

Cognitive and Language Function in Aphasic Patients Assessed With the Korean Version of Mini-Mental Status Examination

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Objective To assess the clinical usefulness of the relatively short instrument, the Korean version of the Mini-Mental State Examination (MMSE-K), for testing the association between cognition and language function in subacute post-stroke aphasia patients.

Methods Medical charts of 111 post-stroke patients (65 men; age 69.6±10.0 years; 124.6±80.6 days post-onset) were reviewed retrospectively. All patients were assessed longitudinally for aphasia using the validated Korean version of the Western Aphasia Battery (K-WAB) and for cognition using the MMSE-K. Patients were categorized and analyzed according to 3 aphasia-severity clusters.

Results All subscales of the K-WAB showed significant improvement in follow-up assessments in all groups ($p < 0.05$ or $p < 0.01$). Only the scores of orientation, language function, and total score of MMSE-K showed significant improvement in all groups ($p < 0.01$). The more severely impaired group showed stronger Pearson correlation coefficients between cognition and language function. Additionally, comparisons between correlation coefficients showed that the association of improvement in orientation with that of fluency and AQ% (aphasia quotient %) was significant in the more severely impaired group.

Conclusion Among subacute post-stroke aphasic patients, patients with more severe aphasia showed greater impairments to cognitive function; in addition, recovery of orientation may be related to recovery of language function.

Keywords Stroke, Aphasia, Cognition, Language, Orientation

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INTRODUCTION

Stroke is a disabling chronic condition including motor weakness, dysphagia, cognitive decline, language disorders, and mood disorders, resulting in serious decrements to mobility, activities of daily living, nutrition, communication, and quality of life [1-3]. In particular, recent research has focused on the relationship between cognition and language after stroke [4-7], because the boundaries of these affected areas are unclear and may overlap [8]. Furthermore, stroke is also associated with concomitant morbidities in memory, orientation, language, and attention [9].

Several studies have focused on the cognitive impacts of language function in post-stroke aphasic patients. In a non-linguistic cognitive examination including abstract reasoning, visual memory, visual perception and construction, and executive functioning, El Hachoui et al. [4] reported that non-linguistic cognitive impairments are common and associated with poor functional outcomes and depression, especially in patients with persisting aphasia. Moreover, Lee and Pyun [6] used computerized neurocognitive functional batteries to assess attention, executive function, and intelligence and reported significantly impaired working memory and sustained attention in aphasic patients and significant correlations between cognitive deficits and aphasia severity in only some tests of attention. Yu et al. [5] used the Loewenstein Occupational Therapy Cognitive Assessment (LOTCA) battery, which is a performance test with minimal verbal requirements except for orientation and is suitable for testing cognitive function in post-stroke patients with language dysfunction, and showed a close relationship between linguistic functions and cognitive orientation, spatial perception, visual perception, and thinking operation [10].

Previous studies, however, have adopted neuropsychological tests which are difficult to apply because they require specialists such as clinical psychologists and long durations of testing. These studies have also not considered aphasia severity, which affects the clinical course of recovery [11,12]. Moreover, most neuropsychological tests that have been used require both linguistic and non-linguistic cognitive domains in their test instructions and performance procedures. Raven's progressive colored matrices [13], which is easily obtained and can be ad-

ministered to most individuals with aphasia independent of their language deficits, mainly targets only visual analogical thinking [14].

If a clear distinction between cognition and language function is possible, popular and easy to adopt neuropsychological tests that assess the impact of cognition on language or vice versa should be utilized for indication of recovery or prognosis in post-stroke aphasia patients. The Korean version of the Mini-Mental State Examination (MMSE-K) has become a widely used cognitive screening tool due to its brevity and straightforward administration [15-17] and is usually included in assessments of post-stroke patients in clinical and research settings. Thus, we aimed to identify the clinical usefulness of MMSE-K for assessing the association between cognition and language function in subacute post-stroke aphasia patients.

MATERIALS AND METHODS

Participants

The current study used a sample of first-ever post-stroke aphasic patients within 12 months of onset who were admitted to speech therapy units within a rehabilitation hospital from March 2009 to July 2013. Patients were excluded if: 1) they were not classified into a specific aphasia type, 2) onset was over a year prior to assessments, or 3) language disturbances occurred following conditions that were not related to stroke, such as traumatic brain injury, neurodegenerative disease, or brain tumors. Patients were categorized into 3 aphasia-cluster groups based on aphasia severity. This study was approved by the Institutional Review Boards at Kangwon National University Hospital including the retrospective review of the patients' medical records (IRB No. 2013-08-007-001).

Measurements

All patients were assessed longitudinally for aphasia and cognition at immediately after admission and at 3 months following admission. They were assessed for aphasia using a validated Korean version of the Western Aphasia Battery (K-WAB) [18]. Two trained speech-language pathologists (SLPs) administered the K-WAB with the same evaluation protocol. The K-WAB consists of 4 domains: fluency (range: 0-20), comprehension (0-200), repetition (0-100), and naming (0-100). For determin-

ing the severity of aphasia, the AQ% (aphasia quotient %; range, 0–100) was calculated using the following formula: (fluency score+[comprehension score/20]+[repetition score/10]+[naming score/10]) \times 2 [19]. Scores in these domains were used for the classification of aphasia subtypes according to Kertesz's method [20].

Cognition among patients was assessed using the MMSE-K [16]. The MMSE-K (total score range, 0–30) for the assessment of cognitive performance was administered by 2 trained occupational therapists with the same evaluation protocol. The battery includes 6 cognitive domains: orientation (range, 0–10), memory registration (0–3), concentration and calculation (0–5), memory recall (0–3), language function (0–7), and comprehension and judgment (0–2) [21,22]. Compared to the MMSE, the MMSE-K includes 'comprehension and judgment' as additional subscores instead of being included under 'language function' as in the original version of MMSE [23].

We also collected descriptive information regarding patients' age, sex, duration of formal education (years), dominant hand (left, right, or both), post-onset days, etiology of stroke (infarction or hemorrhage), and existing brain lesions. Hand dominance was determined by examining the hand that patients typically used for writing, feeding, throwing, using scissors, and cutting while using knives. Left- versus right-handedness was indicated by a preference for a particular hand in >3 of the 5 items modified from the Edinburgh Handedness Inventory [24]. Lesions resulting from strokes were identified after reviewing patients' brain computed tomography (CT) or magnetic resonance imaging (MRI) scan reports.

Statistics

Statistical analyses were performed using SPSS for Windows ver. 20.0 (IBM, Armonk, NY, USA). First, to categorize patients by aphasia severity, two-step cluster analysis (pre-clustering into the many small sub-clusters and then clustering these sub-clusters into the desired number of clusters) was conducted using AQ% scores and Schwarz's Bayesian criteria. This method automatically selects the number of clusters [25]. Descriptive statistics were obtained for demographic variables and measurements according to cluster classification. Second, we compared scores of the K-WAB and MMSE-K at baseline and at 3 months following admission by conducting paired t-tests. The mean differences between the 2 time-point scores

were obtained. Third, Pearson correlation coefficients were calculated to evaluate the association between differences of subscores of the K-WAB and MMSE-K. Comparisons between Pearson correlation coefficients were performed using an on-line calculator for the differences between 2 independent correlation coefficients (<http://www.quantpsy.org/corrtest/corrtest.htm>) [26]: first, each correlation coefficient is converted into a z-score using Fisher r-to-z transformation, then making use of the sample size employed to obtain each coefficient, these z-scores are compared using formula 2.8.5 from Cohen et al. [27]. By convention, z-scores >|1.96| were considered significant for two-tailed tests. Data were presented as mean \pm standard deviation.

RESULTS

The medical charts of 111 post-stroke patients (65 men and 46 women; average age 69.6 \pm 10.0 years; 124.6 \pm 80.6 days post-onset) were reviewed retrospectively. All patients were right-handed and reported left-side brain lesions. After cluster analysis based on AQ%, we obtained the 3 groups of aphasia cluster: group I—anomic (n=9), conduction (n=1), mixed transcortical (n=4), transcortical motor (n=4), transcortical sensory (n=1), Wernicke (n=9); group II, Broca's aphasia (n=31); and group III, global aphasia (n=52) in terms of aphasia type. One-way ANOVA showed greater mean age of group III, as compared to group II (71.8 \pm 10.1 versus 65.9 \pm 9.5; p=0.02 in a Tukey post-hoc test). Education duration and post-onset days were not significantly different. Ischemic stroke was more frequent than hemorrhage stroke in all groups ($\chi^2=6.3$, df=2, p=0.04), while neither categorical age (<65 vs. \geq 65 years), post-onset duration (<6 months vs. 6–12 months), nor sex were statistically different between groups. Cortical brain lesions were more frequent than subcortical lesions in all aphasia-cluster groups ($\chi^2=8.2$, df=2, p=0.02) (Table 1).

Table 2 showed the differences in K-WAB and MMSE-K between the initial and follow-up assessments. All subscales of K-WAB were significantly improved during follow-up assessments in all aphasia cluster groups (p<0.05 or p<0.01). For the MMSE-K, only the scores of orientation, language function, and total score were significantly improved in all groups (p<0.01). Concentration and calculation and comprehension and judgment scores were

Table 1. Baseline characteristics according to the aphasia cluster

Variable	Group I (n=28)	Group II (n=31)	Group III (n=52)	Overall (n=111)
Age (yr) ^{a)}	69.3±9.7	65.9±9.5	71.8±10.1	69.6±10.0
<65	6 (5.4)	13 (11.7)	12 (10.8)	31 (27.9)
≥65	22 (19.8)	18 (16.2)	40 (36.0)	80 (72.1)
Sex				
Men	16 (14.4)	19 (17.1)	30 (27.0)	65 (58.6)
Women	12 (10.8)	12 (10.8)	22 (19.8)	46 (41.4)
Educational duration (yr)	10.5±4.4	8.9±6.1	8.8±5.1	9.3±5.2
Handedness, all right	28 (25.2)	31 (27.9)	52 (46.8)	111 (100)
Post-onset days	120.6±87.6	116.6±78.9	131.5±78.7	124.6±80.6
<6 mo	22 (19.8)	28 (25.2)	37 (33.3)	87 (78.4)
6–12 mo	6 (5.4)	3 (2.7)	15 (13.5)	24 (21.6)
Type of stroke ^{b)}				
Infarction	17 (15.3)	19 (17.1)	43 (38.7)	79 (71.2)
Hemorrhage	11 (9.9)	12 (10.8)	9 (8.1)	32 (28.8)
Brain lesion, all left side ^{c)}				
Cortical lesion	18 (16.2)	23 (20.7)	47 (42.3)	88 (79.3)
MCA territory	15 (13.5)	20 (18.0)	44 (39.6)	79 (71.2)
ACA territory	0 (0.0)	1 (0.9)	0 (0.0)	1 (0.9)
MCA+ACA territory	3 (2.7)	2 (1.8)	3 (2.7)	8 (7.2)
Subcortical lesion	10 (9.0)	8 (7.2)	5 (4.5)	23 (20.7)
Basal ganglia	8 (7.2)	6 (5.4)	4 (3.6)	18 (16.2)
Thalamus	1 (0.9)	1 (0.9)	0 (0.0)	2 (1.8)
Basal ganglia+thalamus	1 (0.9)	1 (0.9)	1 (0.9)	3 (2.7)
Discharge destination				
Home	13 (11.7)	13 (11.7)	10 (9.0)	36 (32.4)
Other facility	15 (13.5)	18 (16.2)	42 (37.8)	75 (67.6)
Aphasia cluster	Anomic (9), conduction (1), mixed transcortical (4), transcortical motor (4), transcortical sensory (1), Wernicke (9)	Broca (31)	Global (52)	
Functional level ^{d)}				
BBT (initial)	23.9±17.5	26.4±15.9	13.3±15.4	19.5±17.0
BBT (follow-up)	34.8±16.0	34.8±17.2	18.9±17.5	27.4±18.6
K-MBI (initial)	43.0±23.4	49.3±23.5	26.7±24.6	37.1±25.8
K-MBI (follow-up)	56.2±23.0	59.0±20.0	36.6±28.4	47.7±27.0

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

n, sample size; MCA, middle cerebral artery; ACA, anterior cerebral artery; BBT, Berg Balance Test; K-MBI, Korean version of Modified Barthel Index.

^{a)}p=0.02 between group II and III by one-way ANOVA followed by Tukey post-hoc test. Educational duration and post-onset days were not significantly different among the groups.

^{b)}p=0.04 by chi-square analysis ($\chi^2=6.3$). Categorical age (<65 vs. ≥65 years) and post-onset duration (<6 mo vs. 6–12 mo) and sex did not show statistical significances.

^{c)}p=0.02 by chi-square analysis ($\chi^2=8.2$) between aphasia clusters and brain lesions (cortical vs. subcortical lesion).

^{d)}Group III showed significantly low functional level, as compared to group I or II by one-way ANOVA followed by Tukey post-hoc test (p<0.05, p<0.01 or p<0.001).

Table 2. Differences in K-WAB and MMSE-K between the initial and follow-up assessments

Variable	Group I		Group II		Group III		Overall					
	Initial	Follow-up	Initial	Follow-up	Initial	Follow-up	Initial	Follow-up				
K-WAB												
Fluency (0-20)	10.6±4.3	12.3±4.4	1.5±1.7**	5.9±2.9	7.7±3.5	2.2±1.6**	1.9±2.0	3.1±2.3	1.4±1.7**	5.2±4.6	6.7±5.0	1.6±1.7**
Comprehension (0-200)	111.5±53.8	133.6±51.7	20.6±19.5**	107.2±29.5	135±31.6	28.7±18**	31.4±21.2	52.2±33.8	15.3±51.6**	72.8±51.8	95.9±56.1	23.1±21.2**
Repetition (0-100)	63.8±31.2	69.6±31.1	7.5±10.2**	26.5±25.4	41.1±29.7	8.3±10.9**	4.1±6.1	10.3±13.4	9.1±15.7**	25.4±32.0	33.9±34.1	8.5±13.1**
Naming (0-100)	42.4±29.1	54.2±29.9	8.4±9.4**	25.9±20.5	37.9±22.9	9.6±11.9**	3.1±4.7	8.8±9	9.0±11.8**	19.4±24.6	28.4±27.8	9.0±11.2**
AQ%	43.4±24	53.5±27.6	7.3±8.9**	24.5±12.9	35.4±18.2	8.8±7.6**	5.9±5.1	10.6±7.8	7.4±8.7**	20.6±20.9	35.5±26.4	7.8±8.4**
MMSE-K												
Orientation (0-10)	5.1±3.3	6.8±3.3	1.4±1.7**	5.8±2.5	7.1±2.6	1.5±2.5**	2.4±2.9	3.7±3.2	1.3±2.2**	4.0±3.3	5.4±3.4	1.4±2.1**
Memory registration (0-3)	2.4±1.2	2.6±1.0	0.1±0.9	2.3±1.1	2.6±0.9	0.6±1.2	1.0±1.3	1.4±1.4	0.2±0.9	1.8±1.4	2.0±1.3	0.3±1.0**
Concentration and calculation (0-5)	0.7±1.4	1.8±1.9	0.6±1.6**	1.1±1.8	1.5±1.8	0.6±1.8	0.3±1.0	0.4±1.2	0.3±1.1	0.6±1.4	1.1±1.7	0.4±1.5**
Memory recall (0-3) ^{a)}	0.8±1.0	1.1±1.2	-0.1±1.0	1.1±1.2	1.3±1.2	0.6±1.2	0.3±0.8	0.6±0.9	0.2±0.9	0.7±1.0	0.9±1.1	0.2±1.0*
Language function (0-7)	4.3±2.1	5.2±2.1	0.6±1.2**	4.3±1.9	5.2±1.6	0.9±1.8**	1.3±1.4	1.9±1.9	0.8±1.4**	2.9±2.3	3.7±2.5	0.8±1.5**
Comprehension and judgment (0-2)	0.8±0.7	1.2±0.8	0.1±0.8**	1.0±0.7	1.3±0.6	0.2±0.6	0.4±0.6	0.4±0.7	0.3±0.6	0.7±0.7	0.9±0.8	0.2±0.7**
Total score (0-30)	14.1±7.6	18.6±8.8	2.6±3.9**	15.6±6.4	18.9±6.1	5.0±4.9**	5.7±6.2	8.8±7.8	3.0±4.4**	10.6±8.1	14.1±9.1	3.5±4.5**

Values are presented as mean±standard deviation

K-WAB, Korean version of Western Aphasia Battery; MMSE-K, Korean version of Mini-Mental Status Examination; AQ%, aphasia quotient %; Δ, changes of K-WAB and MMSE-K subscales between initial and follow-up assessments.

^{a)}p=0.02 between group I and II by one-way ANOVA followed by Tukey post-hoc test.

*p<0.05 or **p<0.01 for the difference between initial and follow-up assessments by paired t-test.

Table 3. Pearson correlation coefficients between differences of K-WAB and MMSE-K, and z-scores showing the differences between two independent correlation coefficients

	Pearson coefficient				z-score		
	Group I	Group II	Group III	Overall	I vs. II	I vs. III	II vs. III
Δ Fluency X							
Δ Orientation	-0.29	0.24	0.28*	0.15	-1.96*	-2.39*	-0.20
Δ Memory registration	-0.02	0.37*	0.14	0.22*	1.50	-0.67	1.04
Δ Concentration and calculation	0.32	0.15	0.28*	0.25**	0.69	0.22	-0.57
Δ Memory recall	-0.10	0.15	0.03	0.07	-0.91	-0.52	0.52
Δ Language function	0.07	0.13	0.31*	0.21*	-0.21	-0.99	-0.79
Δ Comprehension and judgment	0.21	0.43*	0.10	0.20*	-0.88	0.47	1.51
Δ Total score	0.05	0.39*	0.36*	0.32**	-1.33	-1.35	0.15
Δ Comprehension X							
Δ Orientation	0.14	0.25	0.11	0.26**	-0.40	0.13	0.59
Δ Memory registration	-0.01	0.30	0.23	0.32**	-1.18	-1.00	0.34
Δ Concentration and calculation	-0.03	0.01	0.17	0.04	-0.17	-0.85	-0.69
Δ Memory recall	-0.07	0.18	0.20	0.11	-0.92	-1.08	-0.06
Δ Language function	0.24	0.34	0.26	0.36**	-0.41	-0.09	0.38
Δ Comprehension and judgment	-0.05	0.36*	0.12	0.14	-1.54	-0.67	1.09
Δ Total score	0.09	0.49**	0.29*	0.40**	-1.60	-0.83	1.00
Δ Repetition X							
Δ Orientation	-0.23	0.11	0.16	0.09	-1.23	-1.62	-0.25
Δ Memory registration	0.11	0.27	0.15	0.17	-0.63	-0.19	0.55
Δ Concentration and calculation	0.10	0.08	0.20	0.12	0.07	-0.42	-0.52
Δ Memory recall	-0.05	0.01	0.16	0.07	-0.21	-0.84	-0.62
Δ Language function	0.27	0.14	0.26	0.22*	0.48	0.03	-0.53
Δ Comprehension and judgment	0.35	0.23	-0.01	0.13	0.47	1.54	1.05
Δ Total score	0.11	0.16	0.28*	0.21*	-0.20	-0.73	-0.52
Δ Naming X							
Δ Orientation	0.25	0.25	0.32*	0.29**	-0.01	-0.32	-0.32
Δ Memory registration	0.07	0.34	0.26	0.25**	-1.02	-0.82	0.34
Δ Concentration and calculation	0.46*	0.17	0.35*	0.29**	1.20	0.56	-0.81
Δ Memory recall	-0.16	0.03	0.05	0.01	-0.71	-0.88	-0.09
Δ Language function	0.48**	0.14	0.38**	0.31**	1.39	0.52	-1.07
Δ Comprehension and judgment	0.23	0.31	0.01	0.14	-0.34	0.88	1.30
Δ Total score	0.47*	0.27	0.44**	0.39**	0.85	0.16	-0.82
Δ AQ% X							
Δ Orientation	-0.16	0.11	0.33*	0.16	-0.99	-2.04*	-0.97
Δ Memory registration	0.00	0.27	0.17	0.17	-1.00	-0.70	0.44
Δ Concentration and calculation	0.36	0.32	0.46**	0.37**	0.13	-0.52	-0.69
Δ Memory recall	0.04	0.46**	0.03	0.17	-1.66	0.03	1.96
Δ Language function	0.28	0.06	0.36**	0.25**	0.81	-0.39	-1.34
Δ Comprehension and judgment	0.27	0.56**	0.06	0.23*	-1.27	0.91	2.42*
Δ Total score	0.23	0.39*	0.45**	0.38**	-0.62	-1.01	-0.32

K-WAB, Korean version of Western Aphasia Battery; MMSE-K, Korean version of Mini-Mental Status Examination; Δ, changes of K-WAB and MMSE-K subscales between initial and follow-up assessments; X, pairs between each Δ of K-WAB and MMSE-K subscales.

* $p < 0.05$ or ** $p < 0.01$.

only improved among patients with mild-aphasia (group I; $p < 0.01$). A one-way ANOVA followed by Tukey post-hoc tests showed that the difference between initial and follow-up assessments of memory recall in group II was greater than group I ($p = 0.02$).

Table 3 showed the Pearson correlation coefficients between differences in K-WAB and MMSE-K, and z-scores showing the differences between 2 independent correlation coefficients. For group I, there were no significant associations between changes (Δ) of K-WAB and MMSE-K subscales except Δ naming and both Δ concentration and calculation ($p < 0.05$) and Δ comprehension and judgment ($p < 0.01$). For group II, Δ comprehension and judgment was related to Δ fluency ($p < 0.05$), Δ comprehension ($p < 0.05$), and Δ AQ% ($p < 0.01$). For group III, the Δ fluency and Δ naming subscales and Δ AQ% showed significant correlations with Δ orientation, Δ concentration and calculation, and Δ language function ($p < 0.05$ or $p < 0.01$). The absolute values of z-scores between group I and III on Δ orientation of the MMSE-K and Δ fluency and Δ AQ% of the K-WAB were > 1.96 with negative values reflecting more significant correlations in group III. The correlations between Δ orientation and Δ fluency, and between Δ AQ% and Δ comprehension and judgment of group II were greater than those of groups I (z-score = -1.96) and III (z-score = 2.42).

DISCUSSION

Stroke is an important cause of functional disability in language, cognition, and physical performance [28]. Language is a part of cognitive processing and is related to other non-linguistic cognitive domains. In the relationship between non-linguistic cognition and language, there is possibly a substantial cognitive contribution to language processing. Impaired syntactic processing is associated with impairments to corresponding non-linguistic cognitive sequential tasks [4,29]. Language processing should be considered alongside cognitive functions, because language processing requires a sequence of receptive stages of dynamic word and phrase recognition and expressive stages of syntactic and semantic structures [30].

Among the post-stroke patients, it is impossible to clarify the categories of language function and other cognitive domains, due to the overlap between language and cog-

nitive function. The limited cognitive domains evaluated by non-linguistic neuropsychological tests have shown only weak associations between cognition and language function [13]. Moreover, the difficulty of the neuropsychological tests previously used has prohibited active cognitive assessments for aphasic patients.

MMSE-K has been widely used to assess cognitive functioning. A comprehensive review of the MMSE showed that it can be used as a brief screening test to quantitatively assesses the severity of cognitive impairment and record cognitive changes over time [31]. Moreover, each subscale is can be used to assess an independent cognitive domain [32,33]. Thus, in this study we aimed to identify the association between cognition and language function using the easy to adopt MMSE-K, which is regularly used in clinical and research settings. We used the verbal skill assessments of the MMSE-K to indicate language function [34].

Language function outcomes are predicted by initial aphasia severity and other functional outcomes in acute stroke patients [35]; thus, considering the severity of aphasia helps to improve accuracy of determining the association between cognition and language function. We categorized patients into 3 aphasia-cluster groups based on aphasia severity, and compared the results from each group. There were no significant differences in demographic data except age among the 3 groups. Severely impaired aphasia (group III) included global aphasia and moderately impaired aphasia (group II) included Broca's aphasia. Because AQ% is mainly dependent on fluency score, associations between fluency scores and AQ% scores might be expected. In this study, all subscores of K-WAB were also proportional to the AQ% of the aphasia-cluster groups. Significant improvements across all subscales of K-WAB were observed within each group, but there were no significant differences between the aphasia-cluster groups. Subacute post-stroke aphasic patients (mean post-onset days, 124.6 ± 80.6 in this study) did not show a correlation between initial aphasia severity and language functional outcome.

In terms of recovery of MMSE-K, the orientation, language function, and total scores improved in each aphasia-cluster group, reflecting that these domains of the MMSE might be explanatory factors for aphasia severity. These results were supported by the fact that orientation is an indicator of general intellectual functions such as

speech, memory, and attention [36]; in addition, language function of the MMSE-K shares the same cognitive domain as the K-WAB. Moreover, the results of comparisons between correlation coefficients showed that the association of improvement in orientation with that of fluency (group II and III), and improvement in orientation with that of AQ% (group II) were superior to group I. Thus, recovery of orientation may contribute to language function in post-stroke patients.

In this study, Pearson correlation coefficients and their comparisons were used to show the definitive association between cognition and language function. In the mildly impaired (group I), only improvement in the naming scale of the K-WAB was related to improvements in cognitive domains such as concentration and calculation, language function, and total score of the MMSE-K. In other aspects, because group I included anomic aphasia, it may reflect the recovery of naming in these patients. Next, in the moderately impaired (group II), improvements in fluency, comprehension, and AQ% were related to improvements in several cognitive domains such as comprehension and judgment and total score. Additionally, these improvements of comprehension and judgment were also more significantly associated with improvement of AQ% in group II, as compared to group III, reflecting the importance of comprehension and judgment in severity of Broca's aphasia, as compared to global aphasia. Finally in the severely impaired (group III), improvements in all subscales of K-WAB showed associations with improvements in more cognitive domains of MMSE-K, as compared to group II. These results indicated that for more severe aphasic conditions, the associations between language function and cognition are stronger.

Besides the evaluated cognitive domains of the MMSE-K, there are other cognitive and psychological domains related to language function [6]. For instance, a close relationship may exist between language function and visuospatial perception in post-stroke patients [5], which is not considered in the MMSE-K. Thus, other easy to adopt cognitive tests might be considered to show whether other cognitive influences have a significant effect on language function. Moreover, other factors related to language or cognitive functions such as post-stroke depression [37], medications [38,39] or attendance at language or cognitive rehabilitation programs were not considered in this study; thus, further multidimensional evaluation

of post-stroke aphasia patients is required. Additionally, group I showed some inconsistent negative correlations, likely due to inclusion of several kinds of mild aphasia types. However, there were no statistical significances in these values.

This study was the first attempt to show the associations between cognition and language function in subacute post-stroke patients using MMSE-K. The results provided some explanation for the associations. More severely impaired aphasia patients showed a stronger association with cognitive function and recovery of orientation was related to recovery of language function. The MMSE-K can be used as an explanatory tool for predicting severity and recovery of language function in subacute post-stroke patients.

CONFLICT OF INTEREST

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

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REFERENCES

1. Wagle J, Farner L, Flekkoy K, Bruun Wyller T, Sandvik L, Fure B, et al. Early post-stroke cognition in stroke rehabilitation patients predicts functional outcome at 13 months. *Dement Geriatr Cogn Disord* 2011;31:379-87.
2. Sinanovic O, Mrkonjic Z, Zukic S, Vidovic M, Imamovic K. Post-stroke language disorders. *Acta Clin Croat* 2011;50:79-94.
3. Park JH, Kim BJ, Bae HJ, Lee J, Lee J, Han MK, et al. Impact of post-stroke cognitive impairment with no dementia on health-related quality of life. *J Stroke* 2013;15:49-56.
4. El Hachoui H, Visch-Brink EG, Lingsma HF, van de Sandt-Koenderman MW, Dippel DW, Koudstaal PJ, et al. Nonlinguistic cognitive impairment in poststroke aphasia: a prospective study. *Neurorehabil Neural Repair* 2014;28:273-81.
5. Yu ZZ, Jiang SJ, Bi S, Li J, Lei D, Sun LL. Relationship

- between linguistic functions and cognitive functions in a clinical study of Chinese patients with post-stroke aphasia. *Chin Med J (Engl)* 2013;126:1252-6.
6. Lee B, Pyun SB. Characteristics of cognitive impairment in patients with post-stroke aphasia. *Ann Rehabil Med* 2014;38:759-65.
 7. Kwon JY, Kim JS, Park SW, Jang SJ, Kim BS. Influence of aphasia on the cognitive screening test in stroke patients with unilateral cerebral hemispheric lesion. *J Korean Acad Rehabil Med* 2002;26:9-13.
 8. Rice ML. Contemporary accounts of the cognition/language relationship: implications for speech-language clinicians. *J Speech Hear Disord* 1983;48:347-59.
 9. Tatemichi TK, Desmond DW, Stern Y, Paik M, Sano M, Bagiella E. Cognitive impairment after stroke: frequency, patterns, and relationship to functional abilities. *J Neurol Neurosurg Psychiatry* 1994;57:202-7.
 10. Katz N, Itzkovich M, Averbuch S, Elazar B. Loewenstein Occupational Therapy Cognitive Assessment (LOTCA) battery for brain-injured patients: reliability and validity. *Am J Occup Ther* 1989;43:184-92.
 11. Pedersen PM, Jorgensen HS, Nakayama H, Raaschou HO, Olsen TS. Aphasia in acute stroke: incidence, determinants, and recovery. *Ann Neurol* 1995;38:659-66.
 12. Lazar RM, Minzer B, Antoniello D, Festa JR, Krakauer JW, Marshall RS. Improvement in aphasia scores after stroke is well predicted by initial severity. *Stroke* 2010;41:1485-8.
 13. Raven J. Raven progressive matrices. In: McCallum RS, editor. *Handbook of nonverbal assessment*. New York: Kluwer Academic/Plenum Publishers; 2003. p. 223-37.
 14. Helm-Estabrooks N. Cognition and aphasia: a discussion and a study. *J Commun Disord* 2002;35:171-86.
 15. Kwon YC, Park JH. Korean version of Mini-Mental State Examination (MMSE-K). Part I: development of the test for the elderly. *J Korean Neuropsychiatr Assoc* 1989;28:125-35.
 16. Park JH, Kwon YC. Standardization of Korean version of the Mini-Mental State Examination (MMSE-K) for use in the elderly. Part II: diagnostic validity. *J Korean Neuropsychiatr Assoc* 1989;28:508-13.
 17. Guerrero-Berroa E, Luo X, Schmeidler J, Rapp MA, Dahlman K, Grossman HT, et al. The MMSE orientation for time domain is a strong predictor of subsequent cognitive decline in the elderly. *Int J Geriatr Psychiatry* 2009;24:1429-37.
 18. Kim H, Na DL. *Paradise-Korean version of the Western Aphasia Battery*. Seoul: Paradise Welfare Foundation; 2001.
 19. Kertesz A, Poole E. The aphasia quotient: the taxonomic approach to measurement of aphasic disability. *Can J Neurol Sci* 1974;1:7-16.
 20. Kertesz A. *Aphasia and associated disorders: taxonomy, localization, and recovery*. New York: Grune & Stratton; 1979.
 21. Katz N, Elazar B, Itzkovich M. Construct validity of a geriatric version of the Loewenstein Occupational Therapy Cognitive Assessment (LOTCA) battery. *Phys Occup Ther Geriatr* 1995;13:31-46.
 22. Katz N, Hartman-Maeir A, Ring H, Soroker N. Relationships of cognitive performance and daily function of clients following right hemisphere stroke: predictive and ecological validity of the LOTCA battery. *OTJR (Thorofare N J)* 2000;20:3-17.
 23. Folstein ME, Folstein SE, McHugh PR. "Mini-mental state": a practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 1975;12:189-98.
 24. Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia* 1971;9:97-113.
 25. Martinez IN, Moran JM, Pena FJ. Two-step cluster procedure after principal component analysis identifies sperm subpopulations in canine ejaculates and its relation to cryoresistance. *J Androl* 2006;27:596-603.
 26. Preacher KJ. Calculation for the test of the difference between two independent correlation coefficients [Internet]. [place unknown: publisher unknown]; 2002 [cited 2016 Jan 15]. Available from: <http://www.quantpsy.org/corrtest/corrtest.htm>.
 27. Cohen J, Cohen P, West SG, Aiken LS. *Applied multiple regression/correlation analysis for the behavioral sciences*. 3rd ed. Hoboken: Taylor and Francis; 2013.
 28. Kalaria RN, Ballard C. Stroke and cognition. *Curr Atheroscler Rep* 2001;3:334-9.
 29. Dominey PF, Hoen M, Blanc JM, Lelekov-Boissard T. Neurological basis of language and sequential cognition: evidence from simulation, aphasia, and ERP studies. *Brain Lang* 2003;86:207-25.
 30. Massaro DW. *Understanding language: an informa-*

- tion-processing analysis of speech perception, reading, and psycholinguistics. New York: Academic Press; 1975.
31. Tombaugh TN, McIntyre NJ. The mini-mental state examination: a comprehensive review. *J Am Geriatr Soc* 1992;40:922-35.
 32. Schultz-Larsen K, Kreiner S, Lomholt RK. Mini-Mental Status Examination: mixed Rasch model item analysis derived two different cognitive dimensions of the MMSE. *J Clin Epidemiol* 2007;60:268-79.
 33. Lee HJ, Choi HY, Yun KW, Kim YC, Lim WJ, Kim JH, et al. Association between Obesity Indices and MMSE-K in elderly. *J Korean Neuropsychiatr Assoc* 2013;52:447-53.
 34. Feher EP, Mahurin RK, Doody RS, Cooke N, Sims J, Pirozzolo FJ. Establishing the limits of the Mini-Mental State. Examination of 'subtests'. *Arch Neurol* 1992; 49:87-92.
 35. Pedersen PM, Vinter K, Olsen TS. Aphasia after stroke: type, severity and prognosis: the Copenhagen aphasia study. *Cerebrovasc Dis* 2004;17:35-43.
 36. Pedersen PM, Jorgensen HS, Nakayama H, Raaschou HO, Olsen TS. Orientation in the acute and chronic stroke patient: impact on ADL and social activities. The Copenhagen Stroke Study. *Arch Phys Med Rehabil* 1996;77:336-9.
 37. Sinyor D, Amato P, Kaloupek DG, Becker R, Goldenberg M, Coopersmith H. Post-stroke depression: relationships to functional impairment, coping strategies, and rehabilitation outcome. *Stroke* 1986;17:1102-7.
 38. Berthier ML, Green C, Higuera C, Fernandez I, Hinojosa J, Martin MC. A randomized, placebo-controlled study of donepezil in poststroke aphasia. *Neurology* 2006;67:1687-9.
 39. Wong IC, Lhatoo SD. Adverse reactions to new anti-convulsant drugs. *Drug Saf* 2000;23:35-56.