire 5 to 8 weeks after the injury, in which patients reported their functioning of the past week.

Patients had either been treated surgically or conservatively. Patients received the questionnaire on paper or electronically; nonresponders were reminded once.

The methods employed in this study have been reviewed by the local institutional review board, which waived further need for approval. Patients consented with the

participation in this study. The study was carried out in compliance with the principles outlined in the Declaration of Helsinki on ethical principles for medical research involving human participants.

### **Questionnaire and Theoretical Framework**

The SMFA was developed as a shorter alternative to the 101-item Musculoskeletal Function Assessment (MFA) in order to enhance clinical usability.<sup>8,18</sup> Both questionnaires rest on the same theoretical framework. The questionnaires were developed to assess physical functioning of patients with a broad range of musculoskeletal conditions. The SMFA was designed as an instrument that was neither too general nor overly specific. Items that were often overlooked were incorporated, such as coping, adaptation, and acceptance. Four primary categories were used: upper extremity, daily activities, mobility, and mental and emotional functioning. Together these categories made up the function index. The bother index was added to assess the extent to which patients are bothered due to their conditions.

The SMFA consists of 46 items that are scored on an ordinal 5-point Likert scale. The items of both indices can be summed to obtain a score (0-100), wherein 0 equals best possible function and 100 equals worst possible function. The originally (American) English SMFA has been translated and cross-culturally adapted into Chinese, Danish, Dutch, German, Korean, Portuguese, Spanish, and Swedish.<sup>9-16</sup>

### **Evaluation of Structural Validity**

Structural validity has been defined as the degree to which scores of a PROM are an adequate reflection of the dimensionality (ie, the expected number of subscales) of the

construct that is measured.<sup>19</sup> A construct can be regarded as the “hidden variable” that cannot be measured directly but can be measured through multiple other measurements. For example, the construct “lower extremity function” cannot be measured directly, but it can be measured by multiple items of a PROM that evaluate the aspects of lower extremity function.

Factor analysis is a frequently used technique to evaluate a set of latent constructs underlying the items of a PROM.<sup>20</sup> There are 2 main types of factor analysis. The first type, exploratory factor analysis (EFA), may be used when there is no clear idea of how many constructs are represented by a PROM and which items represent the specific constructs.<sup>21</sup> In some of the different cross-cultural validation studies of the SMFA, EFAs were used to explore the factor structure of the SMFA.<sup>9,10,11,14,15</sup> Different factor structures were reported, which caused a lack of clarity about the number of subscales and what items represent these subscales. An EFA provides limited information regarding the structural validity of the found factor structure, and it cannot be used to compare the structural validity of different factor structures.

The second type of factor analysis, confirmatory factor analysis (CFA), overcomes these limitations. In a CFA, explicit relationships between the items in the questionnaire and the constructs that may be evaluated are prespecified; that is, the factor structures of the SMFA that were reported in earlier studies. CFA tests how well the data fits the prespecified factor structure. When the prespecified factor structure yields an improper “goodness of fit” with the data, the model is rejected.<sup>21</sup> For example, with a PROM in which a single score is used, it is critical to demonstrate a good-fitting 1-factor structure. In this study, CFA was used to *confirm* and *validate* the different factor structures of the SMFA.

## Models

The path diagrams of the analyzed factor structures are shown in the Figure and eAppendix 1 (available at <https://academic.oup.com/ptj>). To aid the interpretation of the factor structures, a list of items of the SMFA-NL is shown in eAppendix 2.

*Model 1.* The original 2-index factor structure is the most widely used method of interpreting the SMFA.<sup>22,23</sup> The function index consists of 34 items, and the bother index consists of 12 items. Although construct validity, test-retest reliability, and responsiveness have been evaluated, structural validity of the original 2-index structure has not been evaluated.

*Model 2.* In the Mexican cross-cultural validation study, Guevara et al<sup>15</sup> conducted a principal component analysis and reported a 3-factor solution. The obtained factors were as follows: upper extremity function, lower extremity function, and daily activities. In their analysis, items 14, 16, 29, 31, and 38 were dropped.

*Model 3.* In the Brazilian cross-cultural validation study, Taylor et al<sup>14</sup> conducted a principal component analysis and found that a different 3-factor model fitted best. Subscales were named: upper extremity dysfunction, lower extremity dysfunction, and bother. In their analysis, items 7, 15, 23, 30, 32, 35, 37, and 45 were dropped.

*Model 4.* In the Dutch cross-cultural validation, Reininga et al<sup>11</sup> conducted a principal component analysis and proposed a 4-factor structure containing all items of the SMFA. Subscales were named: upper extremity dysfunction, lower extremity dysfunction, problems with daily activities, and mental and emotional problems.

*Model 5.* In the Chinese cross-cultural validation, Wang et al<sup>9</sup> reported a model that consisted of 6 subscales. Subscales were as follows: daily activities, mobility, arm and hand function, emotional status, sexual activity and driving a car, and difficulties with falling



asleep. Item 36 was excluded from the final model. Although Model 5 is overidentified ( $df = 933$ ), the subscales of difficulties falling asleep and of sexual activity and driving are defined by only 1 and 2 items, respectively. This low number of items per subscale creates susceptibility to empirical underidentification; in other words, preventing the analysis from obtaining a valid and unique set of factor loadings.<sup>21</sup>

*Model 6.* In the Danish cross-cultural validation, Lindahl et al<sup>10</sup> conducted an exploratory factor analysis and reported 4 subscales with a different item distribution than that of Reininga et al<sup>11</sup>. The model of Lindahl et al<sup>10</sup> contained all 46 items. Subscales were called mobility, physical limitations, emotional status, and upper extremity activities.

## Data Analysis

*Sample size.* It has been recommended to include at least 7 patients per item when the structural validity of a PROM is investigated.<sup>24</sup> Our aim was to include at least 460 patients (10 patients per item of the SMFA).

*CFA.* The CFAs were performed using the *R* package lavaan version 0.5-18 (Comprehensive R Archive Network [CRAN]; <http://CRAN.R-project.org/package=lavaan>;

<http://lavaan.org/>).<sup>25,26</sup> All models were evaluated conform the correlated factors model:

each item was restricted to load on 1 factor, and covariance was expressed between

factors.<sup>21,27</sup> Factor loadings, error variance, and factor covariance were freely estimated.

The weighted least-squares means and variances-adjusted (WLSMV) estimator was used.

The WLSMV estimator is robust to nonnormality and is recommended when categorical

indicators are used.<sup>28</sup> Missing data were handled pairwise. Completely standardized factor

loadings were calculated.

The model-implied and population variance-covariance matrices of each model were compared using chi-squared tests.<sup>27</sup> The chi-squared test is a global test of model fit; however, it is considered to be overly strict and sample-size sensitive.<sup>21,27</sup> To evaluate model fit, other goodness of fit indices were examined: the root-mean-square error of approximation (RMSEA), comparative fit index (CFI), and Tucker-Lewis index (TLI). Cutoff values that indicated an acceptable fit were guided by Hu and Bentler<sup>29</sup> and Steiger<sup>30</sup>:  $RMSEA \leq 0.07$ ,  $CFI \geq 0.95$ , and  $TLI \geq 0.95$ . A model fit that did not meet all thresholds was considered an unacceptable fit. In addition to fit indices, we evaluated the magnitude, direction, and significance of factor loadings of all models. Factors were considered to show sufficient discriminant validity when between-factor correlations were  $\leq 0.85$ .<sup>21</sup> There are no strict guidelines for factor loadings, although factor loadings  $\geq 0.4$  were considered salient.<sup>21</sup>

*Internal consistency.* Internal consistency refers to the degree of interrelatedness among the items on a scale. Cronbach alpha was calculated for each subscale of the evaluated models to evaluate internal consistency. It is widely accepted that Cronbach alpha should be  $\geq 0.70$ .<sup>31</sup>

## Results

A total of 491 patients participated (276 men, 215 women). The response rate was 74%. Education level, marital status, and injury types are presented in Table 1. A total of 164 (33%) patients had an upper extremity fracture, and 145 (30%) patients had a lower extremity fracture. Most patients reported that they had no chronic health conditions (Tab.

1). Items 15 and 22, which regarded driving a car and sexual activity, were missing in 2.9% and 2.6%, respectively. All other items were missing in less than 2%.

### **Confirmatory Factor Analyses**

*Model fit.* All analyses succeeded without errors, except for Models 3 and 5. In the first run, the estimation of the factor loadings of items 16 and 38 in Model 3 and of items 7, 11, and 33 in Model 5 yielded a negative error variance and completely standardized factor loading with a value greater than 1.0. This is a theoretically improper solution, known as a Heywood case. The factor loadings of these items were sequentially constrained to 1.0, and models were reanalyzed.<sup>32</sup> Both models yielded a proper solution.

Model 4 was the only model that showed an acceptable fit (RMSEA = 0.070, CFI = 0.973, TLI = 0.971). The fit indices of Models 1, 2, 3, 5, and 6 did not meet the prespecified thresholds for an acceptable fit (Tab. 2).

*Factor loadings.* The factor loadings of all evaluated models are shown in the Appendix. Most factor loadings of Model 4 were higher than 0.80. All factor loadings were > 0.4, statistically significant and positive. The covariance between the individual factors of Model 4 was smaller than 0.85, indicating there was sufficient discriminant validity between all factors.

The majority of the factor loadings of Model 1 ranged between 0.6 and 0.9. The function index contained 4 items that had factor loadings smaller than 0.4 (item 5 and 28). Factor loadings of Model 2 mainly ranged between 0.5 and 0.9. One item showed a factor loading < 0.4 (item 21). Model 3 showed factor loadings ranging between 0.7 and 0.8, and 1

loading was smaller than 0.4 (item 28). Model 5 showed factor loadings generally between 0.7 and 0.9. All factor loadings were  $\geq 0.4$ . Model 6 showed factor loadings that mainly ranged from 0.7 to 0.9. The factor loadings of this model were all  $\geq 0.4$ .

### **Internal Consistency**

Cronbach alpha values are shown in Table 3. Cronbach alpha was  $\geq 0.83$  for all subscales of Model 4. Models 1, 2, 3, and 6 showed sufficient internal consistency on all subscales. Model 5 showed insufficient internal consistency of subscale 5 (sexuality and driving, Cronbach alpha = 0.68). The subscale “difficulties with falling asleep” of Model 5 was not calculable since it contained only 1 item (item 7).

### **Discussion**

It is important that measurements taken with a PROM are based on a valid underlying factor structure. Since its introduction, the original 2-index structure has been used most to calculate the scores of the SMFA.<sup>24</sup> The aim of this study was to investigate the structural validity and internal consistency of the various proposed factor structures of the SMFA in patients with a broad range of acute injuries. A model with 4 subscales<sup>11</sup> provided evidence of structural validity of the SMFA-NL questionnaire.

The 4-factor model of Reininga et al<sup>11</sup> (Model 4) showed an acceptable goodness of fit with generally good-to-excellent factor loadings. The subscales showed sufficient discriminant validity, indicating that all evaluated constructs are sufficiently different from each other. Internal consistency was sufficient, although 3 of the 4 subscales (*upper and lower extremity dysfunction* and *problems with daily activities*) showed Cronbach alpha

values > 0.95, which may indicate that there are redundant items in these scales. However, removal of items was beyond the scope of this study.

The original 2-index (Function Index and Bother Index) model has been investigated and used extensively in clinical settings and research.<sup>22,23</sup> However, in this study this model showed an unacceptable goodness of fit. The 2-index model was originally derived in a similar sample of patients, of which most sustained an injury.<sup>8</sup> Upon the development of the SMFA, the Function Index and Bother Index were considered to reflect conceptually different constructs, of which the Function Index was a more objective measure of physical function and the Bother Index more subjective.<sup>8</sup> For instance, patients could report that their knee locked just “some of the time” while being extremely bothered by it. The distinction of function and botheredness was based on theoretical grounds but was not verified with a factor analysis. This may have been the cause of the insufficient structural validity. The findings of this study suggest that the SMFA-NL does not measure these constructs separately. The various translation studies of the SMFA that performed an EFA did not find the 2-index structure either.

Models 2 (Guevara et al<sup>15</sup>) and 6 (Lindahl et al<sup>10</sup>) showed an unacceptable fit and were, therefore, considered to show insufficient structural validity. The model of Lindahl et al<sup>10</sup> was derived in a sample that consisted half of patients with acute injuries and half of rehabilitation patients with various musculoskeletal conditions, which may have contributed to the unacceptable fit of the model.

Models 3 and 5 (Taylor et al<sup>14</sup> and Wang et al<sup>9</sup>) did not converge due to multicollinearity and empirical underidentification, respectively. Although constraining the error variance to zero may be regarded as a “quick fix,” the underlying problems should be addressed. This was beyond the scope of this study. Both models showed insufficient

structural validity. The study sample of Taylor et al<sup>14</sup> was similar to the present study. The insufficient fit of the model may have been caused by the omission of several items of the questionnaire or cross-cultural differences. The model of Wang et al<sup>33</sup> was derived in a study sample that contained only a minor fraction of patients with injuries. Aside from the nonconvergence, the internal consistency and clinical relevance of the “sexuality and driving” and “difficulties falling asleep” subscales may be a concern for the model of Wang et al.

Van Son et al<sup>34</sup> have performed an exploratory factor analysis in Dutch patients and proposed 2 3-factor structures separate for upper and lower extremity fractures. In that study, double-barrel items were split. This changes the items of the questionnaire and makes comparison with other studies difficult. The models could not, therefore, be evaluated in the present study.

A clinical implication of the present study is that it showed that the SMFA-NL may be used best to evaluate 4 latent constructs using the subscales “upper extremity dysfunction,” “lower extremity dysfunction,” “problems with daily activities and mental and emotional problems.” To enable use of these subscales in patients with injuries in a clinical setting or in applied research, additional clinimetric measurement properties such as construct validity, test-retest reliability, and responsiveness of the subscales should be evaluated.<sup>17</sup>

A limitation of this study is its generalizability. The study sample consisted of patients of the working-age population that had sustained an acute injury. Therefore, it is not clear whether this factor structure can be applied in patients with other musculoskeletal conditions or in people who are elderly. The present study was performed in a Dutch population using the SMFA-NL questionnaire. It is not clear whether the 4-factor solution is valid for other countries. Factor structures that showed an unacceptable fit have all been

conducted in patients who were not Dutch. These models may show sufficient structural validity when evaluated in the original country. We encourage further international evaluation of the structural validity of the SMFA.

One of the strengths of this study was that it was the first time the structural validity of the SMFA was evaluated. The response rate of 74% was considered moderate to high. The demographic characteristics of the study population were similar to the patient characteristics found in the trauma registry of the northern part of The Netherlands.<sup>35,36</sup> Conform the COnsensus-based Standards for the selection of health Measurement INstruments (COSMIN) guidelines, the sample size of 491 patients (10.6 patients per item), which was considered good.<sup>24</sup>

In conclusion, the 4-factor structure of Reininga et al<sup>11</sup> showed good structural validity in a broad range of patients with injuries using the SMFA-NL. The SMFA-NL may be used to evaluate 4 latent constructs using the subscales “upper extremity dysfunction” (6 items), “lower extremity dysfunction” (12 items), “problems with daily activities” (20 items), and “mental and emotional problems” (8 items). Clinical use of the structures that showed insufficient structural validity is discouraged. Future research may be dedicated to the assessment of clinimetric properties of these subscales in a population that consists of a broad range of patients with injuries and further international evaluation of the structural validity of the SMFA.

### **Author Contributions**

Concept/idea/research design: M. El Mounni

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Consultation (including review of manuscript before submitting): I.H.F. Reininga, K.W. Wendt, E. Heineman, M. El Moumni

### **Ethics Approval**

The methods used in this study have been reviewed by the local institutional review board, which waived further need for approval. Patients consented with participation in this study.

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### **Disclosures and Presentations**

The authors completed the ICJME Form for Disclosure of Potential Conflicts of Interest. They reported no conflicts of interest. This manuscript is adapted in part from an abstract that was presented at the European Conference for Trauma & Emergency Surgery (ECTES), April 24-26, 2016.

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Table 1

## General Characteristics

General Characteristics		n (%)
Sex (n = 491)		
	Male	276 (56)
	Female	215 (44)
Age groups (n = 491)		
	18-24	82 (17)
	25-34	72 (15)
	35-44	87 (18)
	45-54	104 (21)
	55-67	146 (30)
Marital status (n = 464)		
	Single	191 (41)
	With partner	273 (59)
Educational level (n = 462)		
	Elementary school	10 (2)
	High school	150 (32)
	College	136 (28)
	Bachelors degree or higher	160 (36)
	Other	6 (1)
Chronic health conditions (n = 452)		
	None	247 (55)
	One	115 (25)
	Two	54 (12)
	Three or more	36 (8)
Injuries (n = 491)		
Fracture		
	Upper extremity	164 (33)
	Lower extremity	145 (30)
	Pelvis and sacrum	25 (5)
	Spine	27 (6)
	Other	0 (0)
	Luxation and rupture	40 (8)
	Sprain and contusion	49 (10)
	Head injury	3 (1)
	Wounds and soft tissue	16 (3)
	Organ injury (including pneumothorax)	12 (2)
	Other	10 (2)

Table 2

Fit Indices for all Models<sup>a</sup>

Models	$\chi^2$	Df	P value	RMSEA $\leq 0.07$	RMSEA 90% CI	CFI $\geq 0.95$	TLI $\geq 0.95$
Model 1	8833.800	988	< .001	0.127	0.125 0.130	0.909	0.905
Model 2	7230.257	776	< .001	0.130	0.128 0.133	0.920	0.915
Model 3 <sup>b</sup>	5367.140	664	< .001	0.120	0.117 0.123	0.928	0.923
<b>Model 4</b>	<b>3351.996</b>	<b>983</b>	<b>&lt; .001</b>	<b>0.070</b>	<b>0.068 0.073</b>	<b>0.973</b>	<b>0.971</b>
Model 5 <sup>b</sup>	5201.451	933	< .001	0.097	0.094 0.099	0.951	0.948
Model 6	6080.009	983	< .001	0.103	0.100 0.105	0.941	0.938

<sup>a</sup> Models that showed an acceptable fit (RMSEA  $\leq 0.07$ , CFI  $\geq 0.95$ , and TLI  $\geq 0.95$ ) are in bold.<sup>b</sup> Constrained 1 or more error variances to 0.

Table 3

Scale Reliability<sup>a</sup>

Models	Subscale					
	1	2	3	4	5	6
Model 1	0.96	0.93				
Model 2	0.94	0.94	0.93			
Model 3	0.96	0.88	0.85			
<b>Model 4</b>	<b>0.95</b>	<b>0.96</b>	<b>0.97</b>	<b>0.87</b>		
Model 5	0.96	0.91	0.90	0.81	0.68	n/a
Model 6	0.96	0.96	0.90	0.95		

<sup>a</sup> Cronbach alpha calculated per subscale. Subscale numbers (n) are the same as in the path models and factor loading tables (eAppendix 1 and the Appendix). Models that showed an acceptable fit (RMSEA  $\leq$  0.07, CFI  $\geq$  0.95, and TLI  $\geq$  0.95) are in bold. n/a = not applicable.