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Original Article

Is the Korean Mini-Mental State Examination (K-MMSE) Useful in Evaluating the Cognitive Function of Brain Injury Patients?: Through Correlation Analysis With Computerized Neurocognitive Test (CNT)

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HIGHLIGHTS

- A significant correlation was noted between the total scores of the Korean Mini-Mental State Examination (K-MMSE) and computerized neurocognitive test (CNT).
- Orientation & attention/calculation components of K-MMSE notably correlated with CNT.
- The K-MMSE is valuable for assessing patients unable to undergo complex testing.

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Is the Korean Mini-Mental State Examination (K-MMSE) Useful in Evaluating the Cognitive Function of Brain Injury Patients?: Through Correlation Analysis With Computerized Neurocognitive Test (CNT)

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ABSTRACT

Patients with brain injury often experience accompanying disabilities that can make it challenging for them to use tools or perform complex tests. Therefore, Korean Mini-Mental State Examination (K-MMSE) is widely used in clinical practice as an alternative to the computerized neurocognitive test (CNT) or Wechsler Adult Intelligence Scale tests to assess cognitive function in these individuals. This study aimed to investigate the correlation between the K-MMSE and CNT in brain injury patients to evaluate the and clinical usefulness of K-MMSE. A total of 120 patients were assessed using both tests, and a significant correlation was observed between the total scores of K-MMSE and CNT. The orientation component of K-MMSE was significantly correlated with CNT components, indicating that individuals who perform well on orientation tasks are likely to have better cognitive abilities overall. While K-MMSE has limitations in evaluating specific cognitive domains, it is a useful tool in clinical practice for evaluating cognitive impairment, especially in patients who have difficulty using more complex cognitive tests.

Keywords: Brain Injury; Cognition; Stroke

INTRODUCTION

Cognitive impairment is a common consequence of stroke, affecting ≤ 35% of the stroke survivors [1]. Moreover, cognitive impairment occurring after brain injury is an important factor that causes severe functional limitations and affects the quality of life of patients with brain injury. Furthermore, severe cognitive impairment decreases the motivation and attention of such patients during rehabilitation programs [2,3]. Additionally, it may limit functional gains and lead to a poor prognosis for rehabilitation. Therefore, an accurate assessment of cognitive function is crucial during the early evaluation of brain injury patients, and this assessment is considered a part of any routine evaluation for successful rehabilitation.

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Conflict of Interest
The authors have no potential conflicts of interest to disclose.

Author Contributions
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Orientation, attention, and memory (including sensory, short-term, and long-term memory) are the components of primary cognitive capacity. Cognition can be broadly defined by neurocognitive functioning (including attention, memory, language functioning, calculation, and visuospatial ability), problem-solving, information-processing, and planning skills. The mini-mental state examination (MMSE) is a widely used screening tool for cognitive abilities in brain injury patients [3,4]. However, despite its good inter-rater reliability and validity, it has several limitations [4]. Notably, many studies have questioned the ability of MMSE to predict cognitive impairment following brain injury owing to the insensitive assessment of complex cognitive functions (such as abstract reasoning and executive functions), visual perception, and construction [5-7].

A rapid development of computer technology has improved the use of computers in various fields. Accordingly, the application of such technology has become an interesting research topic in the field of medicine, including rehabilitation medicine. Numerous cognitive rehabilitation programs have been developed over the past 30 years using computer technology. Moreover, in this field, a computerized program has been used for therapy and assessment of cognition. The computerized neurocognitive test (CNT) is a cognitive test battery that was developed as a routine tool for the clinical assessment of cognitive abilities. This tool has some advantages over traditional cognitive tests used for detecting mild cognitive dysfunction [8,9]. Notably, the reliability, validity, patient acceptability, ability to generate numerous alternative forms, and increased cost-effectiveness of computer assessments are well documented in the relevant literature [10].

MMSE is a widely used tool for assessing cognitive function in brain injury patients who may have difficulty with more complex cognitive function tests due to their disabilities. Therefore, it is important to evaluate the usefulness of the MMSE in comparison to more detailed and comprehensive cognitive function tests, such as the CNT. In this study, we aimed to investigate the correlation between the K-MMSE and the CNT in brain injury patients. By analyzing the relationship between the two tests, we aimed to evaluate the clinical usefulness of the K-MMSE.

MATERIALS AND METHODS

Subject

This retrospective study evaluated patients who were diagnosed with brain injury for the first time via magnetic resonance imaging and computerized tomography and were referred to the Department of Rehabilitation Medicine from 2013 to 2020. The inclusion criteria were 1) diagnosis of brain injury confirmed by magnetic resonance imaging and computerized tomography, 2) cognitive impairment with a K-MMSE score of < 26, and 3) first-time diagnosis of brain injury. The exclusion criteria were 1) being uncooperative or inability to follow instructions, Aphasia patients who were uncooperative or unable to follow instructions were also excluded. 2) visual or hearing impairment, 3) inability to sit on a chair, 4) medical instability, and 5) past history of cognitive impairment. Overall, 120 patients with brain injury were enrolled in this study, and their demographic characteristics are presented in **Table 1**. All patients included in the study had not previously undergone CNT evaluation. This study was approved by the Institutional Review Board (IRB) of Kyungpook National University Hospital (IRB No. 2023-02-019).

Table 1. Demographic data of brain injury patients

Variables	Patients (n = 120)
Sex	
Male	76
Female	44
Age (yr)	55.0 ± 19.0
Post onset duration (days)	85.6 ± 183.4
Type of brain injury	
Hemorrhagic stroke	38
Ischemic stroke	44
Traumatic brain injury	38
MMSE total	19.13 ± 5.91
Orientation time	2.92 ± 1.74
Orientation place	4.07 ± 1.62
Register	2.53 ± 0.67
Recall	0.80 ± 1.00
Attention/calculation	1.74 ± 1.70
Language	4.88 ± 1.35
Visuospatial ability	0.59 ± 0.49
Comprehension/judgement	1.60 ± 0.66
CNT total	421.5 ± 130.7
Verbal memory	112.0 ± 27.2
Visual memory	148.3 ± 31.8
Attention	93.0 ± 26.4
Visuo-motor coordination	45.3 ± 23.2
High cognition	22.9 ± 21.8

Values are presented as mean ± standard deviation,
MMSE, Mini-Mental State Examination; CNT, computerized neurocognitive test.

Instrumentation

CNT

In the present study, CNT (ver. 4.0, Maxmedica, Seoul, Korea) was used to assess cognitive function. CNT (ver. 4.0, Maxmedica) is a test for which several standardization studies have been conducted and validity and reliability analyzes have been performed. It is used as a tool to evaluate cognitive function in clinical practice, and studies have been conducted on its clinical usefulness [11-16]. The results of this test were expressed as percentages. Based on these results, the T-score was calculated. Notably, CNT has five components: verbal memory, visual memory, attention, visuomotor coordination, and high cognition, all of which are included in one computerized program. Further, this test includes 14 subtests that are widely used to evaluate cognitive function and are presented in Appendix 1.

MMSE

MMSE—developed by Folstein et al. [4] in 1975—is a well-known screening tool for cognitive ability. In the present study, all participants were evaluated using the Korean version of MMSE. K-MMSE evaluates a few aspects of cognition and can be easily performed within 5–10 minutes. The maximum score obtained using K-MMSE is 30. Notably, this tool has eight components: orientation time, orientation place, memory register, memory recall, attention/calculation, language, visuospatial ability, and comprehension/judgment.

Inspection process

A trained occupational therapist administered the K-MMSE and CNT. An assessment was completed within 5 days of admission for all patients admitted to the hospital. Both the CNT and K-MMSE tests were performed within 5 days of the patient's admission. Patients who could understand the instructions but were unable to perform the CNT test and K-MMSE test on their own due to functional disability performed the tests with the help of an occupational therapist. In principle, CNT and K-MMSE tests were performed on the same day, but in some cases this was not possible due to lack of time due to other tests. The interval between CNT and K-MMSE tests was no more than 5 days.

Statistical analysis

The SPSS software (ver. 23 for Windows; SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. To confirm the correlation between the components of the two tools used for evaluating cognitive impairment, Pearson's correlation test was used. p values of < 0.05 were considered statistically significant.

RESULTS

A significant correlation was observed in the total scores between K-MMSE and CNT ($r = 0.697$, $p < 0.01$). Looking at the correlation between the components of K-MMSE and those of CNT in **Table 2** and **Fig. 1**, the orientation time of K-MMSE exhibited a high correlation with all CNT components, with the highest being with visuomotor ($r = 0.547$, $p < 0.01$). Orientation place also showed a high correlation with the other CNT components, with the highest being with verbal memory of CNT ($r = 0.485$, $p < 0.01$). The memory register of K-MMSE showed a high correlation with the rest of the components, with the highest being with verbal memory of CNT ($r = 0.307$, $p < 0.01$). Memory recall of K-MMSE showed a high correlation with the other components, with the highest being with high cognition of CNT ($r = 0.459$, $p < 0.01$). Furthermore, attention/calculation of K-MMSE showed a correlation with the other components, with the highest being with high cognition ($r = 0.654$, $p < 0.01$) and visuomotor coordination ($r = 0.502$, $p < 0.01$) of CNT. The language component of K-MMSE was significantly correlated with the visuomotor coordination component of CNT ($r = 0.381$, $p < 0.01$), and visuospatial ability was highly correlated with visuomotor coordination ($r = 0.475$, $p < 0.01$). Moreover, comprehension/judgment of K-MMSE was highly correlated with visuomotor coordination of CNT ($r = 0.293$, $p < 0.01$).

We also investigated the relationship between MMSE component scores and the overall CNT score. Among the seven components, orientation time exhibited a strong correlation with the CNT total score ($r = 0.665$, $p < 0.01$), and orientation place also demonstrated a robust correlation with the CNT total score ($r = 0.547$, $p < 0.01$). Similarly, the attention/calculation component displayed a significant correlation with the CNT total score ($r = 0.604$, $p < 0.01$) (**Table 2** and **Fig. 1**). This pattern persisted even when subjects were categorized based on injury type, aphasia status, age, and MMSE score. **Table 3** and **Fig. 2** presents the findings,

Table 2. Pearson's correlation analysis between the subtests of CNT and K-MMSE in brain injury patients

K-MMSE	CNT					
	Verbal memory	Visual memory	Attention	Visuo-motor coordination	High cognition	CNT total
Orientation time	r = 0.431†	r = 0.595†	r = 0.534†	r = 0.547†	r = 0.540†	r = 0.665†
Orientation place	r = 0.485†	r = 0.421†	r = 0.405†	r = 0.468†	r = 0.419†	r = 0.547†
Register	r = 0.307†	r = 0.197*	r = 0.207*	r = 0.287†	r = 0.230*	r = 0.296†
Recall	r = 0.415†	r = 0.376†	r = 0.356†	r = 0.373†	r = 0.459†	r = 0.422†
Attention/calculation	r = 0.496†	r = 0.391†	r = 0.444†	r = 0.654†	r = 0.502†	r = 0.604†
Language	r = 0.217*	r = 0.250†	r = 0.366†	r = 0.381†	r = 0.281†	r = 0.376†
Visuospatial ability	r = 0.128	r = 0.356†	r = 0.352†	r = 0.475†	r = 0.322†	r = 0.405†
Comprehension judgement	r = 0.152	r = 0.146	r = 0.229*	r = 0.293†	r = 0.225*	r = 0.266†
MMSE total	r = 0.715†	r = 0.688†	r = 0.584†	r = 0.621†	r = 0.651†	r = 0.697†

CNT, computerized neurocognitive test; K- MMSE, Korean Mini-Mental State Examination; r, Pearson's correlation coefficient.
*$p < 0.05$, †$p < 0.01$.

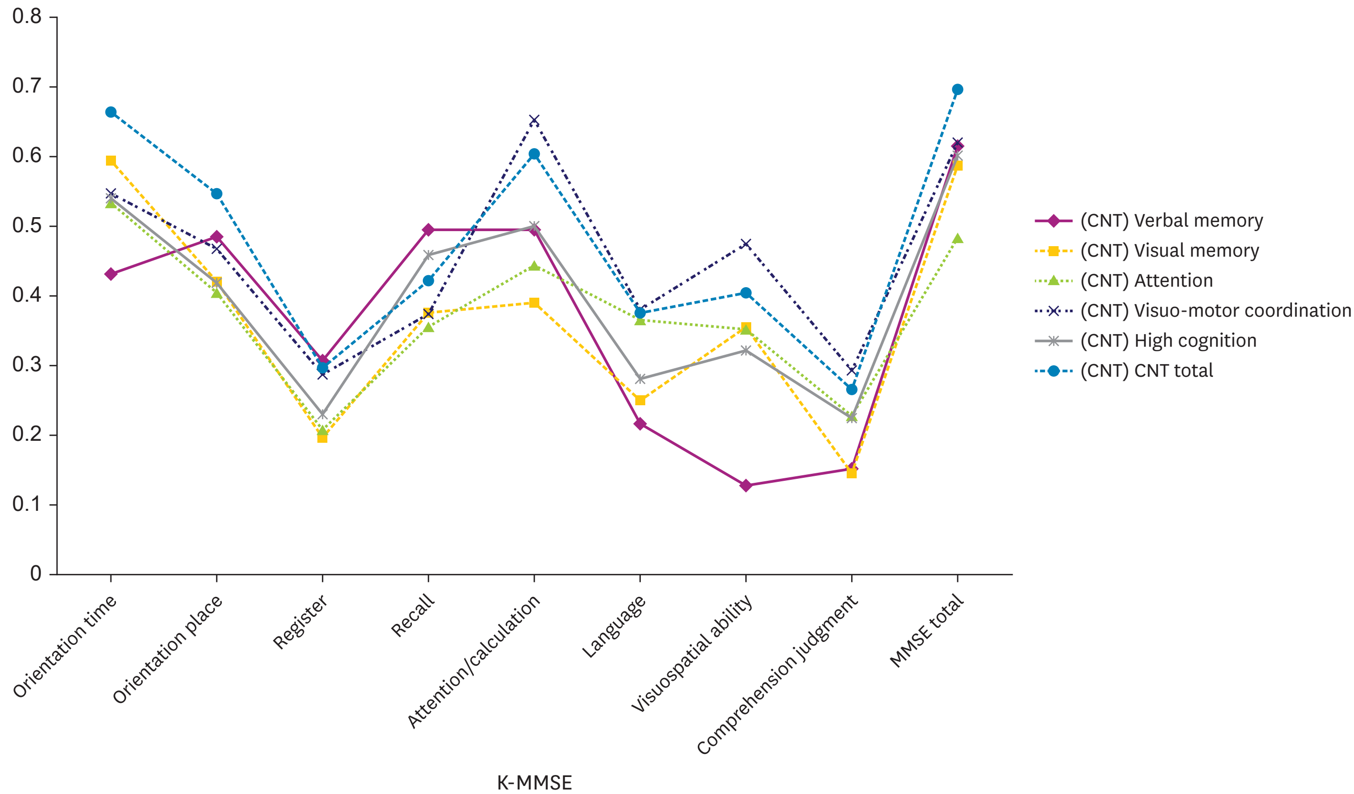

Fig. 1. Table 2 is depicted as a graph. The X-axis represents the Pearson correlation coefficient (r). In the figure, it is evident that the orientation and attention/calculation sections of K-MMSE exhibit a strong correlation with all aspects of CNT and the CNT total score.
K-MMSE, Korean Mini-Mental State Examination; CNT, computerized neurocognitive test.

Table 3. Pearson's correlation analysis between the subtests of CNT and K-MMSE in brain injury patients

K-MMSE	CNT total								
	Injury type			Aphasia		Age		MMSE	
	Infarction (n = 44)	Hemorrhage (n = 38)	TBI (n = 38)	+ (n = 32)	− (n = 88)	> 65 (n = 71)	< 65 (n = 49)	> 20 (n = 63)	< 21 (n = 57)
Orientation time	r = 0.560†	r = 0.635†	r = 0.703†	r = 0.645†	r = 0.666†	r = 0.703†	r = 0.457†	r = 0.492†	r = 0.451†
Orientation place	r = 0.438†	r = 0.473†	r = 0.613†	r = 0.640†	r = 0.524†	r = 0.574†	r = 0.480†	r = 0.462†	r = 0.434†
Register	r = 0.315*	r = 0.352*	r = 0.188	r = 0.595†	r = 0.212*	r = 0.175	r = 0.361*	r = 0.349	r = 0.249
Recall	r = 0.319†	r = 0.433†	r = 0.357†	r = 0.372†	r = 0.382†	r = 0.311†	r = 0.231	r = 0.390*	r = 0.147
Attention/calculation	r = 0.474†	r = 0.660†	r = 0.677†	r = 0.611†	r = 0.591†	r = 0.562†	r = 0.434†	r = 0.448†	r = 0.412†
Language	r = 0.348†	r = 0.329*	r = 0.248	r = 0.520*	r = 0.350†	r = 0.335†	r = 0.390†	r = 0.079	r = 0.187
Visuospatial ability	r = 0.389†	r = 0.362*	r = 0.295	r = 0.302	r = 0.339†	r = 0.419†	r = 0.305*	r = 0.378†	r = 0.239
Comprehension judgement	r = 0.303†	r = 0.331*	r = 0.070	r = 0.331	r = 0.239*	r = 0.164	r = 0.310*	r = 0.087	r = 0.001
K-MMSE total	r = 0.774†	r = 0.600†	r = 0.737†	r = 0.732†	r = 0.773†	r = 0.784†	r = 0.614†	r = 0.625†	r = 0.598†

K-MMSE, Korean Mini-Mental State Examination; CNT, computerized neurocognitive test; MMSE, Mini-Mental State Examination; TBI, traumatic brain injury; r, Pearson's correlation coefficient.
*$p < 0.05$, †$p < 0.01$.

indicating that orientation time, orientation place, and attention/calculation components maintained noteworthy correlations with the CNT total score across various groupings, including brain injury type, aphasia status, age, and MMSE.

DISCUSSION

In this study, we analyzed the correlation between the components of the K-MMSE and the CNT. CNT is known to assess cognitive function more objectively, reliably, and efficiently

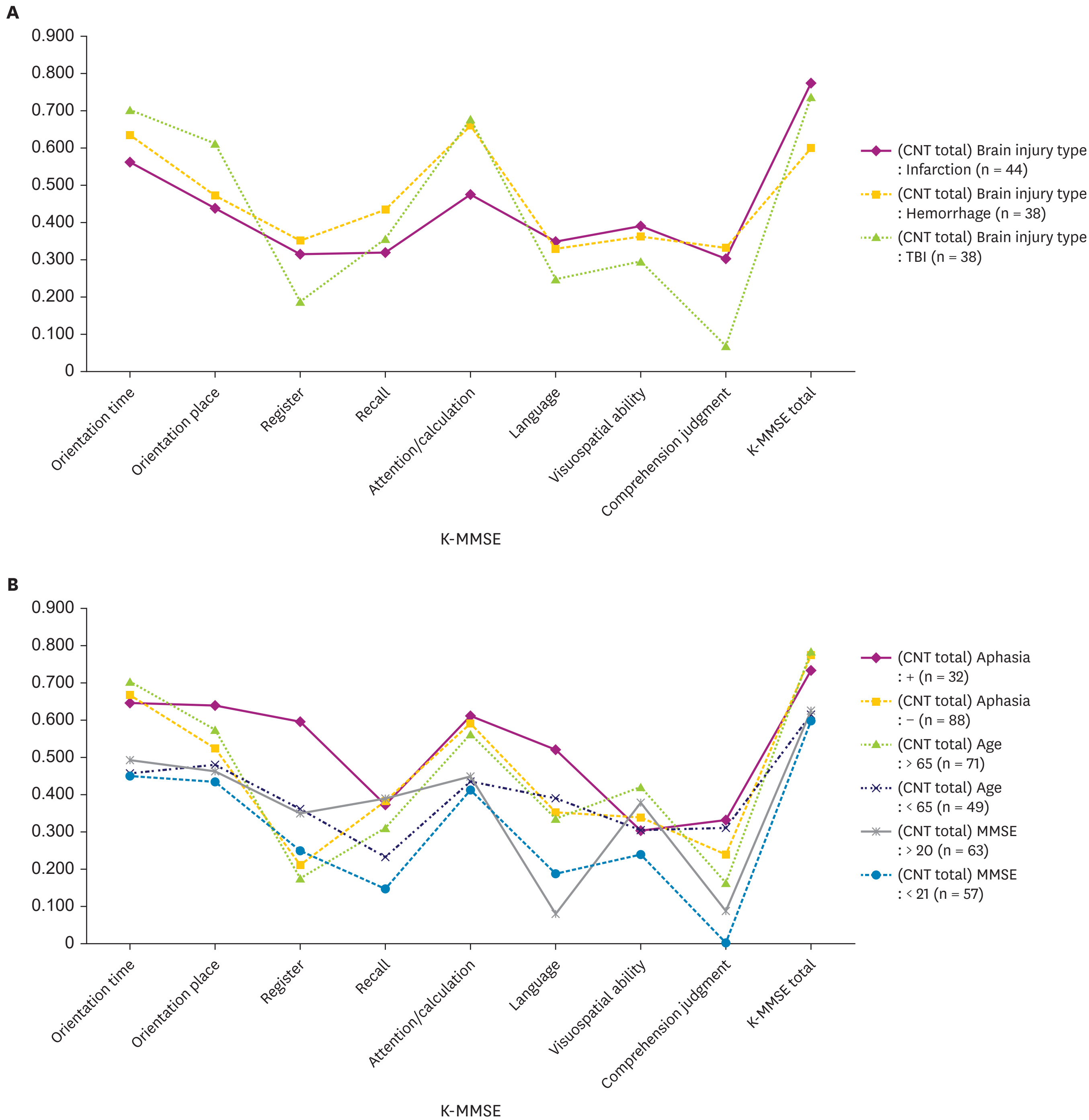

Fig. 2. The figure represents **Table 3** in graphical form. The X-axis denotes the Pearson correlation coefficient (r). (A) Pearson's Correlation coefficient between each component of MMSE and CNT according to brain injury type. (B) Pearson's Correlation coefficient between each component of MMSE and CNT according to aphasia, age, and MMSE level. It is evident from the figure that the orientation and attention/calculation components of K-MMSE exhibit a strong correlation with the CNT total score, irrespective of injury type, aphasia, age, and MMSE level.
K-MMSE, Korean Mini-Mental State Examination; CNT, computerized neurocognitive test; TBI, traumatic brain injury.

than traditional paper-and-pencil tests that use standardized stimuli and responses. We found a high correlation between the results of the K-MMSE and the CNT used to assess patients with brain injury, suggesting that K-MMSE can be sufficiently useful in evaluating the cognitive function level of brain injury patients in clinical practice.

Among the components of K-MMSE, orientation demonstrated a high correlation with all components of CNT. Notably, orientation involves various processes, such as spatial perception, attention, and memory, and it helps individuals to encode, store, and retrieve information in a meaningful way [17-19]. Furthermore, it plays an important role in memory and attention, providing a framework for organizing and categorizing experiences to ensure that the information can be more easily recalled later [20]. In addition, it influences attention by helping individuals filter out irrelevant information and focus on important stimuli, thereby allowing them to direct their attention more effectively by providing a context for interpreting incoming sensory information [21,22]. In the absence of orientation, a person may have difficulty in concentrating and maintaining focus, which can lead to distraction and confusion [23,24]. This proves that orientation is a crucial component of cognitive function and plays an essential role in various cognitive processes such as attention, memory, and spatial perception. The high correlation between orientation and other components of CNT indicates that individuals who perform well on orientation tasks are more likely to have better cognitive abilities overall.

The high proportion of the orientation score in the K-MMSE test also suggests that it is a significant determinant of overall cognitive function. Therefore, the results of the K-MMSE test can be used to assess an individual's cognitive function, and the orientation score can provide valuable information about their cognitive abilities, including attention, memory, and spatial perception.

The memory register of K-MMSE exhibited the highest correlation with the verbal memory of CNT. This is likely due to the similarity in the methods used to evaluate verbal memory in both tests, as the K-MMSE registration task requires the participant to listen to and repeat three words in order. Memory recall of K-MMSE showed the highest correlation with high cognition of CNT. This indicates the importance of recall in the cognitive processes of memory, attention, and high cognition, as it is the process of accessing stored information. An efficient memory recall requires focused attention [25] as it helps direct the brain's resources to retrieve relevant information [26]. High cognition, which involves complex mental processes, such as reasoning, problem-solving, and decision-making, relies on an efficient recall as it requires the retrieval and use of stored information [27-29]. It can be inferred that these processes work together to support overall brain function.

The attention/calculation component of K-MMSE was highly correlated with other components of CNT, and it demonstrated the highest correlation with visuomotor coordination and high cognition. In particular, the visuomotor coordination test involved arranging numbers from 1 to 25 in order. In this test, attention is significantly important. Moreover, attention plays a crucial role in memory and higher cognitive abilities [30]. A previous study suggested that focusing on information helps to better encode and remember it [31-33]. This is because attention strengthens neural connections, making it easier to retrieve information from the memory later [31]. Additionally, attention helps filter out distractions and irrelevant information, allowing the individual to focus on the most important and relevant information. This further improves the ability of the individual to process and understand complex information, indicating that attention is a key component of high cognition [34,35].

The language component of K-MMSE consisted of naming (2 points), command execution (3 points), and repeating (1 point) and exhibited a high correlation with visuomotor coordination and attention of CNT. The ability to use language is influenced by various cognitive processes, such as attention, memory, perception [36,37]. In the CNT test, the visuomotor coordination test is thought to be greatly affected by attention, and eventually the language component of K-MMSE is closely related to the attention of CNT.

Although the total score for visuospatial ability in K-MMSE was only 1, it exhibited a high correlation with the visuomotor coordination of CNT. The comprehension/judgment component of K-MMSE had the highest correlation with visuomotor coordination, followed by high cognition and attention. Comprehension requires the ability to pay attention to, process, and understand information, which are important in high cognition [38]. The ability to make judgments involves weighing options and making decisions, which requires sustained attention and focused thinking, both of which are also integral components of high cognition [39]. However, the total score for the visuospatial ability and comprehension/judgment components in K-MMSE is only 3, which may not provide sufficient evaluation results.

Looking at each component of the MMSE and the CNT total score, the orientation and attention/calculation components of the MMSE showed a high correlation with the CNT total score of $r > 0.5$. This tendency can also be confirmed when 120 subjects are grouped according to brain injury type, presence of aphasia, age, and MMSE (**Table 3** and **Fig. 2**). Therefore, although there may be differences in the degree and area of cognitive impairment depending on the injury type, we interpreted that this does not affect the result that the orientation and attention/calculation components of MMSE show a high correlation with CNT. A robust orientation to one's surroundings is integral to cognitive function, influencing memory, spatial cognition, decision-making, and interpersonal interactions, thereby fostering adaptive and effective cognitive processes in everyday life. Attention is fundamental to cognitive function, serving as a crucial gateway for selecting, processing, and integrating information into conscious awareness. This mechanism allows individuals to focus on specific stimuli, filtering out irrelevant details and facilitating efficient cognitive processing. Through this fact, we can see that among the MMSE components, the higher the orientation and attention/calculation, the higher the correlation with the CNT test. When evaluating patients, a higher score in orientation, attention/calculation component of the MMSE indicates better cognitive function and can be used as an indicator. Even if the MMSE score is the same, with high orientation and attention/calculation, cognitive therapy using a computerized cognitive tool can be performed more effectively, yielding positive results in cognitive evaluation. Additionally, when assessing a patient's overall cognitive function in clinical practice, preserved orientation and attention/calculation functions suggest a high level of cognitive function, enabling appropriate rehabilitation treatment.

The K-MMSE is a screening tool used to evaluate cognitive impairment in patients. It is a brief assessment that focuses on several cognitive domains, including orientation to time and place, memory, and attention [40]. While it has limitations in that it does not provide a comprehensive assessment of cognitive function and may not be as sensitive or specific as more comprehensive neuropsychological assessments [6], it is still a useful tool in clinical practice for evaluating cognitive impairment, especially in patients who have difficulty using more complex cognitive tests. Its brevity and simplicity make it a practical choice for busy clinical settings where a quick screening is needed to identify potential cognitive deficits.

This study has several limitations. First, our sample size was relatively small and only included patients with stroke and traumatic brain injury, which may limit the generalizability of our findings to other brain injury patients. A larger sample size and more diverse patient population would provide a more robust evaluation of the efficacy of K-MMSE as a screening tool. Second, many brain injury patients suffer from motor impairments, and neglect syndrome or visual field defects can impair their ability to perform CNT accurately, which may lead to an underestimation of actual cognitive function. Third, the score for the orientation and attention/calculation components of K-MMSE is 15 points out of a total score of 30, which shows that the score proportion is larger than that of other parts. In our study, the orientation component showed a high correlation with all components of CNT. It is possible that the higher scores of the orientation and attention/calculation components of the K-MMSE compared to other areas may have had some influence.

Our study highlights the importance of orientation, attention as a crucial component of cognitive function, playing a vital plays a pivotal role across cognitive domains, influencing perception, memory, decision-making, and problem-solving. The high correlation between orientation, attention/calculation of MMSE and other components of CNT suggests that individuals who perform well on orientation, attention tasks are more likely to have better cognitive abilities overall. Therefore, the orientation component of K-MMSE can provide valuable information about an individual's cognitive function. Although K-MMSE has limitations in evaluating specific cognitive domains, it is a useful tool in clinical practice for evaluating cognitive impairment, especially in patients who have difficulty using more complex cognitive tests.

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Appendix 1. Components of the CNT

Test	Subtest
Verbal memory test	Digital span forward
	Digital span backward
	Ver. learning
	Ver. learning-delayed recall
Visual memory test	Visual span forward
	Visual span backward
	Vis. learning
	Vis. learning-delayed recall
Attention test	Aud. CPT
	Vis. CPT
	Word color T
Visuomotor coordination test	Trail-making A
	Trail-making B
High cognition test	Card-sorting T

CPT, continuous performance test.