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Original Article

Normative Data for the Korean Version of Addenbrooke's Cognitive Examination

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SUMMARY

Background: The Addenbrooke's Cognitive Examination-Revised (ACE-R) scale is used to assess cognitive impairment in clinical practice and research. This study obtained normative data associated with demographic characteristics using the Korean version of the ACE-R (K-ACER).
Methods: The K-ACER was administered to a normative study group comprising 722 healthy middle-aged and older community-dwelling adults representative of the age and education level distribution within the Korean population. The obtained data were analyzed with respect to demographic variables, including age, sex, and education levels.
Results: The mean (standard deviation) age in the overall study population and proportion of male participants (n = 329) were 60.3 ± 8.1 years and 45.6%, respectively. The mean K-ACER score was 80.7 ± 13.2 points. Older age and a lower educational level were associated with lower K-ACER scores. Subdivided percentile norms were calculated in the sub-analyses after age and education level stratification, which significantly affected K-ACER scores. Based on these findings, we determined normative data according to age and educational level.
Conclusions: Used with the detailed normative data we obtained, the K-ACER is a reliable, standardized instrument for screening and follow-up cognitive examinations.

1. Introduction

With a rapidly increasing global incidence due to population aging, dementia has emerged as a national health problem; therefore, early diagnosis and proper management are important factors in mitigating the public health burden of dementia.[1,2] The Mini-Mental State Examination (MMSE) is an easy-to-use, convenient, and widely used instrument to assess cognitive dysfunction.[3] However, the MMSE was found to have a low sensitivity with limitations in detecting early dementia.[4]

A cognition assessment test needs to be comprehensive, sensitive, and convenient to administer to detect early dementia. Addenbrooke's Cognitive Examination (ACE) is a cognitive function screening instrument currently used in several countries, has high reliability and validity. It incorporated the MMSE, but elaborates on memory, language, and visuospatial components, and adds components tests of verbal fluency, and is known to be capable of differentiating Alzheimer's disease from frontotemporal dementia.[5–7]

The ACE was adapted into Malayalam, French, and Spanish,[8,9] and in 2006, Mioshi et al.[7] developed Addenbrooke's Cognitive Examination-revised (ACE-R). Subsequently, the ACE-III was developed to improve upon the weaknesses of the ACE-R and was later adapted for local use, resulting in its widespread application in numerous countries.[10,11] In South Korea, the authors conducted a standardization study in 2009 for the Korean version of the ACE based on the ACE-R (K-ACER). They demonstrated that the K-ACER was a highly reliable and valid instrument useful in the screening for cognitive dysfunction.[12] The internal consistency of the K-ACER was high (Cronbach's alpha = 0.854), and the test-retest and inter-rater reliability were also very good (coefficient = 0.929 and 0.984, respectively). The validity of the K-ACER was high through correlations between K-ACER and Korean version of MMSE ($r = 0.939$, $p < 0.01$) and the Korean version of the Short Blessed Test ($r = -0.871$, $p < 0.01$).[12] However, the study sample included relatively few subjects in the age range of 60–79 years. Other studies in Korea compared patients with cognitive decline and cognitive normal;[13,14] therefore, specific standardized norm criteria could not be established for different age groups.

This study was conducted to investigate middle-aged and elderly male and female participants, without a history of stroke or dementia, capable of undertaking functions of normal daily living in the local community. This study aimed to develop specific standard criteria for the K-ACER while considering demographic characteristics, such as age, sex, and education levels.

2. Materials and methods

2.1. Composition of the K-ACER

A literal, word-for-word translation of the K-ACER was made, with small corrections for cultural and linguistic differences between English and Korean by Guillemin et al.[15] The K-ACER has been described previously in the standardization, cross-sectional study.[12]

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The instrument assesses five cognitive domains: Attention-Orientation (18 points), Memory (26 points), Verbal Fluency (14 points), Language (26 points), and Visuospatial Ability (16 points). The maximum total score for the K-ACER is 100 points, of which 30 points comprise the scores of the MMSE and its components.

2.2. Participants and procedure

The study participants were participants in an early screening program for the prevention of stroke and dementia that was conducted by the Asan-si Center and Wonkwang University Hospital for Prevention of Stroke and Dementia between July 1, 2007 and December 31, 2009. We selected middle-aged and older (50 years over) men and women without a history of stroke or dementia capable of undertaking normal activities of daily living without any complaint of cognitive decline. From the 28,779 persons living in six neighborhoods (*dongs*) in Asan-si, 1,603 persons were selected by systematic random sampling of public administrative residential records. Of these, 594 persons were excluded because they could not be reached by postal mail or telephone, 26 because of a history of stroke or dementia, 76 because they had moved to a different address, 58 because they refused to complete the K-ACER test, and 16 because they died before undergoing the examination. Four hundred and thirteen persons refused to participate in the study-related examinations; the remaining 722 persons were included in this study. All the patients provided written informed consent in accordance with the study protocol approved by the Wonkwang University Hospital ethics committee (approval no. 2016-08-HRE-083). This study was performed according to the Declaration of Helsinki protocols.

Before administering the K-ACER and obtaining participant consent, the purpose of the test was thoroughly explained to the participants. The test was administered by a clinical psychologist or trained research nurse in an examination room on a 1:1 basis (k = 0.984).[12] The examiners were trained in and adhered to the prespecified guidelines and protocols to minimize procedural errors. The time taken to complete the test was approximately 20–25 min. The educational levels were categorized as 0–6, 7–9, or ≥ 10 years and age was categorized as 50–59, 60–69, or ≥ 70 years to develop the standard norm criteria for middle-aged and older Korean adults. The percentile rank was a standard score that was useful for interpreting examination results. Scores below the fifth percentile were likely abnormal and fall below the -1 and -2 standard deviations (SDs) on the normal distribution curve.[12,16]

2.3. Statistical analyses

The statistical analyses were performed on data obtained from the 722 persons who completed the K-ACER. Gender differences were analyzed using an independent *t*-test, and differences based on age and education levels were analyzed using *F* tests. Statistical Package for the Social Sciences (SPSS) 13 for Windows (IBM Corp., Armonk, NY) was used for the statistical analyses, and a two-sided p value < 0.05 was defined as being indicative of statistical significance.

3. Results

3.1. Demographic characteristics

The mean age and educational level among the 722 study participants were 60.3 (SD ± 8.1) and 9.3 (SD ± 4.5) years, respectively. There were 329 male participants (45.6%), with a mean age and educational level of 59.9 (SD ± 8.2) and 11.0 (SD ± 4.1) years, respectively. The mean age and educational level of 393 female participants (54.4%) were 60.6 (SD ± 8.0) and 7.9 (SD ± 4.4) years, respectively. The mean K-ACER score was 80.7 ± 13.2 points for all participants, 84.6 ± 9.6 for men, and 77.4 ± 14.9 for women. The mean K-MMSE score was 26.3 ± 3.5 points for all participants, 27.1 ± 2.6 for men, and 25.6 ± 3.9 for women. Table 1 summarizes the characteristics of the study sample, including age, sex, educational levels, and mean K-ACER and K-MMSE scores.

3.2. Effects of sex, age, and educational level

The individual cognitive domain and total K-ACER scores were compared according to age, sex, and educational levels. With regard to sex-related differences, the cognitive domain and total scores were higher in men than in women. Participants were categorized into three groups of 50–59, 60–69, and ≥ 70 years to investigate the effects of age. The Scheffés post-hoc test after ANOVA test showed that the five cognitive domains and total scores decreased with increasing age (Table 2). Furthermore, the cognitive domain and total scores increased with increasing educational levels (Table 3). Through stepwise multiple regression analysis, education had the most influence on K-ACER, followed by age. But gender was not statistically significant (Table 4).

Table 1
Demographic data and mean (± SD) of the participants from the Korean version of the Addenbrooke's Cognitive Examination-Revised and Korean version of the Mini-Mental State Examination.

Age (years)	Education (years)	N	M:F	Age (years)	Education (years)	K-ACER	K-MMSE
50–59	0–6	78	24:54	55.2 (2.3)	5.1 (2.0)	75.2 (12.4)	24.8 (3.4)
	7–9	84	29:55	53.9 (2.6)	8.8 (0.5)	83.5 (6.7)	27.2 (2.2)
	≥ 10	233	134:99	53.6 (2.8)	13.2 (2.1)	89.4 (5.1)	28.1 (1.6)
	Subtotal	395	187:208	54.0 (2.7)	10.7 (3.7)	85.4 (9.2)	27.3 (2.5)
60–69	0–6	98	28:70	64.5 (3.1)	4.0 (2.5)	70.7 (14.8)	23.9 (4.2)
	7–9	31	16:15	63.5 (3.0)	8.8 (0.4)	79.8 (9.3)	26.5 (2.7)
	≥ 10	72	45:27	64.2 (3.1)	13.3 (2.3)	85.7 (7.4)	27.6 (2.0)
	Subtotal	201	89:112	64.3 (3.1)	8.1 (4.8)	77.5 (13.6)	25.6 (3.7)
≥ 70	0–6	71	18:53	74.2 (4.2)	3.4 (2.6)	63.1 (16.4)	22.5 (4.6)
	7–9	21	8:13	71.7 (2.1)	8.5 (0.6)	76.4 (11.3)	26.0 (2.5)
	≥ 10	34	27:7	73.1 (2.1)	13.4 (2.0)	83.6 (6.5)	27.0 (2.1)
	Subtotal	126	53:73	73.5 (3.6)	7.0 (4.9)	70.8 (16.3)	24.3 (4.3)
Total		722	329:393	60.3 (8.1)	9.3 (4.5)	80.7 (13.2)	26.3 (3.5)

F, female; K-ACER, Korean version of the Addenbrooke's Cognitive Examination-Revised; K-MMSE, Korean version of the Mini-Mental State Examination; M, male; No, numbers of subjects; SD, standard deviation.

Table 2
Age differences of the participants from the Korean version of the Addenbrooke's Cognitive Examination-Revised.

	50–59 years (n = 395)	60–69 years (n = 201)	≥ 70 years (n = 126)	*p* value	Scheffe's comparison
AO	16.7 (1.6)	15.9 (2.2)	15.2 (2.9)	0.000	1 > 2 > 3
Me	22.5 (3.7)	19.9 (4.9)	17.4 (6.0)	0.000	1 > 2 > 3
Vf	9.2 (2.2)	8.0 (2.4)	7.4 (2.8)	0.000	1 > 2 > 3
La	21.9 (3.0)	19.6 (4.1)	17.5 (4.4)	0.000	1 > 2 > 3
Vis	15.1 (1.7)	14.0 (2.8)	13.3 (3.2)	0.000	1 > 2 > 3
Total	85.4 (9.2)	77.5 (13.6)	70.8 (16.3)	0.000	1 > 2 > 3

Values are presented as means ± standard deviations. For Scheffe's comparison, 50–59 years = 1, 60–69 years = 2, ≥ 70 years = 3.
AO, attention–orientation; La, language; Me, memory; Vf, verbal fluency; Vis, visuospatial.

3.3. K-ACER percentile ranks and normal criteria

The percentile ranks for total K-ACER scores were obtained after stratification based on age and educational levels. Table 5 shows the scores for the groups defined by age and educational levels. In the 50–59 years age group, the participants with 0–6, 7–9, and ≥ 10 years of education had mean K-ACER scores of 75.5, 83.5, and 89.4 points and fifth percentile scores of 50, 71, and 80 points, respectively. Among participants in the 60–69 years age group, those with 0–6, 7–9, and ≥ 10 years of education had mean K-ACER scores of 70.7, 79.7, and 85.7 points and fifth percentile scores of 46, 62, and 68 points, respectively. Among participants in the ≥ 70 years age group, those with 0–6, 7–9, and ≥ 10 years of education had mean K-ACER scores of 63.1, 76.4, and 83.6 points and fifth percentile scores of 31, 50, and 73 points, respectively.

4. Discussion

This study aimed to determine the norm values for the K-ACER while accounting for demographic characteristics, such as age and educational levels, in community-dwelling, healthy, middle-aged, and elderly individuals. The findings of our previous study[12] and results of this study have indicated that the K-ACER with more detailed normative data is a useful test instrument for screening cognitive dysfunction. In addition, the ACE-R was proved to have a higher sensitivity and better cross-cultural usage than ACE, although ACE-III has not yet been validated in Korea. Educational levels and age were expected to affect the results of the K-ACER in this study; we found that educational levels had a stronger effect on the outcome than age. Regarding gender differences, although male participants had higher scores than female participants, and as a social characteristic of Korea, the older they get, the lower their education level in females. However, there were no statistically significant differences after adjusting for educational levels and age. This finding was consistent with that of another study.[17]

In general, age and educational levels were known to be associated with cognitive function assessment scores.[4] This study found that age and educational level had a great impact on the test scores. Specifically, older age and a lower educational level were associated with lower scores. In this study, comparisons between men and women showed significant differences in the K-ACER total scores and cognitive subdomain scores, although the stepwise multivariate analysis showed that sex did not influence the K-ACER scores. These results were consistent with several other studies on tests used to screen for cognitive impairment in patients.[12,18] In a study by Kang,[19] among participants with a low educational level (uneducated or ≤ 3 years of education), men had higher performance scores on cognitive function tests than women. However, among participants with ≥ 4 years of education, there was no sex difference, which was similar to the trend noted in this study. Because males have lots of opportunities for social stimulation or informal learning even though low education class, but females are less exposed to these opportunities, there is a difference in the amount of actual learning. Whereas females with at least 7 years of education have enough learning opportunities to achieve basic cognitive abilities. It is presumed that this is why the effect of the gender difference is insignificant. Therefore, based on the results of this study, we developed criteria for the K-ACER percentiles by combining only age and educational levels. In particular, because this study included an even distribution of participants in their 50s, 60s, or 70s, we extracted the percentiles for these age groups.

Although the participants were enrolled in 2009, there may be some differences between these study results and the current population. The salient strength of this study was its use of systematic random sampling to select healthy participants aged ≥ 50 years, which allowed for more precise health criteria to be compiled according to age and educational levels through stratification. Hence, we thought it could reflect cognitive status in the community.

A limitation of this study was that there could have been a selection bias; the participants were recruited from a single-center, cross-sectional, observational study and patients with mild cognitive impairment or dementia were not included. Therefore, a clinical comparison could not be undertaken. Because the purpose of this study is to obtain normative data from health community elderly. Future research will be necessary to include specific clinical groups, such as patients with Alzheimer's disease, vascular dementia, depression, or mild cognitive impairment, and derive diagnostic criteria scores using receiver operating characteristics curves (for sensitivity and specificity).

Table 3
Participant differences based on educational levels from the assessment scores of the Korean version of the Addenbrooke's Cognitive Examination-Revised.

	0–6 years (n = 247)	7–9 years (n = 136)	≥ 10 years (n = 339)	Scheffe's comparison
AO	14.9 (2.7)	16.5 (1.6)	17.0 (1.2)	1 < 2 < 3
Me	17.1 (5.6)	21.5 (3.7)	23.4 (2.5)	1 < 2 < 3
Vf	7.2 (2.6)	8.3 (1.8)	9.7 (1.9)	1 < 2 < 3
La	18.0 (4.5)	20.4 (3.2)	22.3 (2.6)	1 < 2 < 3
Vis	12.9 (3.2)	14.9 (1.6)	15.5 (1.1)	1 < 2 < 3
Total	70.1 (15.3)	81.6 (8.5)	88.0 (6.2)	1 < 2 < 3

Values are presented as means ± standard deviations. *p*-value < 0.001 for all. For Scheffe's comparison, 0–6 years = 1, 7–9 years = 2, and ≥ 10 years = 3.
AO, attention-orientation; La, language; Me, memory; Vf, verbal fluency; Vis, visuospatial.

Table 4
Multiple regression analysis of demographic variables of the Korean version of the Addenbrooke's Cognitive Examination-Revised.

Model	Predictor	R	R^2	Standardized coefficient beta (β)	p value
1	Education	0.710	0.505	0.710	< 0.001
2	Education	0.756	0.572	0.601	< 0.001
	Age			-0.281	< 0.001
3	Education	0.758	0.575	0.576	< 0.001
	Age			-0.289	< 0.001
	Sex			-0.063	0.08

Table 5
Normative data of the participants from the Korean version of the Addenbrooke's Cognitive Examination-Revised, based on age and education levels.

Age	Educational level		AO (18)	Me (26)	Vf (14)	La (26)	Vis (16)	K-ACER (100)	K-MMSE (30)
50–59 years	0–6 years	Mean ± SD	15.6 ± 2.2	19.0 ± 5.1	7.9 ± 2.4	19.5 ± 3.8	13.5 ± 2.9	75.5 ± 12.4	24.8 ± 3.4
		Percentile 05	11	8	4	11	7	50	18
		Percentile 25	14	16	6	17	13	68	23
		Percentile 75	17	23	10	23	15	85	27
		Percentile 95	18	25	12	24	16	91	29
		Percentile 99	18	26	13	25	18	95	30
	7–9 years	Mean ± SD	16.7 ± 1.5	22.0 ± 3.0	8.5 ± 1.9	21.1 ± 2.8	15.2 ± 1.0	83.5 ± 6.7	27.2 ± 2.2
		Percentile 05	14	17	5	16	13	71	24
		Percentile 25	16	20	7	19.5	15	79.5	26
		Percentile 75	18	24	10	23	16	88	29
		Percentile 95	18	26	11	25	16	93	30
		Percentile 99	18	26	12	25	16	96	30
	≥ 10 years	Mean ± SD	17.1 ± 1.1	23.8 ± 2.2	10.0 ± 1.9	22.9 ± 2.1	15.6 ± 0.9	89.4 ± 5.1	28.1 ± 1.6
		Percentile 05	15	19	7	19	14	80	25
		Percentile 25	17	23	9	22	16	87	27
		Percentile 75	18	25	11	24	16	92	29
		Percentile 95	18	26	13	26	16	96	30
		Percentile 99	18	26	14	26	16	98	30
60–69 years	0–6 years	Mean ± SD	15.1 ± 2.6	17.4 ± 5.2	7.2 ± 2.5	18.2 ± 4.5	12.9 ± 3.1	70.7 ± 14.8	23.9 ± 4.2
		Percentile 05	11	6	3	9	5	46	17
		Percentile 25	14	14	5	15	12	63	22
		Percentile 75	17	22	9	21	15	81	27
		Percentile 95	18	24	11	24	16	88	29
		Percentile 99	18	26	12	27	16	94	30
	7–9 years	Mean ± SD	16.4 ± 1.8	21.2 ± 3.9	7.9 ± 1.7	19.7 ± 3.5	14.5 ± 2.1	79.8 ± 9.3	26.6 ± 2.7
		Percentile 05	13	13	6	12	9	62	21
		Percentile 25	15	20	7	19	14	75	25
		Percentile 75	18	24	9	23	16	86	29
		Percentile 95	18	26	11	24	16	92	30
		Percentile 99	18	26	12	25	16	92	30
	≥ 10 years	Mean ± SD	16.8 ± 1.3	22.8 ± 2.6	9.2 ± 1.9	21.6 ± 2.9	15.3 ± 1.7	85.7 ± 7.4	27.6 ± 2.0
		Percentile 05	14	18	6	15	11	68	24
		Percentile 25	16	21	8	20	15	83.5	27
		Percentile 75	18	25	11	23	16	91	29
		Percentile 95	18	26	12	26	16	96	30
		Percentile 99	18	26	13	26	16	97	30
≥ 70 years	0–6 years	Mean ± SD	14.0 ± 3.2	14.7 ± 5.8	6.3 ± 2.8	16.1 ± 4.4	12.0 ± 3.6	63.1 ± 16.4	22.5 ± 4.6
		Percentile 05	8	6	1	9	4	31	13
		Percentile 25	12	10	5	13	10	52	19
		Percentile 75	17	19	8	20	15	76	27
		Percentile 95	18	23	10	22	16	84	28
		Percentile 99	18	25	14	23	16	89	29
	7–9 years	Mean ± SD	16.1 ± 1.8	19.8 ± 5.2	8.2 ± 2.1	18.2 ± 3.4	14.1 ± 2.1	76.4 ± 11.3	26.0 ± 2.5
		Percentile 05	12	8	5	13	11	50	21
		Percentile 25	16	20	7	15	13	72	25
		Percentile 75	17	23	10	21	16	85	28
		Percentile 95	18	25	11	23	16	88	29
		Percentile 99	18	25	11	23	16	88	29
	≥ 10 years	Mean ± SD	17.0 ± 1.2	21.8 ± 3.0	9.3 ± 1.9	20.2 ± 3.7	15.3 ± 0.8	83.6 ± 6.5	27.0 ± 2.1
		Percentile 05	15	17	5	14	14	73	23
		Percentile 25	17	20	8	16	15	78	26
		Percentile 75	18	24	10	23	16	88	29
		Percentile 95	18	26	13	24	16	94	30
		Percentile 99	18	26	13	26	16	94	30

AO, attention-orientation; K-ACER, Korean version of the Addenbrooke's Cognitive Examination-Revised; K-MMSE, Korean version of the Mini-Mental State Examination; La, language; Me, memory; Vf, verbal fluency; Vis, visuospatial.

In conclusion, anyone with appropriate training in a clinical setting or epidemiological research can easily administer the K-ACER. Moreover, this instrument can aid dementia screening in patients with suspected cognitive dysfunction and follow-up monitoring of therapeutic effects. This instrument is considered reliable and suitable for use, giventhe specific normative criteria for the various age groups.

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Data availability statement

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflicts of interest

The authors of this work have no conflicts of interest to disclose.

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