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THE MULTI-DIMENSIONALITY OF THE FIM MOTOR ITEMS PRECLUDES AN INTERVAL SCALING USING RASCH ANALYSIS

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ABSTRACT. Rasch analysis scaling is said to produce an interval scale of Functional Independence Measure (FIM) motor function items. Rasch analysis requires that the data to be analysed represent the influence of a single underlying unidimensional variable. A unidimensional interval scale of activities of daily living means that a person who can perform the most difficult item on a scale can also perform the easiest item. For a FIM motor function interval scale, the ability to climb stairs would imply necessarily an ability to eat normally. As this need not be the case, the FIM motor items do not constitute an adequate interval scale. Eating and walking are different activities, and a unidimensional construct linking them is unsatisfactory. A principal components analysis of the admission FIM motor function items of 515 consecutive patients admitted to an inpatient rehabilitation unit revealed that more than one significant factor was necessary to explain the variance in scores. The counter-factual and statistical evidence argues that a unidimensional construct does not underly the FIM motor function items, and the use of Rasch analysis will not lead to a description of interval properties of the FIM motor function items.

Key words: FIM, Rasch analysis, dimensions.

INTRODUCTION

Following a paper by Merbitz et al. (11) in 1989, criticising the use of ordinal scales as if they were interval scales, the unreferenced assertion was made by Wright & Linacre (16) that Rasch analysis was a method of constructing interval scales from ordinal data which "has been shown to be not only sufficient but also necessary for the construction of measures in any science". Wright & Linacre (16) also stated "an occasional objection to Rasch measurement is its imposition on the data of a single underlying unidimensional variable." Since that time, a number of studies have appeared using Rasch analysis to examine the properties of scales of activities of daily living (7, 10, 12).

Claims have been made that the motor functions of the Functional Independence Measure (FIM) have been transformed from an ordinal scale to an interval scale by the use of Rasch analysis (4), with eating being the easiest item, walking being moderately difficult, and stair climbing being the hardest task. As an interval scale of behaviour measures a continuum so that success on a difficult item necessarily must mean success on an easy item, we were puzzled by the claim. We have seen people who could walk but not swallow, swallow but not walk, and even climb stairs but not swallow. These patients do not fit the interval scale. Their performance argues against a unidimensional construct underlying FIM, and suggests that each item of the motor function FIM probes disability in a different way. We wondered if an exploration of the relationships between motor function FIM items using multi-variate analysis might not clarify whether the motor function FIM items constituted a unidimensional construct.

MATERIAL AND METHODS

We maintain a data base (3) of information concerning patients admitted to a 24-bed inpatient Rehabilitation Unit at Fairfield Hospital, and a 214-bed general hospital in the metropolitan south-west of Sydney. Data is collected according to the Uniform Data Set for Medical Rehabilitation, and collated and analysed using CRS (Clinical Reporting System) (2) database software and SPIDA (Statistical Package for Interactive Data analysis) statistical software (13).

We analysed the admission FIM scores of 519 patients consecutively admitted to the Unit between July 1991 and December 1994. We selected the following motor function items: eating; grooming; bathing; dressing upper body; dressing lower body; toileting; bladder management; bed, chair, wheelchair transfer; toilet transfer; tub/shower transfer; walk; and stairs. Patients whose major method of locomotion was by a wheelchair were excluded, leaving 515 patients for whom data was available.

Table I. *The correlation matrix of admission FIM motor item scores for 515 patients*
Pearson's correlation

	1	2	3	4	5	6	7	8	9	10	11	12	13
Eat	1.000	0.701	0.494	0.619	0.440	0.506	0.384	0.464	0.399	0.423	0.415	0.342	0.080
Groom	0.701	1.000	0.639	0.746	0.589	0.645	0.496	0.545	0.554	0.572	0.573	0.456	0.221
Bath	0.494	0.639	1.000	0.715	0.825	0.813	0.545	0.544	0.749	0.774	0.762	0.619	0.418
Dress up	0.619	0.746	0.715	1.000	0.722	0.738	0.477	0.496	0.630	0.670	0.655	0.535	0.297
Dress low	0.440	0.589	0.825	0.722	1.000	0.834	0.506	0.488	0.765	0.785	0.768	0.625	0.428
Toilet	0.506	0.645	0.813	0.738	0.834	1.000	0.596	0.538	0.800	0.863	0.845	0.665	0.435
Bladder	0.384	0.496	0.545	0.477	0.506	0.596	1.000	0.697	0.552	0.566	0.557	0.439	0.217
Bowel	0.464	0.545	0.544	0.496	0.488	0.538	0.697	1.000	0.513	0.529	0.516	0.408	0.183
Trans bed	0.399	0.554	0.749	0.630	0.765	0.800	0.552	0.513	1.000	0.908	0.899	0.757	0.505
Trans toi	0.423	0.572	0.774	0.670	0.785	0.863	0.566	0.529	0.908	1.000	0.967	0.731	0.488
Trans tub	0.415	0.573	0.762	0.655	0.768	0.845	0.557	0.516	0.899	0.967	1.000	0.718	0.470
Walk	0.342	0.456	0.619	0.535	0.625	0.665	0.439	0.408	0.757	0.731	0.718	1.000	0.543
Stairs	0.080	0.221	0.418	0.297	0.428	0.435	0.217	0.183	0.505	0.488	0.470	0.543	1.000

Table II. *The principal components analysis of admission. FIM motor item scores for 515 patients*

Component	1	2	3	4	5	6	7
Eat	0.156	−0.227	−0.410	−0.294	0.172	−0.071	0.236
Groom	0.228	−0.210	−0.402	−0.282	0.005	−0.079	0.252
Bath	0.244	0.027	−0.111	0.100	−0.182	0.070	−0.207
Dressup	0.270	−0.076	−0.430	−0.090	−0.148	−0.160	−0.124
Dresslow	0.316	0.117	−0.159	0.277	−0.328	0.052	−0.501
Toilet	0.353	0.064	−0.099	0.247	−0.136	−0.073	−0.008
Bladder	0.311	−0.569	0.527	0.052	−0.154	−0.510	0.056
Bowel	0.238	−0.458	0.191	−0.207	0.071	0.769	−0.181
Transbed	0.311	0.191	0.112	0.122	0.212	0.089	0.206
Transtoi	0.323	0.173	0.068	0.233	0.167	0.111	0.300
Transtub	0.316	0.170	0.065	0.248	0.197	0.106	0.347
Walk	0.299	0.319	0.196	−0.469	0.512	−0.241	−0.456
Stairs	0.154	0.387	0.254	−0.531	−0.622	0.095	0.273
Variance	27.585	4.377	3.005	1.743	1.429	1.195	1.033
% Var	63.886	10.137	6.959	4.038	3.310	2.767	2.393

We calculated the correlation matrix for the items for all impairment groups (515 patients), for all neurological conditions (313 patients), and for all amputees (41 patients). We then performed a principal components analysis using both the correlation and covariance matrix methods. As the results for the two matrices were similar, only the covariance matrix method is reported.

RESULTS

The correlation matrix (Table I) shows strong correlations between the transfer items, and very poor correlation between stair climbing and eating.

The principal components analysis shows that for all impairment groups (Table II), for the neurological impairment group (Table III) and amputee group (Table IV), more than one factor was required to explain the variance. If eigenvalues greater than one are used as a rule of thumb to identify factors of importance, then the dimensionality is at least six. To explain more than 80% of the variance three factors are required for the group containing all the patients and the neurological group and four factors are required for the amputation patients. A major factor can be identified that appears to consist of toileting, lower limb dressing and transfers, though the structure of this factor changes depending on the Impairment group.

Based on our analysis, we dispute the assertion that the mobility items of FIM constitute a unidimensional system.

DISCUSSION

We did not report a Factor Analysis using maximum likelihood as this technique is sensitive to

Table III. *The principal components analysis of admission FIM motor item scores for 313 patients with neurological conditions*

Component	1	2	3	4	5	6
Variance	30.620	5.062	2.781	1.499	1.310	1.089
% Var	67.124	11.097	6.096	3.286	2.872	2.388

Table IV. *The principal components analysis of admission FIM motor item scores for 41 patients with amputations*

Component	1	2	3	4	5	6
Variance	20.614	3.522	2.423	2.184	1.513	1.378
% Var	58.508	9.998	6.877	6.200	4.294	3.912

non-normality of data. As FIM data is discrete rather than continuous, with fractions of FIM scores being undefined, assumptions of normality are not warranted. There are many other methods of multivariate analysis, however we feel that principal component analysis is one form appropriate for the interpretation of this data.

The advantage of principal components analysis in this situation is that no assumption is made about the probability distribution of the original variables. We do not, however, wish to make too much of our interpretations of the factor loadings, as no standard system exists to decide which factors are "large".

Rasch analysis is a part of a general system called Item Response Theory or Latent Trait analysis, commonly concerned with the probability of success when someone attempts a multiple-choice question (6, 8, 9, 17). The idea is that there exist quantities B(i) representing the difficulty of an item (i), and Θ(j) representing the ability of subject j, and that p(ij), the probability of subject j responding correctly to item i is given by:

$$p(ij) = \text{ an increasing function of } (\Theta(j) - B(i))$$

The Rasch model puts this as:

$$p(ij) = \exp[\Theta(j) - B(i)]/1 + \exp[\Theta(j) - B(i)]$$

The parameter (Θ(j) – B(i)) is estimated from the data rather than being measured directly. The advantage of the Rasch model is that the total number of items which a subject answers correctly is a sufficient statistic for estimating the subject's ability. Items can be ordered by the probability distance, expressed as a logit, where one logit signifies the distance along the unidimensional continuum for which the odds of observing the event increase by a factor e which is the base of natural logarithms. Other models of Item Response theory exist, taking into account parameters for guessing, and parameters for the discriminative property of items. The Rasch model assumes all items have equal discriminative power.

The Rasch model is supposed to have probabilities of a correct response running from zero to one. The logistic transformation of the probability mathematically avoids the problem of having predicted probabilities from the data outside the range (0,1). Other transformations apart from the logistic transformation exist, and have been shown to lead to different estimates of ability and ranking of ability (5). The method of scoring FIM does not appear to us to allow a lower asymptote of 0, as the chance of producing a correct score is 1/7 for any FIM item, thereby providing a problem for the Rasch model.

The Rasch model in its various forms assumes that item parameters are the same across all samples. Choppin (1) has noted that as items are tested in different groups, "eventually every item will show discrepancies; every item can be discarded; no item fits the model exactly." Linacre et al. (10) report misfit of 6 out of the 13 motor function items in their Rasch analysis of FIM motor item scores. These six items exceeded the "useful range of mean square fit statistics" of 0.7–1.3. There is no agreed standard method of interpretation of mis-fit statistics (6). No description of the sample distribution exists in Rasch analysis. Any system of measurement based on probabilities must necessarily be imprecise. To us, these shortcomings are important.

Our chief objection to the claim that Rasch analysis has allowed FIM to be scaled as an interval measure rests with the fact that Rasch analysis supposes a one-dimensional latent space (5, 6, 14, 15), or, in other words, that a single continuum of performance is being measured. Our results, and the counterfactual examples cited in the introduction, clearly show that the FIM mobility items are not measuring a unidimensional construct, and therefore Rasch analysis will not transform the current FIM items into an interval scale. In this regard, it should be noted that tests of dimensionality have not been reported by those applying Rasch analysis to FIM data, and the first order indices of item misfit such as described by Wright & Stone (18) are said to be insensitive to multidimensionality (5, 6, 14, 15).

The fact that Rasch analysis does not allow a post hoc scaling to make the summed FIM scores more useful should not dissuade clinicians from using the FIM. The use of standard, reliable, valid and sensitive instruments for measuring disability should be encouraged. Caution should be exercised when performing comparisons between different groups or different Rehabilitation Units if careful matching for age, sex, impairment and socio-economic variables has not occurred, and the statistical methodologies employed should be appropriate to the data.

There would be value in further multivariate analyses of FIM data to explore the question of the factor structure.

Detailed figures are available in extended tables which could be received upon request from: Dr F Köhler; Department of Rehabilitation and Geriatrics; Liverpool Hospital; PO Box 103; Liverpool, NSW, 2170; Australia.

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