Original Article

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The Korean Version of the Fugl-Meyer Assessment: Reliability and Validity Evaluation

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Objective To systematically translate the Fugl-Meyer Assessment (FMA) into a Korean version of the FMA (K-FMA).

Methods We translated the original FMA into the Korean version with three translators and a translation committee, which included physiatrists, physical therapists, and occupational therapists. Based on a test-retest method, each of 31 patients with stroke was assessed by two evaluators twice, once on recruitment, and again after a week. Analysis of intra- and inter-rater reliabilities was performed using the intra-class correlation coefficient, whereas validity was analysed using Pearson correlation test along with the Motricity Index (MI), Motor Assessment Scale (MAS), and Berg Balance Scale (BBS).

Results The intra- and inter-rater reliabilities were significant for the total score, and good to excellent reliability was noted in all domains except for the joint range of motion of the lower extremity domain of the K-FMA. The MI and MAS scores were significantly correlated with all domains, all with $p<0.01$. The results for the MI ranged from $r=0.639$ to $r=0.891$ and those for the MAS from $r=0.339$ to $r=0.555$. However, the BBS was not significantly correlated with any domain, as the K-FMA lacks balance evaluation items.

Conclusion The K-FMA was found to have high reliability and validity. Additionally, the newly developed manual for the K-FMA may help minimise errors that can occur during evaluation and improve the reliability of motor function evaluation.

Keywords Restroke rehabilitation, Fugl-Meyer Assessment, Translation, Reliability, Validity

INTRODUCTION

Stroke survivors commonly experience long-term impairments, including motor impairment, activity limitation, and decreased participation in social life [1]. Motor recovery after stroke is closely related to the direction of

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the patient's rehabilitation and also to the prognosis, return to society, and life expectancy [2,3]. Accordingly, accurate evaluation of post-stroke recovery cannot be overstated for stroke rehabilitation. Currently, many clinical assessment tools are used to evaluate functional ability and motor function [4].

The Fugl-Meyer Assessment (FMA) is a tool proposed by Fugl-Meyer to evaluate sensorimotor impairment in patients with stroke based on the Brunnstrom recovery stages, which is a classification of motor function recovery in patients with post-stroke hemiplegia [5]. Currently, the FMA is one of the most widely used tools for quantitative measurements of motor impairment after stroke [6]. Additionally, it has been robustly used for planning and estimating improvement during or after treatment [7]. The FMA has been reported to have excellent inter- and intra-rater reliabilities, signifying that its use as a reproducible and consistent measurement tool for stroke has been proven [8-11]. The FMA has also been validated as a tool for patients with stroke and has good correlation with the Motor Assessment Scale (MAS), Functional Independence Measure, Barthel Index, and Action Research Arm Test, which are used for evaluation of patients with stroke [12-17].

However, several studies have suggested that the FMA can be interpreted in various ways because the original text is long and complex, and therefore, there may be differences in the evaluation results depending on interpretation [10,11,18]. Consequently, the reliability of the FMA application might be questionable if it is not evaluated using the exact same standard. This issue becomes more important when the FMA is used in countries that use languages other than English, since confusion may arise with each clinician translating it into their native language. Therefore, multiple studies have translated the FMA into other languages, including Japanese, Spanish, Danish, and Brazilian, followed by verification of validity and reliability [4,7,19,20]. However, the FMA has not been systematically translated into Korean. Although we have found a few Korean versions of the FMA (K-FMA), these have not met international translation guideline standards, and there are difficulties in standardisation because of translation errors, lack of agreement on the meanings of terms, and inaccuracies in conveying meanings and in accounting for cultural differences. In the process of registering a K-FMA as a new medical technology with the Health Insurance Review and Assessment service, the Korean Academy of Rehabilitation Medicine (KARM) encountered obstacles in the lack of authorised evaluation tools and lack of approval from the original author. We decided to address these problems to produce the official Korean version with the consent of KARM. Therefore, the aim of this study was to systematically translate the FMA into Korean according to international translation guidelines and to verify the reliability and validity of the final instrument.

MATERIALS AND METHODS

Translation procedure

Permission for translating the FMA to the Korean language from the original form of the FMA was obtained from the University of Gothenburg, which possesses the copyright of the FMA. Forward and reverse translations were performed by experienced translators, and evaluation, revision, and cognitive debriefing of the translated product were conducted by a translation committee comprising eight experts including physiatrists, physical therapists, and occupational therapists. Forward translation was performed separately by two translators fluent in both English and Korean after receiving an explanation regarding the questionnaires of the FMA. The translation committee then created K-FMA version 1.0 with the aim of resolving any inconsistencies between the two versions.

Another bilingual translator who was fluent in both English and Korean conducted reverse translation of K-FMA version 1.0 into English [21]. The translation committee compared the forward and reverse translations to examine whether K-FMA version 1.0 and the original version of the FMA were consistent. In consistencies were resolved by the translation committee, and K-FMA version 2.0 was created. Cognitive debriefing was performed on K-FMA version 2.0 to identify other conceptual issues that could cause confusion, and the final version of the K-FMA was established by resolving these issues (Appendix 1).

Throughout the translation process, medical terms were selected from Medical Terminology, which was published by the Korean Medical Association and the KARM. In addition, external advisers from the KARM also consulted on version 1.0 and version 2.0.

Participants

A total of 34 stroke survivors who were admitted to a rehabilitation hospital were recruited between November 2019 and April 2020. The inclusion criteria were as follows: (1) first diagnosis of haemorrhagic or ischaemic stroke, (2) age of >19 years, (3) Brunnstrom stage of upper or lower extremity from 2 to 4, and (4) sufficient cognitive function to allow understanding and following the instruction of the researcher. Participants with history of psychiatric or neurological diagnosis, severe aphasia, decreased level of consciousness, disorders affecting movement other than stroke such as motor neurone disease, Parkinson's disease, polyneuropathy, or mononeuropathy; and uncontrolled comorbidities such as cancer and severe organ failure were excluded. Among the 34 participants who were recruited, three were transferred to other hospitals for further treatment during the course of the study; thus, the data of 31 participants were finally analysed in this study to verify the reliability and validity of the K-FMA. This study was approved by the Institutional Review Boards of the National Rehabilitation Center (NRC-2019-03-017), and all participants provided written informed consent prior to enrolment.

Reliability and validity

A prospective evaluation was conducted to verify the intra-rater reliability, inter-rater reliability, and concurrent validity of the final version of the K-FMA. According to a test-retest method for the analysis of reliability, two experienced physical therapists, evaluator 1 and evaluator 2, measured all participants with the K-FMA, and repeated the measurement after 1 week. The two evaluators performed evaluations on the same day. For intra-rater reliability, the first and second assessments of each evaluator were compared, and for inter-rater reliability, the first K-FMA results of each evaluator were compared. For robust comparisons, the second K-FMA results of each evaluator were also compared. Concurrent validity analysis was carried out using Pearson correlation test of the mean value of K-FMA and other evaluation tools for patients with stroke in clinical areas, the Motricity Index (MI), MAS, and Berg Balance Scale (BBS).

Assessments

The original FMA consists of four domains: motor, sensory, joint range of motion (ROM), and joint pain [5]. Each evaluation item is graded on a 3-point ordinal scale from 0 to 2, with a higher score representing less impairment [5]. In the motor function domain, the upper extremity (UE) motor function evaluation consists of 33 items with scores ranging from 0 to 66, and the lower extremity (LE) motor function evaluation consists of 17 items with scores ranging from 0 to 34. The domain of sensory function includes four items evaluating the light touch sensation of the UE and LE and eight items assessing the proprioception of the UE and LE. The sensory function score ranges from 0 to 24. The domains of joint ROM and joint pain are composed of 12 items for UE and 10 items for LE, and the scores range from 0 to 44 in both domains.

The MI is an index used to measure limb strength, consisting of three items each in the UE (pinch grip, elbow flexion, and shoulder abduction) and LE (ankle dorsiflexion, knee extension, and hip flexion) [22]. Scores in the MI are calculated based on the sum of the scores of the three items in the UE and LE each, and range from 0 (complete paresis) to 100 (normal strength) [22].

The MAS is an assessment tool for evaluating the functional capabilities of patients with stroke, which consists of eight motor items: supine to side lying onto intact side, supine to sitting over the side of the bed, balanced sitting, sitting to standing, walking, upper arm function, hand movement, and advanced hand activities [12]. Each motor item is rated on a 7-point scale, ranging from 0 to 6, with higher scores representing lesser impairment. The total MAS score ranges from 0 to 48 [12].

The BBS is a quantitative evaluation tool consisting of 14 items measuring static and dynamic balance while sitting, standing, or shifting weight [23,24]. Each item is graded on a 5-point scale from 0 to 4, and 4 points represent independent completion of the item. The total score is a sum of the scores obtained for each item, out of an overall score of 56 [23].

Statistical analysis

The intra-rater reliability and inter-rater reliability of the K-FMA were evaluated with the intraclass correlation coefficient (ICC) with values between 0.74 and 1.0 representing excellent reliability, between 0.60 and 0.74, good reliability; between 0.40 and 0.59, fair reliability; and below 0.4, poor reliability [25]. The concurrent validity of the K-FMA was tested using Pearson's correlation

test and compared with the MI, MAS, and BBS scores. A correlation between the K-FMA and other evaluation tools with a correlation coefficient of 0.7 or higher was regarded as highly positive [26]. A value of $p<0.05$ was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics version 20.0 for Windows (IBM SPSS, Armonk, NY, USA).

Table 1. Baseline characteristics of the participants (n=31)

Characteristic	Value
Sex	
Male	18 (58.1)
Female	13 (41.9)
Time after stroke onset (mo)	11.2±7.9
Age (yr)	53.6±16.1
Height (cm)	165.8±8.5
Weight (kg)	65.4±12.3
Hemiplegic side	31
Right hemiplegia	11
Left hemiplegia	17
Quadriplegia	3
Motricity Index	40.2±17.9
Motor Assessment Scale	23.6±10.9
Berg Balance Scale	35.2±13.6

Values are presented as number (%) or mean±standard deviation.

RESULTS

Demographic characteristics and results of other evaluation tools

Subjects' baseline characteristics including sex, age, and duration after stroke onset were collected. The demographic characteristics and results of other evaluation tools of the participants are presented in Table 1.

Intra-rater reliability

The intra-rater reliabilities are show in Table 2. All domains had ICC >0.74, except passive ROM, in which variation was found for the LE, and joint pain. All domains were statistically significant at $p<0.05$. According to the results of intra-rater reliability of evaluator 1, the total motor score recorded the highest ICC (0.961), and the passive ROM of the LE showed the lowest ICC (0.596). Similarly, as per the intra-rater reliability results of evaluator 2, the motor function of the UE had the highest ICC (0.977) and the passive ROM of the LE had the lowest ICC (0.512).

Inter-rater reliability

The inter-rater reliability results between evaluators 1 and 2 are provided in Table 3. The assessment was divided into two parts: part 1 was the first-test comparison and part 2 was the retest comparison. The analysis found all ICCs >0.74, except the passive ROM for LE and joint

Table 2. Intra-rater reliability of the Korean version of the Fugl-Meyer Assessment (n=31)

Test	Evaluator 1				Evaluator 2			
	Test	Retest	p-value	ICC	Test	Retest	p-value	ICC
K-FMA total score	139.19±19.23	138.23±20.07	<0.001	0.938**	138.81±20.80	140.94±19.78	<0.001	0.944**
K-FMA UE motor score	23.52±11.64	22.84±12.91	<0.001	0.959**	23.55±12.32	24.13±11.97	<0.001	0.977**
K-FMA LE motor score	20.13±6.09	19.03±6.04	<0.001	0.912**	19.26±6.52	19.74±6.11	<0.001	0.802**
K-FMA total motor score	43.65±15.65	41.87±16.81	<0.001	0.961**	42.81±16.69	43.87±16.37	<0.001	0.946**
Tactile sensitivity for UE	6.45±5.02	6.32±5.15	<0.001	0.935**	6.35±5.03	6.48±5.08	<0.001	0.940**
Tactile sensitivity for LE	8.32±3.60	8.61±3.51	<0.001	0.927**	8.29±3.63	8.65±3.65	<0.001	0.939**
Passive ROM for UE	21.84±2.19	22.03±2.18	<0.001	0.866**	22.03±1.89	22.23±2.03	<0.001	0.961**
Passive ROM for LE	18.52±1.18	18.87±1.36	0.007	0.596**	18.71±1.22	18.42±2.35	0.028	0.512*
Joint pain for UE	21.06±2.94	21.06±3.84	<0.001	0.721**	21.19±2.93	21.81±2.74	<0.001	0.887**
Joint pain for LE	19.35±1.23	19.45±1.77	0.002	0.677**	19.42±1.03	19.48±1.71	<0.001	0.780**

Values are presented as mean±standard deviation.
ICC, intra-class correlation coefficient; K-FMA, the Korean version of the Fugl-Meyer Assessment; UE, upper extremity; LE, lower extremity; ROM, range of motion.
*p<0.05, **p<0.01.

Table 3. Inter-rater reliability of the Korean version of the Fugl-Meyer Assessment (n=31)

Test	Part 1				Part 2			
	Evaluator 1	Evaluator 2	p-value	ICC	Evaluator 1	Evaluator 2	p-value	ICC
K-FMA total score	139.19±19.23	138.81±20.80	<0.001	0.974**	138.23±20.07	140.94±19.78	<0.001	0.967**
K-FMA UE motor score	23.52±11.64	23.55±12.32	<0.001	0.980**	22.84±12.91	24.13±11.97	<0.001	0.983**
K-FMA LE motor score	20.13±6.09	19.26±6.52	<0.001	0.880**	19.03±6.04	19.74±6.11	<0.001	0.949**
K-FMA total motor score	43.65±15.65	42.81±16.69	<0.001	0.966**	41.87±16.81	43.87±16.37	<0.001	0.984**
Tactile sensitivity for UE	6.45±5.02	6.35±5.03	<0.001	0.995**	6.32±5.15	6.48±5.08	<0.001	0.995**
Tactile sensitivity for LE	8.32±3.60	8.29±3.63	<0.001	0.993**	8.61±3.51	8.65±3.65	<0.001	0.993**
Passive ROM for UE	21.84±2.19	22.03±1.89	<0.001	0.902**	22.03±2.18	22.23±2.03	<0.001	0.975**
Passive ROM for LE	18.52±1.18	18.71±1.22	<0.001	0.782**	18.87±1.36	18.42±2.35	0.032	0.498*
Joint pain for UE	21.06±2.94	21.19±2.93	<0.001	0.971**	21.06±3.84	21.81±2.74	<0.001	0.727**
Joint pain for LE	19.35±1.23	19.42±1.03	<0.001	0.851**	19.45±1.77	19.48±1.71	<0.001	0.997**

Values are presented as mean±standard deviation.
ICC, intra-class correlation coefficient; K-FMA, the Korean version of the Fugl-Meyer Assessment; UE, upper extremity; LE, lower extremity; ROM, range of motion.
*p<0.05, **p<0.01.

Table 4. Pearson correlation test of the Korean version of the Fugl-Meyer Assessment comparing with Motricity Index, Motor Assessment Scale, and Berg Balance Scale (n=31)

K-FMA	Motricity Index	Motor Assessment Scale	Berg Balance Scale
K-FMA total	0.788**	0.496**	0.233
K-FMA UE total	0.639**	0.446*	0.126
K-FMA LE total	0.754**	0.399*	0.334
K-FMA motor	0.891**	0.613**	0.223
K-FMA UE motor	0.778**	0.555**	0.144
K-FMA LE motor	0.861**	0.549**	0.323

The data showed Pearson correlation coefficients.
K-FMA, Korean version of the Fugl-Meyer Assessment; UE, upper extremity; LE, lower extremity.
*p<0.05, **p<0.01, calculated by Pearson correlation test.

pain for the UE, and all these results were statistically significant at p<0.05. Tactile sensitivity for the UE had one of the highest ICCs (0.995) in both parts 1 and 2. Joint pain for the LE had the highest ICCs in both parts 1 and 2 (0.851 and 0.997, respectively). The LE passive ROM had the lowest ICC in both parts 1 and 2 (0.782 and 0.498, respectively).

Concurrent validity

Results of the concurrent validity analysis of the K-FMA with MI, MAS, and BBS with Pearson correlation coefficient are provided in Table 4.

The total score (sum of all four domains) was significantly correlated with the MI, which had the highest correlation of all evaluation tools examined (r=0.788). It was also significantly correlated with the MAS, with a comparatively lower correlation coefficient (r=0.496). The total K-FMA score was not significantly correlated with the BBS score (p=0.22), unlike the other tools. The total K-FMA scores for the UE and LE showed similar results. The total score for the motor domain (sum of the UE and LE motor scores) was also significantly correlated with the MI, which had the highest correlation coefficient (r=0.891) among all evaluation tools. The total score for the K-FMA motor domain was also significantly correlated with the MAS score (r=0.613). The motor-domain subscores for the UE and LE showed similar significant correlations. None of the K-FMA motor domains showed significant correlations with the BBS score (p=0.22), similar to the K-FMA total score.

DISCUSSION

Intra-rater reliability and inter-rater reliability

The total score and all domains of the K-FMA showed significant intra- and inter-rater reliabilities, with good to excellent reliability in most domains of the K-FMA except joint ROM for LE. In the intra-rater reliability analysis, the sum of the motor functions of the UE and LE in evaluations by evaluator 1 and the motor function of UE in the evaluation by evaluator 2 showed the highest degree of reliability, whereas passive ROM of the LE had the lowest reliability in the evaluations of both evaluators. Regarding inter-rater reliability, the tactile sensitivity of the UE and joint pain of the LE represented the highest reliability, while the passive ROM of the LE had the lowest reliability in both test and retest.

Similar to previous findings, the motor domains of the K-FMA (total motor, UE motor, and LE motor scores) showed excellent reproducibility in intra- and inter-rater reliabilities [7-10]. The motor domain of the FMA is often used alone for evaluating motor function because of its superiority and consideration of the time required [6].

The sensory domain of the K-FMA showed excellent intra-rater and inter-rater reproducibility, and the joint pain domain showed good to excellent reliability, although these two domains rely on the subjective appeal of the participants, which can result in loss of objectivity [6].

Conversely, the ICC for the domain of joint ROM for LE was low in both the intra-rater and inter-rater analyses. Since the intra-rater reliability was low, the inter-rater reliability was also low. The result of the intra-rater reliability analysis might be influenced by inconstant spasticity and change in the ROM after interventions. In particular, changes in ROM according to the pre- and post-physical therapy status might significantly impact the test results, although there were no changes in other functions. Additionally, there was no unified training programme on standardisation of the evaluation of LE joint ROM for evaluators before this study began. In a previous study on the Brazilian version of the FMA, the ICC value of the domain for joint ROM for LE improved significantly from 0.50 ($p>0.05$) to 0.90 ($p<0.001$) in the inter-rater reliability analysis after the evaluators adapted to the improved and detailed manual attached with illustrating photographs [7]. After the adaptation of the standardised manual, the reliability of the sensory function domain was also enhanced. Another study reported excellent intra-rater and inter-rater reliabilities of the FMA with a standardised manual and rater training programme [10]. A study suggested the use of a standardised manual for FMA providing detailed instructions on the test process, grading, patient guidelines, and equipment [11]. Hence, we also translated the original manual for the FMA into Korean with standardisation of the measurement instructions to increase the reliability of the K-FMA. Similar to the process for the translation of the FMA, with consent from the original author for usage of the original manual, the manual for the K-FMA was prepared through forward translation, revision, reverse translation, and cognitive debriefing. Images of postures for evaluation were created and added to the manual (Appendix 2). We expect this manual to be widely used to improve the reliability of the K-FMA.

Validity

The MI and MAS scores were statistically significantly correlated with the K-FMA score when analysed with Pearson correlation test, while the BBS score was not. This result was expected, considering that the MI and MAS are evaluation tools for motor function. Specifically, the MI showed a highly positive correlation with the K-FMA score, but the MAS showed a moderately positive correlation, probably because there were no evaluation items for the trunk muscles or balance in the K-FMA, unlike in the MAS, which has items to evaluate the trunk muscles and balance, such as supine to sitting over the side of the bed or balanced sitting, whereas the MI consists of items for evaluating muscles of the extremities. Moreover, the FMA and MI both evaluate patient impairment, unlike the MAS, which evaluates activities such as gait and movements of the extremities. Similar to the modified Rivermead Mobility Index, the FMA also showed a statistically significant correlation with the tools evaluating activities such as the Modified Barthel Index [27,28]. Accordingly, the FMA is considered useful for evaluating both motor function and the mobility of patients with stroke.

Although the BBS, which is a widely used evaluation tool for measuring balance, was previously reported to have moderate to good correlation with the motor function of the FMA, the results of our study showed no

statistically significant correlation between the K-FMA and BBS [29]. In another study, the FMA did not show a statistically significant correlation with the evaluation tool regarding balance ability, including static balance, dynamic balance, and weight distribution asymmetry indices, which was consistent with the results of our study [30]. It is considered that classifying the FMA and BBS together as similar types of assessment tools for motor function would be difficult, since the K-FMA mainly focuses on motor and sensory function evaluation and does not include balance evaluation items. The FMA is especially valuable for evaluating recovery of motor impairment after stroke, but other domains are considered inadequate, as they do not correspond to the intended aim of the FMA [6].

There are some limitations to this study. First, it was difficult to generalise the results of this study because only participants with Brunnstrom stages 2–4 were recruited, whereas those with Brunnstrom stages 1, 5, and 6 were not. However, considering that patients in Brunnstrom stages 2–4 have the greatest variability, which affects the reliability and complicates the evaluation, the high reliability in our study implies that the K-FMA can be used in the clinical field. Second, raters were not trained to use a standardised manual for the K-FMA and evaluated patients based on their own standards, which could have adversely affected the objectivity of the evaluation. Improvement of reliability would be expected with the application of a standardised manual for the K-FMA, as in previous studies [7,10]. Nevertheless, the K-FMA was verified as an evaluation tool with high reliability and validity for patients with stroke and can be used effectively in the domestic rehabilitation field. We also produced a manual of K-FMA containing a training video and graphic illustration in each evaluation process as a standardised measurement method. Additional studies are being conducted on the effectiveness of training using this manual, and the manual is expected to play a vital role as a standardised training guideline.

In conclusion, the FMA and the manual for the FMA were translated into Korean through standardised translation and several verification processes, and this newly translated K-FMA was verified as a tool for sensorimotor evaluation in patients with stroke with a high level of reliability and validity.

The K-FMA is expected to be used as a standardised tool to replace the original FMA in Korea with high reliability and validity. Additionally, the newly developed manual for the K-FMA is anticipated to minimise errors that can occur in the evaluation and help improve the reliability of motor function evaluation in patients with stroke.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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AUTHOR CONTRIBUTION

Conceptualization: Shin JH. Methodology: Shin JH. Formal analysis: Hwang SH, Lee WJ, Kim EH, Hwang JW, Cho IY, and Lee JA. Project administration: Shin JH. Visualisation: Kim EH, Hwang JW, Cho IY, and Lee JA. Writing–original draft: Kim TL, Park JH, and Shin JH. Writing–review and editing: Kim TL, Park JH, and Shin JH. Approval of final manuscript: all authors.

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Appendix 1. The Korean version of the Fugl-Meyer Assessment (K-FMA)

A. 상지 (앉은 자세)

Ⅰ. 운동반사		없음	유발됨
굽힘근: 위팔두갈래근 및 손가락 굽힘근(최소 한 부위)		0	2
폄근: 위팔세갈래근		0	2
	소계 Ⅰ (최대 4점)		

Ⅱ. 협동군(시너지) 내에서의 수의적 움직임(중력의 도움 없이)			수행 못함	부분적 수행	완전한 수행
굽힘근 협동작용: 손을 반대쪽 무릎에서 같은쪽 귀로 이동. 폄근 협동에서(어깨 모음/안쪽돌림, 팔꿉 폄, 아래팔 엎침) 굽힘 협동(어깨 벌림/바깥돌림, 팔꿉 굽힘, 아래팔 뒤침)으로	어깨	뒤당김	0	1	2
		올림	0	1	2
		벌림(90°)	0	1	2
		바깥돌림	0	1	2
	팔꿉	굽힘	0	1	2
	아래팔	뒤침	0	1	2
폄근 협동작용: 손을 같은쪽 귀에서 반대쪽 무릎으로	어깨	모음/안쪽돌림	0	1	2
	팔꿉	폄	0	1	2
	아래팔	엎침	0	1	2
		소계 Ⅱ (최대 18점)			

Ⅲ. 혼합 협동군 내에서의 수의적 움직임(보상작용 없이)		수행 못함	부분적 수행	완전한 수행
손을 허리뼈로 (무릎위에 손)	수행하지 못하거나 손이 위앞엉덩뼈가시(ASIS) 앞에	0		
	손이 위앞엉덩뼈가시 뒤에(보상작용 없이)		1	
	손이 허리뼈로(보상작용 없이)			2
어깨 굽힘 0°-90° (팔꿉 0°/엎침-뒤침 0°)	즉각적 벌어짐 또는 팔꿉 굽혀짐	0		
	움직이는 동안의 벌어짐 또는 팔꿉 굽혀짐		1	
	어깨의 벌어짐 또는 팔꿉의 굽혀짐 없이 90° 굽힘			2
엎침-뒤침 (팔꿉 90°/어깨 0°)	엎침/뒤침 못함, 준비자세 불가능	0		
	제한적 엎침/뒤침, 준비자세 유지		1	
	완전한 엎침/뒤침, 준비자세 유지			2
	소계 III (최대 6점)			

IV. 협동작용이 거의 없거나 없는 수의적 움직임		수행 못함	부분적 수행	완전한 수행
어깨 벌림 0°-90° (팔꿉 0°/아래팔 엎침)	즉각적인 뒤침 또는 팔꿉 굽혀짐	0		
	움직이는 동안의 뒤침 또는 팔꿉 굽혀짐		1	
	벌림 90°, 폄과 엎침 유지			2
어깨 굽힘 90°-180° (팔꿉 0°/엎침-뒤침 0°)	즉각적 벌어짐 또는 팔꿉 굽혀짐	0		
	움직이는 동안의 벌어짐 또는 팔꿉 굽혀짐		1	
	굽힘 180°, 어깨의 벌어짐 또는 팔꿉 굽혀짐 없이			2
엎침/뒤침 (팔꿉 0°/어깨 30°-90° 굽힘)	엎침/뒤침 못함, 준비자세 불가능	0		
	제한적 엎침/뒤침, 준비자세 유지		1	
	완전한 엎침/뒤침, 준비자세 유지			2
	소계 IV (최대 6점)			

Ⅴ. 정상 운동 반사 (항목 Ⅳ에서 6점 만점을 획득한 경우에만 평가한다; 건측과 비교)		과항진	나타남	정상
위팔두갈래근, 위팔세갈래근, 손가락 굽힘근	세 개 중 두 개의 반사가 현저히 과항진 되어있음	0		
	하나의 반사가 현저히 과항진 되거나 또는 최소 두 개의 반사가 나타남		1	
	최대 하나의 반사가 나타남, 과항진 반사 없음			2
	소계 V (최대 2점)			
	총점 A (최대 36점)			

B. 손목 (준비자세를 취하거나 유지하기 위해서 팔꿉에 지지 가능, 손목에는 지지없음, 검사전 손목의 수동관절가동범위 확인)		수행불가	부분적 수행	완전한 수행
15° 손등굽힘에서의 안정성 (팔꿉 90°, 아래팔 엎침, 어깨 0°)	능동적 손등굽힘 15° 미만 손등굽힘 15°, 저항에 견디지 못함 저항에 대한 손등굽힘 유지	0	1	2
반복적 손등굽힘/손바닥 굽힘 (팔꿉 90°, 아래팔 엎침, 어깨 0°, 약간의 손가락 굽힘)	수의적으로 수행하지 못함 제한된 능동관절가동범위 완전한 능동관절가동범위, 부드럽게	0	1	2
15° 손등굽힘에서의 안정성 (팔꿉 0°, 아래팔 엎침, 약간의 어깨 굽힘/벌림)	능동적 손등굽힘 15° 미만 손등굽힘 15°, 저항에 견디지 못함 저항에도 손등굽힘 유지	0	1	2
반복적 손등굽힘/손바닥 굽힘 (팔꿉 0°, 아래팔 엎침, 약간의 어깨 굽힘/벌림)	수의적으로 수행하지 못함 제한된 능동관절가동범위 완전한 능동관절가동범위, 부드럽게	0	1	2
회전 (팔꿉 90° 굽힘, 아래팔 엎침, 어깨 0°)	수의적으로 수행하지 못함 덜컥거리는(jerky) 움직임 또는 불완전한 완전하고 부드러운 회전	0	1	2
	총점 B (최대 10점)			

C. 손 (팔꿉 굽힘 90° 유지를 위해서 팔꿉에 지지 제공가능, 손목에는 지지 불가, 건측 손과 비교, 물건들을 놓아두고, 능동적 잡기)		수행불가	부분적 수행	완전한 수행
전체 굽힘 능동 또는 수동으로 완전히 편 상태에서		0	1	2
전체 폄 능동 또는 수동으로 완전히 굽힌 상태에서		0	1	2
잡기				
a. 고리 잡기 몸쪽 손가락뼈사이관절과 먼쪽 손가락뼈사이관절(제2–5 손가락)굽힘, 제2–5 손가락 손허리손가락관절 폄	수행할 수 없음 자세유지가능하나 약함 저항에 대하여 자세를 유지	0	1	2
b. 엄지 모음 제1손목손허리관절, 손허리손가락관절, 손가락뼈사이관절 0°, 엄지와 제2손허리손가락관절 사이에 종이 끼움	수행할 수 없음 종이잡기를 유지할 수 있으나 당기면 버티지 못함 당겨도 종이잡기를 유지할 수 있음	0	1	2
c. 손끝 잡기(맞섬) 엄지손가락 바닥을 두 번째 손가락 바닥에 맞댄다, 연필, 위로 당김	수행할 수 없음 연필잡기를 유지할 수 있으나 당기면 버티지 못함 당겨도 연필잡기를 유지할 수 있음	0	1	2
d. 원통 잡기 원통 모양의 물건(작은 캔), 위로 당김, 엄지와 손가락들의 맞섬	수행할 수 없음 원통잡기를 유지할 수 있으나 당기면 버티지 못함 당겨도 원통잡기 유지할 수 있음	0	1	2
c. 구형 잡기 손가락들의 벌림/굽힘, 엄지 맞섬, 테니스 공, 당김	수행할 수 없음 공잡기를 유지할 수 있으나 당기면 버티지 못함 당겨도 공잡기를 유지할 수 있음	0	1	2
	총점 C (최대 14점)			

D. 협응/속도 (앉은 자세, 양팔로 한번의 시도 후, 눈은 감은 상태, 두 번째 손가락 끝을 무릎에서 코로, 가능한 빠르게 5회)		**현저함**	**약간**	**없음**
떨림	최소 한번의 완전한 움직임	0	1	2
겨냥이상	현저하거나 비체계적	0		
	약하거나 체계적		1	
	겨냥이상 없음			2
		≥6 s	2–5 s	<2 s
시간	건측보다 최소 6초 이상 느림	0		
손을 무릎에서 시작해서 끝냄	건측보다 2–5초 느림		1	
	건측과의 차이가 2초 미만			2
	총점 D (최대 6점)			

H. 감각, 상지 (눈은 감은 상태, 건측과 비교)		**무감각**	**감각저하 또는 이상감각**	**정상**
가벼운 촉각	위팔, 아래팔	0	1	2
	손바닥	0	1	2
		3/4 미만 인지 또는 인지 못함	3/4 인지 또는 건측과 차이가 명확함	100%인지, 건측과 차이가 거의 없음 또는 없음
위치감각 위치의 작은 변화	어깨	0	1	2
	팔꿈	0	1	2
	손목	0	1	2
	엄지손가락(손가락뼈사이관절)	0	1	2
			총점 H (최대 12점)	

I. 수동관절운동, 상지 (앉은 자세, 건측과 비교)	**제한된 작은 각도 (어깨 10° 미만)**	**감소**	**정상**	**J. 관절 통증** (수동운동 동안, 상지) **움직임 동안의 뚜렷한 통증 또는 끝에서 매우 현저한 통증**	**약간의 통증**	**통증 없음**
어깨						
굽힘(0°-180°)	0	1	2	0	1	2
벌림(0°-90°)	0	1	2	0	1	2
바깥돌림	0	1	2	0	1	2
안쪽돌림	0	1	2	0	1	2
팔꿈						
굽힘	0	1	2	0	1	2
폄	0	1	2	0	1	2
아래팔						
엎침	0	1	2	0	1	2
뒤침	0	1	2	0	1	2
손목						
굽힘	0	1	2	0	1	2
폄	0	1	2	0	1	2
손가락관절						
굽힘	0	1	2	0	1	2
폄	0	1	2	0	1	2
총점 (최대 24점)				총점 (최대 24점)		

A. 상지	/36
B. 손목	/10
C. 손	/14
D. 협응/속도	/6
총점 A–D (운동 기능)	/66

H. 감각	/12
I. 수동관절운동	/24
J. 관절통증	/24

E. 하지

Ⅰ. 운동반사(바로누운자세)		없음	유발됨
굽힘근: 무릎 굽힘근		0	2
폄근: 무릎힘줄, 아킬레스힘줄(최소 한 부위)		0	2
	소계 Ⅰ (최대 4점)		

Ⅱ. 협동군(시너지) 내에서의 수의적 움직임(바로누운자세)		수행 못함	부분적 수행	완전한 수행
굽힘 협동작용: 엉덩관절 최대 굽힘(벌림/바깥돌림), 무릎과 발목 관절의 최대 굽힘 (능동적 무릎 굽힘 확인을 위한 먼쪽 힘줄 촉지)	엉덩관절굽힘	0	1	2
	무릎굽힘	0	1	2
	발목발등굽힘	0	1	2
폄 협동작용: 굽힘 협동에서 엉덩관절 폄/모음, 무릎 폄과 발목관절 발바닥굽힘으로. 능동적 움직임을 확인하기 위해서 저항을 적용, 움직임과 근력을 모두 평가(건측과 비교)	엉덩관절 폄	0	1	2
	모음	0	1	2
	무릎 폄	0	1	2
	발목발바닥굽힘	0	1	2
	소계 Ⅱ (최대 14점)			

Ⅲ. 혼합 협동군 내에서의 수의적 움직임 (앉은 자세, 무릎은 침대/의자 끝에서 10 cm)		수행 못함	부분적 수행	완전한 수행
무릎 굽힘	능동적 움직임 없음	0		
능동 또는 수동적으로	90° 미만의 능동적 굽힘, 넙다리뒤인대 촉지		1	
펴진 무릎에서	90° 이상의 능동적 굽힘			2
발목 발등굽힘	능동적 움직임 없음	0		
건측과 비교	제한된 발등굽힘		1	
	완전한 발등굽힘			2
	소계 Ⅲ (최대 4점)			

Ⅳ. 협동작용이 거의 없거나 없는 수의적 움직임 (선 자세, 엉덩관절 0°)		수행 못함	부분적 수행	완전한 수행
무릎 90° 굽힘	능동적 움직임 없음 또는 즉각적, 동시적 엉덩관절 굽혀짐	0		
엉덩관절 0°, 균형지지 허용됨	90° 미만의 무릎 굽힘 그리고/또는 움직임 동안에 엉덩관절 굽혀짐		1	
	동시적 엉덩관절의 굽혀짐 없는 최소 90° 무릎 굽힘			2
발목 발등굽힘	능동적 움직임 없음	0		
건측과 비교	제한된 발등굽힘		1	
	완전한 발등굽힘			2
	소계 Ⅳ (최대 4점)			

Ⅴ. 정상 운동 반사 (바로누운자세, 항목 Ⅳ에서 4점 만점을 획득한 경우에만 평가한다; 건측과 비교)		과항진	항진 (나타남)	정상
운동 반사	세 개 중 두 개의 반사가 현저히 과항진 되어있음	0		
무릎굽힘근, 무릎힘줄, 아킬레스힘줄	하나의 반사가 현저히 과항진 되거나 또는 최소 두 개의 반사가 나타남		1	
	최대 하나의 반사가 나타남, 과항진 반사 없음			2
	소계 Ⅴ (최대 2점)			
	총점 E (최대 28점)			

F. 협응/속도 (바로누운자세, 양다리로 한번의 시도 후, 눈은 감은 상태, 발뒤꿈치를 반대쪽 다리의 무릎뼈로, 가능한 빠르게 5회)		**현저함**	**약간**	**없음**
떨림	최소 한번의 완전한 움직임	0	1	2
겨냥이상	현저하거나 비체계적	0		
	약하거나 체계적		1	
	겨냥이상 없음			2
		≥6 s	2–5 s	<2 s
시간	건측보다 최소 6초 이상 느림	0		
손을 무릎에서 시작해서 끝냄	건측보다 2–5초 느림		1	
	건측과의 차이가 2초 미만			2
	총점 D (최대 6점)			

H. 감각, 하지 (눈은 감은 상태, 건측과 비교)		**무감각**	**감각저하 혹은 이상감각**	**정상**
가벼운 촉각	다리	0	1	2
	발바닥	0	1	2
		3/4 미만 인지 또는 인지 못함	3/4 인지 또는 건측과 차이가 명확함	100% 인지, 건측과 차이가 거의 없음 또는 없음
위치감각	엉덩관절	0	1	2
위치의	무릎	0	1	2
작은 변화	발목	0	1	2
	엄지발가락(발가락뼈사이관절)	0	1	2
			총점 H (최대 12점)	

I. 수동관절운동, 하지 (바로누운자세, 건측과 비교)	**제한된 작은 각도 (엉덩관절 10° 미만)**	**감소**	**정상**	**J. 관절통증** (수동운동 동안, 하지) **움직임 동안의 뚜렷한 통증 또는 끝에서 매우 현저한 통증**	**약간의 통증**	**통증 없음**
엉덩관절						
굽힘	0	1	2	0	1	2
벌림	0	1	2	0	1	2
바깥돌림	0	1	2	0	1	2
안쪽돌림	0	1	2	0	1	2
무릎						
굽힘	0	1	2	0	1	2
폄	0	1	2	0	1	2
발목						
발등굽힘	0	1	2	0	1	2
발바닥굽힘	0	1	2	0	1	2
발						
엎침	0	1	2	0	1	2
뒤침	0	1	2	0	1	2
총점 (최대 20점)				총점 (최대 20점)		

E. 하지	/28
F. 협응/속도	/6
총점 E–F (운동 기능)	/34

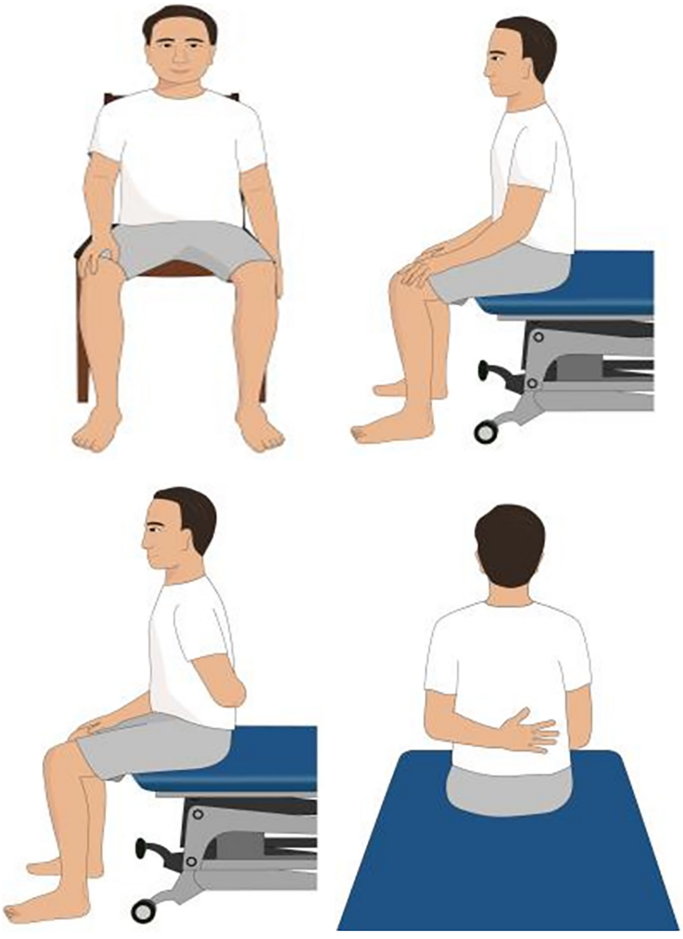
H. 감각	/12
I. 수동관절운동	/20
J. 관절통증	/20

Appendix 2. Example of the instruction and illustration of the manual

Ⅲ. 혼합 협동군 내에서의 수의적 움직임

a. 손을 허리뼈로 (무릎 위에 손)
환자는 어깨 0°, 팔꿉 0° 인 상태로 팔을 자연스럽게 몸 옆에 두고 앉는다.
건측부터 먼저 움직임을 수행하게 한다.
환측을 검사하기 전, 검사할 각 관절의 수동관절가동범위를 확인한다.
환자에게 "손을 허리 뒤로 가져가세요." 라고 지시하여 환측의 손이 능동적으로 허리 뒤쪽으로 움직이도록 한다.
환측 검사를 3회 반복하고 가장 잘하는 움직임을 기준으로 점수를 부여한다.

(평가지시) 자연스럽게 팔을 옆에 두고 앉은 상태에서 손을 허리 뒤로 가져가세요. 뒷짐을 지세요. 이렇게요.



점수(최대 2점)
(0)-수행 못함
(수행하지 못하거나 손이 위앞엉덩뼈가시에 도달하지 못한다)

(1)-부분적 수행
(손이 반드시 위앞엉덩뼈가시를 지나야 한다)

(2)-완전한 수행
(위앞엉덩뼈가시를 완전히 지나 엉치뼈를 향해 팔을 펼 수 있다. 2점을 충족시키기 위해서 팔꿉을 완전히 펴지 않아도 된다.)