

Activities of daily living measurement after ischemic stroke

Rasch analysis of the modified Barthel Index

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Abstract

In patients with ischemic stroke, activities of daily living were used as an outcome indicator, and correct assessment is very important. We sought to examine the reliability and validity of the modified Barthel Index as an evaluation tool of activities of daily living in ischemic stroke patients by applying the Rasch analysis.

We used a prospectively collected cohort of ischemic stroke patients in the department of neurology. Rasch analysis was used for evaluating the reliability and validity of the modified Barthel Index.

A total of 231 patients were included in the analysis. The average of modified Barthel Index was 36.2 ± 17.8 . The modified Barthel Index had high reliability of 0.88. There were no extremely mismatched items, and considered unidimensional, but the Point-Measure of bowels and bladder were 0.27, extremely lower than other items. The scale was stable in different sex and age, but had notable differential item functioning in muscle strength of the limbs. Rating categories were not functioning adequately in items. The item difficulty and patient ability were not matched, with a difference of 1.17 logits. 29.4% patients, no easy items could match their ability.

The modified Barthel Index had high reliability but a relatively bad matching degree between item difficulty and patient ability. It still needs further improvement to reflect the activities of daily living in ischemic stroke patients.

Abbreviations: ADL = activities of daily living, BI = Barthel Index, IS = ischemic stroke, MBI = modified Barthel Index.

Keywords: activities of daily living, applicability, ischemic stroke, modified Barthel Index, Rasch analysis

1. Introduction

Stroke, affecting nearly 800,000 individuals, and approximately 15% to 30% of stroke survivors experiencing permanently disabled as a direct consequence.^[1,2] Ischemic stroke (IS) accounts for 70% of stroke.^[3] More than 70% of IS patients have neurological defects,^[4,5] 26% remain disability in basic activities of

daily living (ADL) (Framingham cohort), and 50% have declined mobility due to hemiparesis.^[6] Correct and effective evaluation of ADL in IS acute phase can provide evidence for decision-making in treatment, rehabilitation, and nursing.

A variety of ADL assessment scales had been used for stroke patients. These included the Barthel Index (BI),^[7] the modified BI (MBI),^[8] the Functional Independence Measure (FIM),^[9] the Stroke Impairment Assessment Set (SIAS),^[10] and the modified Rankin Scale (mRS).^[11] Each of these tools had different advantages and disadvantages. For example, mRS was easy to use, but not as detailed as the others. FIM and SIAS were sensitive to changes, but require advanced knowledge for their administration. The BI and MBI had the advantages of them, suitable for assessing the ADL in the clinic.

BI was originally established for assessing the ADL of stroke patients and has been widely used in stroke patients.^[7,12] The MBI was developed to achieve greater sensitivity, and its internal consistency has been confirmed for use among stroke patients.^[8,13] MBI is a five-level rating scale, including evaluation of bathing, grooming, feeding, dressing, bowels, bladder, toilet, stairs, chair/bed transfers, and walking. Higher scores represent higher degree of ADL independence. Despite the MBI was an efficient, reliable, and valid assessment of ADL for stroke patients, it remains unclear how individual MBI items function in the population of IS patients with limb dysfunction.

Rasch model is a probability mathematical model, which can evaluate whether the items have good quality in reflecting the response parameters of patients.^[14] The basic principle of the Rasch model is that individuals have a certain probability of responding to items.^[14] The Rasch model is objective since

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whether the patient can answer the question correctly only depends on the ability of the patient and the difficulty of the question.^[14] Several studies have applied the Rasch model to analyze the reliability and validity of BI in stroke patients, and found the items of BI needed to be revised to assess the ADL ability of IS patients,^[15,16] but few studies focused on the applicability of MBI in disabled IS patients.

Therefore, in the current study, we applied the Rasch model to examine the reliability and validity of MBI in a disabled IS population, to assess the applicability of MBI in IS patients with limb dysfunction.

2. Methods

2.1. Sample and procedures

In this study, we retrospectively reviewed the data of consecutive patients recruited in the CIRCLE study (ClinicalTrials.gov ID: NCT03702452) between November 21, 2018 and November 19, 2019. The CIRCLE study was to verify that nursing-directed rehabilitation in IS patients can compensate for the shortage of professional rehabilitation therapists. The inclusion criteria:

- (1) between 18 and 90 years old;
- (2) diagnosed as having an IS by CT or MRI and meeting the diagnostic criteria of WHO;
- (3) having an initial IS within 7 days, with limb dysfunction (muscle strength of the limbs is less than 5);
- (4) maintaining consciousness (NIHSS scale consciousness level 0 or 1); and
- (5) having signed an informed consent form.

The exclusion criteria:

- (1) blood vessels that were recanalized after thrombolysis or thrombectomy;
- (2) cardiopulmonary dysfunction; a history of craniocerebral trauma, with fracture trauma or with rheumatoid arthritis; or already had a physical disability or other diseases that had an impact on the affected limb;
- (3) cognitive impairment or other mental illness that prevents cooperation with researchers.

All the patients were assessed with the MBI within 24 hours of hospital admission before rehabilitation. Demographic data (age, gender, muscle strength of the limbs) were gathered from medical records.

2.2. Ethics statement

All subjects had been given written informed consent before the study, and the protocols had been approved by the human ethics committee of The Second Affiliated Hospital of Zhejiang University. All clinical investigation has been conducted according to the principles expressed in the Declaration of Helsinki.

2.3. Instrument

The MBI^[17] consists of 10 items and 5 different weights of rating scales: unable, attempts but unsafe, moderate help, minimal help, fully independent. There is a score range of 0 to 5 for bathing, grooming; a score range of 0 to 10 for feeding, dressing, bowels, bladder, toilet, stairs; and a score range of 0 to 15 for chair/bed transfers, walking. Higher score represents higher degree of ADL independence.

2.4. The Rasch model

The Rasch analysis^[18] was performed on WINSTEPS Rasch measurement software (Version 3.74.0). First, item rating categories were examined, for each item, there were 5 rating categories, ranging from 0 (unable) to 4 (fully independent), which were checked for verifying whether the 5 rating categories were reasonable, the item rating categories should meet 5 criteria:

- 1) each option must have 10 observations at least,
- 2) the unidimensionality of the scale,
- 3) values of item rating categories should be monotonically asymptotic,
- 4) outfit MnSq < 2.0,
- 5) the difficulty difference between adjacent categories > 0.81 logits.^[19]

Second, the validity was examined by assessing whether each item fits with Rasch model expectations through the mean squares (MnSq) and the easy items for patients by item hierarchy, the values of infit MnSq and outfit MnSq range from 0.5 to 1.5 were accepted.^[20] Third, bivariate correlation coefficients between item residuals were examined for the local independence among items, the bivariate correlation coefficients > 0.7 indicated local dependence.^[20] Fourth, a principle component analysis of the residuals was examined for ascertaining the unidimensionality of the scale.^[21] Fifth, the reliability of the scale was examined by the person separation index and the item separation index, the reliability coefficient > 0.8 was good, > 0.9 was were good.^[16] Sixth, differential item functioning (DIF) was examined for different gender, age, or muscle strength of the limbs, the absolute value of DIF contrast > 0.43, and $P < .05$, indicated DIF.^[20] Finally, targeting was assessed, which was the extent of whether the abilities of patients match the difficulties of items.

3. Result

Over the research period, 231 patients with IS were included in this study. The average age of patients was 62.3 ± 13.0 years old, and 69 (29.9%) of them were female. The average scores of muscle strength of the affected upper limbs and lower limbs were 2.3 ± 1.7 and 2.9 ± 1.5 , respectively. The average score of MBI was 36.2 ± 17.8 , the distribution of response for each item was shown in Table 1.

3.1. Item rating categories

The results showed that not all 10 items met the set criteria of appropriate item rating categories. Some options of the feeding, bathing, grooming, dressing, bowels, bladder, toilet, stair did not have 10 observations (Table 1). Average measures of the adjacent options increased not evenly, though no disordered thresholds were observed. The outfit MnSq values of other options were > 2 except for the rating 2 (moderate help) and 4 (fully independent). The difficulty gap between the rating 3 (minimal help) and 4 (fully independent) was small. The item rating categories should not meet the 5 criteria, which means the rating categories were not functioning adequately in items.

3.2. Item fit with Rasch model

The infit MnSq of feeding, dressing, bowels, bladder, stairs, and walking range from 0.52 to 1.28, which in the acceptable range of 0.5 to 1.5. The infit MnSq of transfer, bathing, grooming, and

Table 1
Distribution of response for each item of the MBI for ischemic stroke patients.

Item	Score	Count	Percent (%)
Feeding	0	134	58
	2	48	21
	5	38	16
	8	5	2
	10	5	2
Bathing	0	140	61
	2	56	24
	3	34	15
	4	1	0
Grooming	0	132	57
	2	50	22
	3	42	18
	4	6	3
	5	1	0
Dressing	0	135	58
	2	56	24
	5	33	14
	8	6	3
	10	1	0
Bowels	8	7	3
	10	224	97
Bladder	0	7	3
	10	224	97
Toilet	0	111	48
	2	67	29
	5	51	22
	8	2	1
Transfer	0	69	30
	3	76	33
	8	38	16
	12	33	14
	15	15	6
Walking	0	115	50
	3	53	23
	8	37	16
	12	14	6
	15	12	5
Stair	0	169	73
	2	33	14
	5	15	6
	8	7	3
	10	7	3

MBI= modified Barthel Index.

toilet was 1.69, 0.33, 0.42, and 0.35, respectively. To check for the possible influence of unfit items, the analysis was repeated after the unfit items were removed. The results showed the reliability was lower. Hence, results using the complete items were presented. Error ranged from 0.03 to 0.05, which showed that the item was relatively stable in estimating the ability of the IS patients. Both Point (PT)-Measures of bowels and bladder were 0.27, which were extremely lower than PT-Measure of other items (range from 0.64 to 0.90) (Table 2 and Fig. 1).

3.3. Construct validity

Construct validity was demonstrated by the item hierarchy (Table 2). Construct validity of bowels and bladder was easy for the IS patients, but the construct validity of bathing and grooming was difficult for the IS patients.

3.4. Local independence

No evidence of local dependency between items was found as the correlation coefficients between item residuals were <0.7.

3.5. Dimensionality

The first principal component was found to explain 54.2% of the variance. However, there was substantial unexplained variance (44.8%) and the first 2 contrasts had eigenvalues > 2 (4.5 and 2.3, respectively), and the possibility of the existence of additional components was examined. The 2 potential factors effect were very low, supporting unidimensionality of the scale, with the factor sensitivity ratio values of 10.8% (4.5/41.7) and 5.5% (2.3/41.7), respectively.

3.6. Person and item separation and reliability

The obtained person separation index value was 3.73, which was associated with a reliability coefficient of 0.88. Furthermore, the item separation index value was 20.87, which was associated with a reliability coefficient of 1.00.

3.7. Differential item functioning (DIF)

All DIF contrasts of gender and age were found to be less than the criterion of <0.43, and all the items were free from the substantial DIF. But not all muscle strength of the limbs were found to be less than the criterion of <0.43. The items of feeding, bathing,

Table 2
Item measures, fit statistics, and PT-Measure correlation for the MBI for ischemic stroke patients.

Item	Measure	Error	Infit Mnsq	Zstd	Outfit Mnsq	Zstd	PT-Measure
Feeding	0.49	0.04	0.99	0.0	0.69	-2.0	0.72
Bathing	0.78	0.05	0.33	-5.2	0.26	-4.9	0.82
Grooming	0.70	0.05	0.42	-4.6	0.47	-3.2	0.80
Dressing	0.55	0.04	0.82	-1.3	0.61	-2.5	0.72
Bowels	-1.66	0.04	0.52	-4.2	0.37	-5.0	0.27
Bladder	-1.58	0.04	0.62	-3.2	0.79	-1.3	0.27
Toilet	0.45	0.04	0.35	-7.1	0.34	-5.6	0.86
Transfer	-0.41	0.04	1.69	4.6	3.17	9.0	0.90
Walking	0.00	0.03	1.28	2.3	1.14	1.1	0.84
Stair	0.67	0.04	1.23	1.4	0.61	-2.2	0.64

MnSq= mean squares, PT-Measure = point-measure.

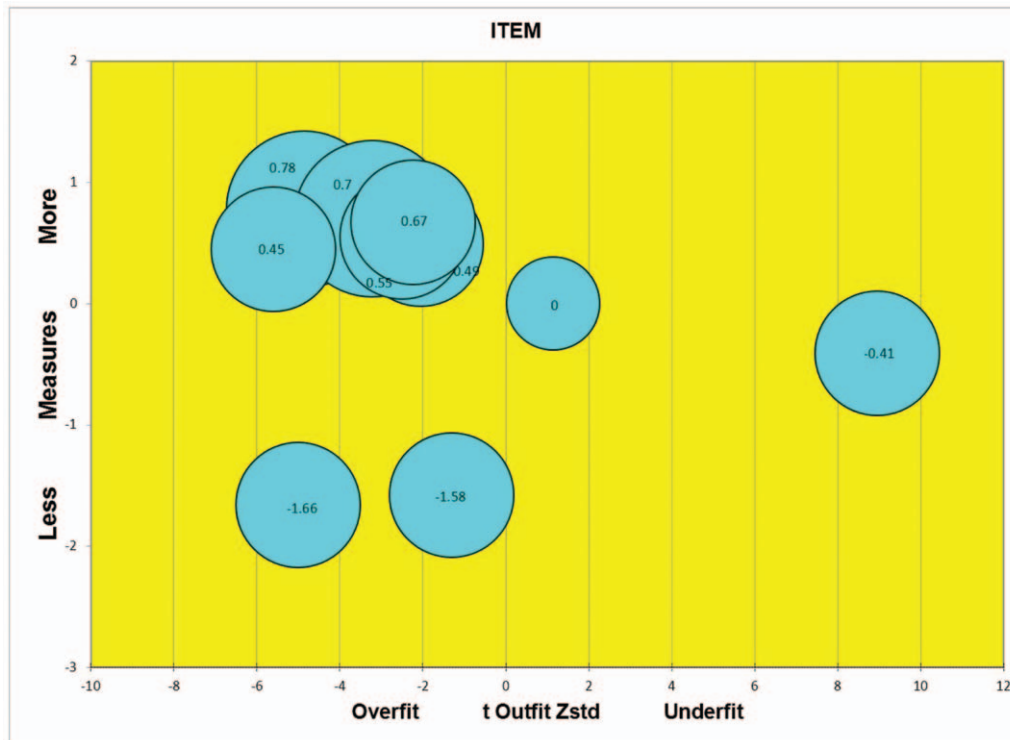


Figure 1. The bubble plots of item.

grooming, dressing, bowels, and bladder had DIF for upper limbs muscle strength, the items of bowels, bladder, transfer, walking, and stair had DIF for lower limbs muscle strength, the item of toilet was free from the substantial DIF. Figure 2 shows the detail about the DIF contrasts of all muscle strength of the limbs.

3.8. Targeting

The matching degree of item difficulties and personability was not satisfied (Fig. 3), with a difference of 1.17 logits. 29.4% patients, no easy items could match their abilities, the items of MBI were difficult for disabled patients.

4. Discussion

In this study, the main findings were

- 1) The MBI was highly reliable to assess the ADL;
- 2) The items rating categories were not very satisfactory, which need to merge;
- 3) The unfit items of transfer, bathing, grooming, and toilet were worth keeping, but the items of bowels and bladder may be not suitable for IS patients;
- 4) All the items were free from substantial DIF for gender and age, but not all muscle strength of the limbs were found be free from substantial DIF;
- 5) The matching degree of item difficulties and patients ability was not satisfied, the items were difficult for IS patients.

The results of the Rasch analyses showed that the reliability for the MBI in this sample of patients with IS was good both for persons and items, with values of 0.88 and 1.00, respectively, these results indicate that scale items were validly and reliably to

assess the patient' ADL. Higher reliability represents smaller measurement error.^[22] That is, the MBI measure the ADL is more precise. With an item and person separation >2.0, the range of difficulty can be distinguished, indicating that the scale could separate, with high consistency. The level of separation in this study showed that the MBI was useful for evaluation ADL.

Even the range of difficulty can be distinguished, but rating categories were not very satisfactory, with a small difficulty gap (between the rating 3 and 4). The fact is that “minimal help” represented the items could be finished, but unskilled, need somebody beside to give little assistance if needed, and “fully independent” represented to finish alone. Therefore, there was no obvious difference between minimal help and fully independence. Both of them could be finished, the little difference was whether finished it alone. Besides, the IS patients had limb dysfunction, ADL were affected, most IS patients could not finish feeding, bathing, grooming, dressing, toilet, and stair alone in the acute phase. The results suggest that options 4 and 5 of the feeding, bathing, grooming, dressing, toilet, and stair should be merged.

The research found that the items of transfer, bathing, grooming, and toilet were unfit with the Rasch Model (Table 2). When we removed the unfit items,^[23] the reliability was lower than before. One reasonable explanation was that the Rasch model is an ideal model, and confounding factors were very common in clinical practice.^[24] The values of the items were not extremely high or low. Therefore, simply deleting unfit items were leads to lower reliability. The items of transfer, bathing, grooming, and toilet were the basis of ADL, which could reflect the ADL of IS patients. These items were worth keeping, but needed to be revised to fit the Rasch Model. From the PT-Measure values (Table 2 and Fig. 1), the conclusion could be that the bowels and bladder were less relevant to other items.

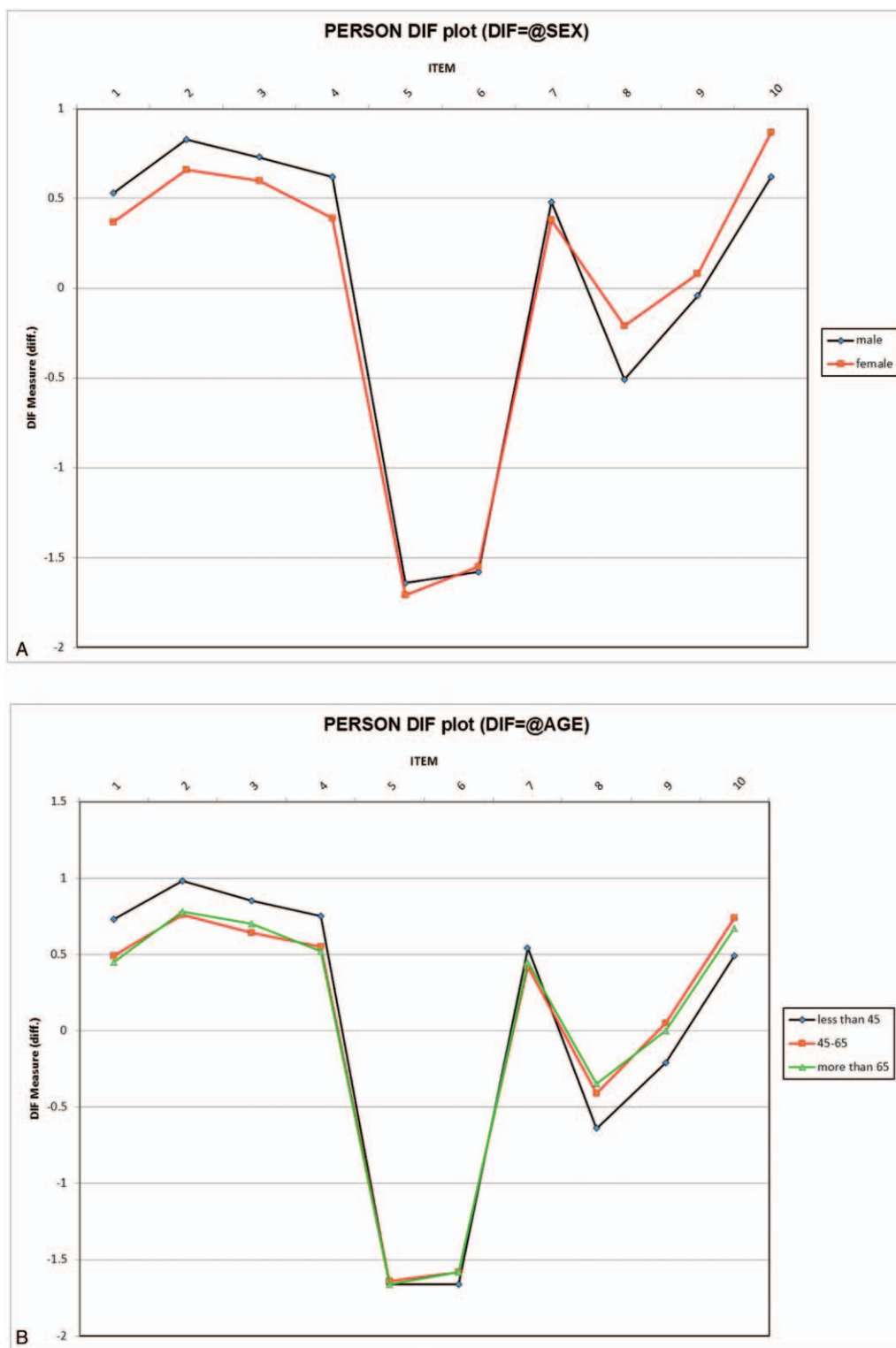


Figure 2. DIF contrasts for a) gender, b) age, and c) muscle strength of the limbs for the MBI.

Conceptually, the incontinence differs from other items, and the World Health Organization classifies incontinence as impaired bodily function and other items are activity restriction.^[25] Impairments to the incontinence were not common problems

caused by brain lesions following a IS^[17] and the IS patients with communicative and cognitive problems were excluded which was the most important clinical risk factor for urinary incontinence.^[26] Therefore, most of the IS patients had very good

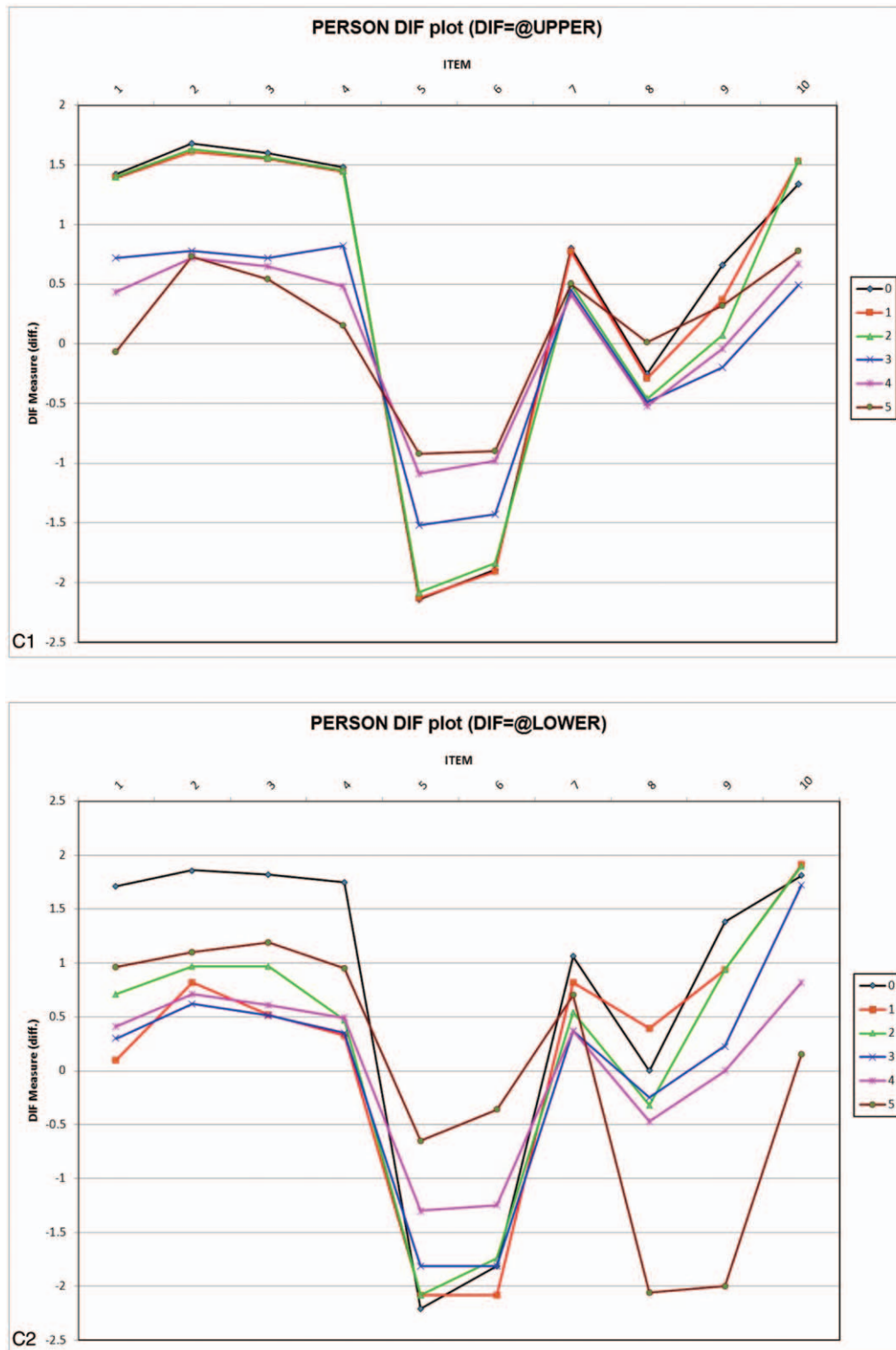


Figure 2. Continued

control of both the bowels and bladder function, and had scores of 10. That told us the items of bowels and bladder were not suitable for IS patients.

In addition, all scale items were free from substantial DIF for gender and age, but there was a DIF effect in muscle strength of

the limbs (Fig. 2). The items of feeding, bathing, grooming, dressing need upper limbs' help, higher muscle strength of the limbs, easier for patients to finish the items. Whether muscle strength of the limbs >3, the degree of patient involvement was greatly different. With item toilet need the upper and lower limbs'

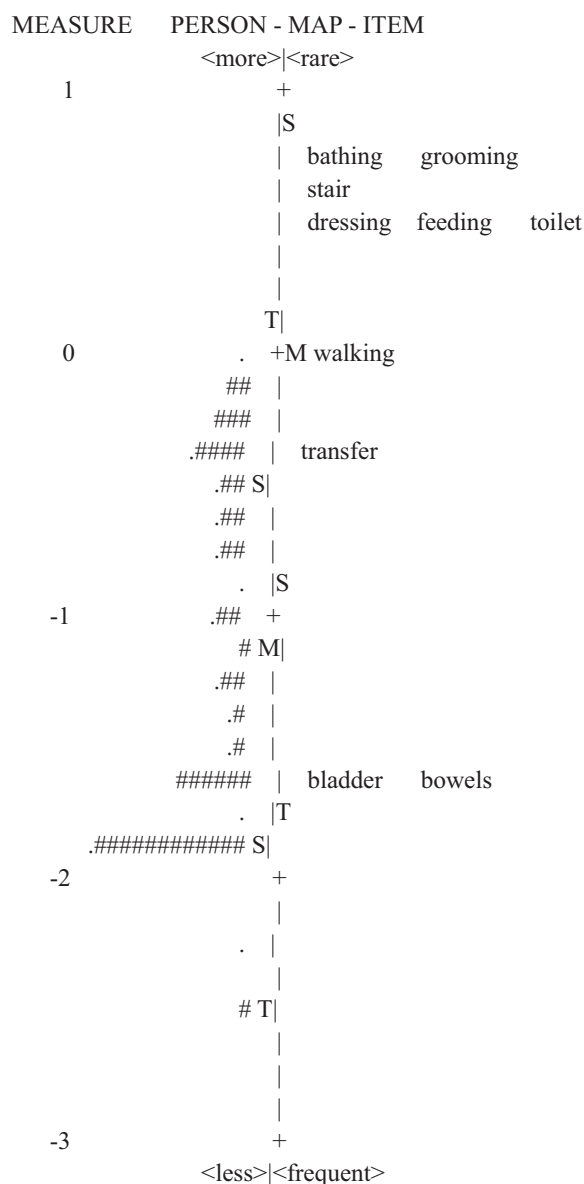


Figure 3. Distribution map for persons and items.

help, DIF contrast had no obvious difference neither upper nor lower limbs. Items of stairs, chair/bed transfers, and walking need low limbs' help. The effect was similar to the upper limbs. The DIF contrast of items bowels and bladder had a difference between muscle strength of the limbs, which told us the scores of bowels and bladder were unstable between muscle strength of the limbs. But the muscle strength of the limbs did not affect the scores of bowels and bladder. A possible explanation was that incontinence was not associated with muscle strength of the limbs, incontinence items were not suitable for IS patients.

Examining the distribution map (Fig. 3), the conclusion could be that there was a mistargeting between item difficulty and personability. In 29.4% patients, the items of MBI were difficult for disabled patients. The patients with extremely disabled might have lower ability than the item difficulty, and their muscle strength of the limbs also might be too low to complete the items. Hence, the items may be cannot reflect the real ability of the

disabled patients. In other words, better mobility does not represent more independence, and the total scores may not be used to disabled patients as an indicator of treatment, rehabilitation, and nursing. Further analysis may be needed to verify the finding or more easier items will need to be added to the scale. A wider range of levels for ADL could be helped to draw the conclusion.

5. Limitations

This study had some limitations. First, only the IS patients in the neurology department were included. A further multi-center study is needed. Second, the MBI was assessed by the researcher based on the ADL of the patients, which might be affected by the subjective consciousness of the researcher. Finally, the sample consisted of the IS patients with hemiplegic, and the findings of the study might not be generalized to all IS patients.

6. Conclusion

In conclusion, the MBI had high reliability but a relatively bad matching degree between item difficulty and patient ability. The items still need further improvement to reflect the activities of daily living in IS patients.

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