

Comparison between the accuracy of Montreal Cognitive Assessment and Mini-Mental State Examination in the detection of mild cognitive impairment

Nayyereh Aminisani

University of Neyshabur

Rasoul alimi (✉ rasulalimi@yahoo.com)

University of Neyshabur

Ali Javadpour

Shiraz University of Medical Sciences

Mohammad Asghari-Jafarabadi

Tabriz University of Medical Sciences

Mozhgan Jourian

University of Neyshabur

Chris Stephens

Massey University

Morteza Shamshirgaran

University of Neyshabur

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Abstract

Introduction: Ageing can cause major changes in the central nervous system of the body, resulting in cognitive decline and associated disorders. Therefore, there is a growing need for an effective cognitive screening method to enhance the diagnosis of mild cognitive impairments and to prevent occurring dementia and Alzheimer's Disease (AD). Our study aimed to compare the accuracy of MMSE (Mini-Mental State Examination) and MoCA (Montreal Cognitive Assessment) while evaluating the independent and interaction effects of age and educational level on these screening tools in a healthy sample.

Method: The data for the current study was based on the registration phase of the study during 2016-2018 in Neyshabour Longitudinal Study on Ageing (NeLSA). Both the MoCA and MMSE tests were used to assess cognitive decline among 3326 participants aged 50-94 years of old. The ROC curve analysis and the predictive values were performed to evaluate the diagnostic accuracy of MMSE to discriminate Mild Cognitive Impairment (MCI) from the cognitively healthy adult basis of MoCA scores as a gold test. A two-way ANCOVA was run to examine the effect of Age and Education level on MoCA and MMSE score, while controlling for a gender effect. Data were analyzed using MedCalc Statistical Software version 13.0.6 (MedCalc Software bvba, Ostend, Belgium; <http://www.medcalc.org>; 2014).

Results: The chi-square test shows that MoCA ((72% and 90%) significantly (p -value <0.001) classified more persons as cognitively impaired than the MMSE (45.1%), respectively; using a cutoff score of 24 on the MMSE, 23 and 26 on the MoCA. The cut-off point of below 25 yielded the highest Youden J index for the MMSE in discrimination between MCI and healthy basis of MOCA <23 with an AUC of 0.9 (95% CI: 0.89-0.91) and MOCA <26 with an AUC of 0.87 (95% CI: 0.86-0.89). A two-way ANCOVA results show that the effect of education variable on the MMSE and MoCA score is more important than the age variable.

Discussion: Although the cut-off scores give a clear indication of the sensitivity and specificity, they are unable to monitor the impact of confounders, which increase the risk of incorrect classification. Taken together, these findings demonstrate the use of demographically adjusted MoCA and MMSE scores that could provide clinicians with a more reliable estimation of the severity of cognitive impairment, thus increasing the instrument's clinical usefulness.

Introduction

The world is witnessing an irreversible change in the age structure of the population. Worldwide, the number of people aged 60 years and up reached to 962 million in 2017; it is expected to double again by 2050. In developing countries, ageing of the population has become a significant concern, as two-thirds of the world's older adults live in these countries. These regions will be facing faster growth in numbers of older adults than in developed areas in the next decades (1).

Ageing can cause significant changes in the body's Central Nervous System (CNS) and lead to cognitive impairment and related disorders, including Mild Cognitive Impairment (MCI), dementia, and Alzheimer's Disease (AD) (2). Therefore, cognitive impairment is one of the most common health problems in the elderly, and it is estimated that the prevalence of cognitive impairment among older adults aged 80 and over is more than 40% (3). As life expectancy increases, the global prevalence of these disorders is expected to increase exponentially in the coming years. In 2015, it was reported that there were more than 46 million people with dementia, with 9.9 million new cases in the world, and 58% of patients living in low- and middle-income countries. This number is expected to reach more than 130 million by 2050 (4). Furthermore, among adults over 65 years, the prevalence rate almost doubles every five years (5). The growing prevalence means that the economic, health, and social effects of dementia will increase. Dementia can lead to disability or hospitalization of the elderly, significantly reducing the quality of life of patients, as well as creating an economic burden for the families of patients and society in general (6,7).

Hence, there is an urgent need to prevent or slow down the onset and progression of the disease and recent research has focused on the transition from healthy cognitive ageing to dementia. This transition period, known as MCI, is characterized by a measurable deterioration in cognitive function that is more than expected based on a person's age and education but does not have a significant effect on a person's daily performance (8). It is estimated that the prevalence of MCI in people aged 65 years and older is 10-20%, and this rate increases with age (9). MCI is a significant risk factor for dementia with an annual conversion rate of 6% (10), 10-15% (11), and 31% (12) to Alzheimer's disease. And in about 80% of people with MCI, the symptoms of dementia appear within six years (13,14)

Therefore, both patients and family members and the community benefit from accurate and early diagnosis and appropriate intervention. The most important of these benefits will be the opportunity to start effective and adequate early intervention as well as improve patient access to support services, which can increase the quality of life of patients and their caregivers (15).

The standardized test for assessing dementia and cognitive impairment is Neuropsychological testing. However, these assessments are difficult for many large clinical trials and clinical practice because they are lengthy, often limited to the presence of a psychologist, include multiple tests, and are expensive (16).

Therefore, there is a growing demand for an effective cognitive screening tool to improve diagnosis of MCI and prevent the onset of dementia and AD. One of the most utilized tools, which has been validated in more than 100 studies, is the Mini-Mental State Examination (MMSE) assessment due to its simplicity and cost-effectiveness, however, it has poor sensitivity to the early stages of dementia especially among educated patients (17). MMSE has also incurred criticism because of under representation of memory and executive functioning tasks, ceiling and floor effects, and restriction of use by copyright (18).

The Montreal Cognitive Assessment (MoCA) is an alternative screening tool for CI that is designed to diagnose mild to moderate disorders. It contains items assessing executive functioning and has good sensitivity and specificity (19), but it is rarely used in research. Evidence of its superiority over MMSE has been shown in many clinical populations (20–22).

According to a study by Milne et al., 79% of health professionals use at least one screening test, 51% of which include MMSE testing and its modified variants (23). Another study that evaluated common types of screening tests to diagnose dementia showed that only 5% of them use MoCA (24).

A variety of factors may influence the choice of test used, such as clinicians' familiarity with the test, availability of translations, copyright, ease of administration, time constraints, the evidence base of the test and its perceived accuracy (17). For example, the MoCA is lengthy, which makes it more suitable for specialized cognitive screening of outpatients but difficult for first-line neurology physicians to apply in primary care (25). A brief, sensitive but accurate screening scale is required in these situations. MoCA is not used commonly in practice in Iran, due to different sociocultural factors and rapid growth of ageing and dementia as its major consequence, our study aimed to compare the accuracy of MMSE and MoCA in distinguishing healthy individuals from people with MCI while evaluating the independent and interaction effects of age and level of education on MMSE and MOCA scores in a healthy sample.

Methods

1.1 Study population

Neyshabour Longitudinal Study on Ageing (NeLSA) is an elderly component of the Prospective Epidemiological Research Studies in Iran (PERSIAN) which was launched in 2016 (26). NeLSA is the first comprehensive longitudinal study on ageing among people aged 50–94 years in Iran aims to assess the different aspects of ageing, monitoring changes in health and wellbeing of older adults using a wide range of data collection including a comprehensive questionnaire on demographic, socioeconomic, lifestyle, physical and psychological aspects, clinical examination, as well as mobility assessment, biologic samples (blood, urine, nail and hair) and anthropometric measures.

Measures

The data for the current study was based on the registration phase of the study during 2016–2018. Both the MoCA and MMSE were used to assess cognitive decline among 3326 participants aged 50–94 years of old. The MMSE consists of three parts (understanding time, understanding location, and backwards spelling or numbering) which each item scored five points in total include five one-point questions. Each item in two parts (memorise-recall part and do a command part) scored three points in total include three one-point items, a two-points part (object recognition part) and four one-point items (repeat, write, read and copy). Its three-point items include a three-step command (such as get up, walk, sit) to evaluate long-term and short-term memory (27).

MoCA is suitable to screen mild cognitive disorders, and most of the items in this test are highly dependent on the level of education. This test measures executive function, language, navigation, computation, conceptual thinking, memory, visual comprehension, and focus, and attention. The test takes 15 minutes, and the total score equals to 30 (19).

For assessing MCI, the cut-off score is 26 and the sensitivity of the original MoCA version is 0.90 (19). In studies conducted in other languages, the cut-off score is 22–27, and the sensitivity is 0.89–0.92 (28–31). Some studies have shown that the recommended cut-off score of 26 leads to an increase in false positives compared to the results in the original study (8,32). A recent meta-analysis study found that a MoCA 23 cut-off score reduced false positives and showed better overall diagnostic accuracy (33). In the case of the MMSE test, although the optimal sensitivity and specificity are probably to vary depending on the age and level of education of the individuals, studies have shown that a general cut-off score of 23/24 or 24/25 is appropriate for most primary care of populations (34,35).

In this study, we used a cut-off score of 24 for MMSE, 23 and 26 for MoCA, so a score equal to or less than 24 in MMSE and equal or less than 23 and 26 in MoCA was considered a cognitive impairment.

Statistical analysis

Data were analyzed using MedCalc Statistical Software version 13.0.6 (MedCalc Software bvba, Ostend, Belgium; <http://www.medcalc.org>; 2014). Normal and non-normal numeric variables were expressed as mean (\pm standard deviation) or median [range IQ1-IQ3], respectively. The normality of the variables was assessed by Kolmogorov-Smirnov test. Categorical variables expressed as frequency and percentage. Mann-Whitney U test was used to compare age and education levels between males and females. Chi-square test was used for comparison of proportions between MoCA and MMSE.

The Receiver Operating Characteristics (ROC) curve analysis and the predictive values were performed to evaluate the diagnostic accuracy of MMSE to discriminate MCI from the cognitively healthy adult basis of MoCA scores as a gold standard test. In this analysis, the Areas Under the Curve (AUC) can vary between 0.5 and 1, with larger AUC indicates better diagnostic accuracy. The Youden index, which is equal to the sensitivity plus specificity minus 1, is a valued way to summarize the performance of a diagnostic test, maximum values of the index indicate the optimal cut-off point. Diagnostic accuracy indices (Sensitivity, Specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV)) were presented along their 95% CI.

A two-way ANCOVA was run to examine the effect of age and education level on MoCA and MMSE score, while controlling for a gender effect. Numeric variables were stratified by six age groups (50–54, 55–59, 60–64, 65–69, 70–74, ≥ 75 years old) and four education levels (illiterate group, literate to 5 years, 6–12, more than 13 years education). In all analyses, $P < 0.05$ was taken into account as significant.

Results

The study included 3326 subjects. The mean age was 60.99 ± 7.94 ranging from 50 to 94 years old. Demographic characteristics of the participants are reported in Table 1. A Mann-Whitney U test indicated that the age was higher for men (Mdn = 60.5) than for women (Mdn = 58), $Z = -10.14$, $P < 0.001$. Also, the result of this test indicated that men had a higher education (Mdn=5) than women (Mdn=2), $Z = -15.02$, $P < 0.001$.

Table 1. Demographic characteristics of the study participants

Variable	Male		Female		Total	
	N	%	N	%	N	%
Age (years)						
Mean \pm SD	62.45 \pm 8.23		59.72 \pm 7.44		60.99 \pm 7.94	
50-54	267	17.2	545	30.8	812	24.4
55-59	467	30.0	546	30.8	1013	30.5
60-64	337	21.7	315	17.8	652	19.6
65-69	210	13.5	165	9.3	375	11.3
70-74	128	8.2	110	6.2	238	7.2
≥ 75	147	9.4	89	5.0	236	7.1
Education (years)						
0	268	17.3	630	35.7	898	27.1
1-5	585	37.7	727	41.2	1312	39.5
6-12	549	35.4	335	19.0	884	26.6
≥ 13	151	9.7	74	4.2	225	6.8

We calculated the percentage of persons classified as having a cognitive impairment at different MOCA cutoff values (51.3 % of persons who had a score of ≥ 24 on the MMSE, scored abnormally on the MOCA less than 23. 82.1 % of persons who had a conservative ≥ 24 on the MMSE, scored abnormally on the MOCA less than 26).

The chi-square test shows that MoCA significantly (p -value <0.001) classified more persons as cognitively impaired than the MMSE (72% and 90% vs 45.1%, respectively; using a cutoff score of 24 on the MMSE, 23 and 26 on the MoCA) (Table 2).

Table 2. Percentage of patients classified as cognitively impaired

MOCA Cutoff Scores	Abnormal MOCA	Abnormal MMSE (<24)	Proportion of MOCA Impaired Patients with Normal MMSE
<23	2394(72%)	1500(45.1%)	51.3% 936/1826
<26	2995(90%)	45.1%	82.1% 1500/1826

Cutoff points

Graphic representations of the ROC curves are provided in Figure 1. The optimal cutoff point for maximum accuracy (Youden J index) and the respective values of sensitivity, specificity, PPV, NPV are described in Table 3. The cutoff point of below 25 yielded the highest Youden index for the MMSE in discrimination between MCI and healthy basis of MOCA<23 with an AUC of 0.9 (95% CI: 0.89-0.91) and MOCA<26 with an AUC of 0.87 (95% CI:0.86-0.89). With these cutoff points, MMSE had good sensitivity, specificity, PPV and NPV.

Table 3. The optimal cutoff point for maximum accuracy (Youden J index) and the respective values of sensitivity, specificity, PPV, NPV for evaluation the diagnostic accuracy of MMSE

	Cutoff	Youden index J	Sensitivity, %	Specificity, %	PPV	NPV
MMSE FOR MOCA<23	≤23	0.56	60.90	95.49	97.2	47.8
	≤24	0.63	71.14	91.95	95.8	55.4
	≤25	0.66	81.24	84.23	93.0	63.6
	≤26	0.57	88.35	68.56	87.8	69.6
	≤27	0.42	95.28	46.46	82.1	79.3
MMSE FOR MOCA<26	≤23	0.48	49.92	98.49	99.6	15.3
	≤24	0.57	59.10	97.58	99.6	20.9
	≤25	0.62	69.05	92.75	98.9	24.9
	≤26	0.58	78.20	80.06	97.3	28.9
	≤27	0.49	88.41	60.12	95.3	36.4

MOCA: Montreal Cognitive Assessment, MMSE: Mini-Mental State Examination, PPV: Positive Predictive Value, NPV: Negative Predictive Value

The mean score of MoCA was 18.87(±5.31) and 23.67 (±3.84) for MMSE. The mean (SD) scores according to the age group, and education level are shown in Table4.

Table 4. MoCA and MMSE scores on Age group and Education level

Variable		MOCA		MMSE	
		Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
AGE	50-54	20.38±4.78	21(17-24)	24.50±3.42	25(22-27)
	55-59	19.83±4.98	20(16-24)	24.34±3.54	25(22-27)
	60-64	18.75±5.08	19(15-22)	23.58±3.63	24(21-26)
	65-69	17.74±5.06	18(14-22)	23.21±3.75	23(21-26)
	70-74	16.52±5.18	17(13-20)	22.24±4.01	22(20-26)
	>75	14.00±5.49	13(10-18)	20.29±4.53	20(17-24)
EDUCATION	0	13.71±4.37	14(11-17)	20.24±3.68	20(18-23)
	1-5	19.02±3.93	19(16-22)	23.87±2.96	24(22-26)
	6-12	22.33±3.64	23(20-25)	25.94±2.65	26(24-28)
	>13	25.10±2.33	25(24-27)	27.28±2.04	28(26-29)

MOCA: Montreal Cognitive Assessment, MMSE: Mini-Mental State Examination, SD: standard deviation, IQR: interquartile range

The mean and SD values of the MMSE and MOCA total scores for each of the age- education- group are shown in Table 5. The median with IQR values was also reported since the information could be useful for clinical reference.

A two-way ANCOVA was run to examine the effect of age and education level on MoCA and MMSE score, while controlling for a gender effect.

There was a significant interaction between the effects of age and education level on MMSE, while controlling for gender effect, F= 1.92, p = .02, partial η² = .01. The effect size is negligible. Simple main effects analysis showed that people with higher education level have a significantly higher score in MMSE than people with lower education level at any age level (p < .05). Also, Simple main effects analysis showed that in people with high education (>13 years), there was no significant difference in the scores of MMSE between any age level (p > .05). But, in people with education years less than 12 years, the scores of MMSE significantly decrease with increase age (p < .05).

There was no significant interaction between the effects of age and education level on MoCA, while controlling for gender effect, $F= 1.48, p = .14$, partial $\eta^2 = .01$. But, the main effects of education ($F= 552.50, p < .001$, partial $\eta^2 = .34$) and age ($F= 19.34, p < .001$, partial $\eta^2 = .03$) were statistically significant. Partial eta squared showed that the relative impact of education is more than age. Bonferroni post hoc test showed that people with higher education level have a significantly higher score in MoCA than people with lower education level ($p < 0.05$). Also, Bonferroni post hoc test showed that people with higher age have a significantly lower score in MoCA ($p < 0.05$). In general, the above results show that the effect of education on the MMSE and MoCA score is more important than the age.

Table 5. MoCA and MMSE scores on Age- and Education-stratified groups

Age	Education	MOCA		MMSE	
		Mean \pm SD	Median (IQR)	Mean \pm SD	Median (IQR)
50-54	0	14.61 \pm 4.08	15(12-17)	20.95 \pm 3.62	21(19-23)
	1-5	19.76 \pm 3.75	20(17-23)	24.16 \pm 2.86	24(22-26)
	6-12	22.97 \pm 3.40	23(21-25)	26.09 \pm 2.55	26(25-28)
	>13	25.42 \pm 2.25	25(24-27)	27.37 \pm 2.11	28(26-29)
55-59	0	14.97 \pm 4.36	15(12-18)	21.21 \pm 3.55	21(19-24)
	1-5	19.34 \pm 4.09	20(17-22)	24.09 \pm 3.03	24(22-27)
	6-12	23.14 \pm 3.11	23(21-26)	26.46 \pm 2.28	27(25-28)
	>13	25.12 \pm 2.31	25(24-27)	27.45 \pm 1.81	28(27-29)
60-64	0	13.89 \pm 4.02	14(11-17)	20.41 \pm 3.24	20(18-23)
	1-5	18.80 \pm 3.75	19(16-21)	23.64 \pm 2.85	24(22-26)
	6-12	22.12 \pm 3.54	22(20-25)	25.96 \pm 2.56	26(25-28)
	>13	25.19 \pm 2.27	26(24-26)	26.68 \pm 2.54	27(26-28)
65-69	0	13.81 \pm 4.08	14(11-16)	20.54 \pm 3.33	21(18-23)
	1-5	17.98 \pm 3.60	18(15-20)	23.65 \pm 2.92	24(22-26)
	6-12	21.52 \pm 3.79	22(18-24)	25.43 \pm 2.96	26(23-28)
	>13	23.90 \pm 2.57	24(22-25)	27.45 \pm 1.96	27(26-29)
70-74	0	12.95 \pm 3.99	13(11-16)	19.75 \pm 3.48	20(18-22)
	1-5	17.85 \pm 3.20	18(16-20)	23.43 \pm 2.80	24(21-26)
	6-12	20.54 \pm 3.98	21(20-23)	24.85 \pm 3.19	25(22-27)
	>13	25.10 \pm 2.38	26(24-27)	27.70 \pm 1.25	28(27-28)
>75	0	10.69 \pm 4.33	11(7-13)	17.57 \pm 3.90	18(15-20)
	1-5	16.73 \pm 4.12	16(13-19)	22.51 \pm 3.10	22(20-25)
	6-12	18.16 \pm 4.14	18(16-21)	24.05 \pm 3.07	24(22-26)
	>13	23.80 \pm 2.49	23(22-24)	26.20 \pm 1.30	26(25-27)

MOCA: Montreal Cognitive Assessment, MMSE: Mini-Mental State Examination, SD: standard deviation, IQR: interquartile range

Discussion

Our results show that MoCA classifies more patients as cognitively impaired than MMSE. The MoCA classified 90% of our sample who scored less than 26 as having cognitive deficits, including 82.1% of patients who scored 24 or higher on the MMSE. With a cutoff point of 23, MoCA classified 72% of individuals as having cognitive impairment, including 51.3% of patients who scored 24 or higher on the MMSE. In fact, more than half of patients with normal MMSE were classified by MoCA as cognitively impaired. Based on the study of Toglietta et al. the majority of patients classified as cognitively impaired using MoCA appear to be somewhat related to a better assessment of impaired visuoexecutive and verbal fluency structures, which have not been well tested using MMSE (22). In a study conducted by Soleimani et al. in the north of Iran among 393 older adults, 70% suffered from cognitive impairment based on MMSE (36) which was 45.2% higher than our study. This difference can be explained by the higher percentage of people over 70 in that study compared to our research.

Without a gold standard neuropsychological assessment, we cannot conclude whether MoCA or MMSE have correctly identified people's cognitive abilities. MoCA, in addition to the benefits of MMSE, has been developed as a more challenging test that includes executive function, higher-level language, and complex visuospatial processing to enable detection of mild impairment with less ceiling effect (19). This test is more sensitive to detecting mild levels of cognitive impairment in MCI and dementia (37). However, MoCA has a more extended evaluation time (10-15 minutes) than MMSE (5-10 minutes) and is not suitable for outpatients due to the simple and easy use of MMSE (19,38).

Using ROC analysis for MCI versus healthy, MMSE cutoff values of greater 25 was chosen to relatively emphasize sensitivity (81.24 to 69.05 %) over specificity (84.23 to 92.75 %) basis of MoCA cutoff 23 and 26. In a meta-analysis by Ciesielska (39), most often sensitivity and specificity for scoring: 27/28 (n = 6 studies); 25/26 (n = 5); and recommended 26/27 (n = 4) was presented.

In our study, even with a 1 point correction in the MoCA test, a significant proportion of participants (90%) were below the recommended cutoff score of 26. Not surprisingly, this difference is more pronounced in the older age group and those with lower education (< 5 years). Freitas et al.

found that 49% of the changes in MoCA scores were related to age and education (40). In addition, it has been shown that less accuracy is observed in MMSE in the older educated group. This is due to the ceiling effect that occurs in older people with higher education when performing MMSE (37).

O'Bryant et al. found that in a sample of highly educated adults, a cutoff score of 27 or 28 in MMSE provided optimal diagnostic accuracy in identifying cognitive impairment (41). These findings may be problematic given that the normal range for MMSE scores is between 24 and 30. Because many physicians are familiar with it and have identified a range of 24 to 30 as the normal range for their patient's population, it may be difficult for them to utilize a "normal" score as a cutoff for a particular segment of the patient's population. In this case, it is helpful to use the normative approach set by age and education and provide a more accurate assessment to the physician (42).

The results of Tables 4 and 5 show that MoCA and MMSE show comparable results, but MoCA showed a lower average with a broader range of scores. This finding was also observed in a study by Ohta et al. that MMSE and MoCA scores were 26.3 ± 3.6 (range 12-30) and 20.9 ± 5.0 (range 5-30), respectively (43).

According to the findings of this study, participants with higher education had better cognitive performance scores compared to their low-educated counterparts. Similarly, differences in cognitive performance scores between age groups were evident, with lower age groups performing better cognitively than older age groups. Compared to MMSE, there are more differences between each age group in MoCA, which could indicate that MoCA is more sensitive to age-related changes in cognitive impairment than MMSE. Similar to our study, a study by Rossetti et al. showed that cognitive performance measured by MoCA decreased slightly with age in people over 12 years of education, but decreased more in those with lower education (44). The Iranian study by Arab Ahmadi et al. in Relapsing Remitting MS patients showed significant inverse association between education and CI by both MMSE and MoCA (45). In a longitudinal study that has been conducted in the elderly, it has shown less MMSE performance in the elderly with cognitive impairment, especially among the elderly and people with low education (46).

Although the age and level of education were reported as factors influencing the normative value for the MMSE or MoCA, the two way ANCOVA showed that the duration of education was the important factor associated with the score on both tests. This result was consistent with the previously reported studies, which showed a higher effect of education level on the MMSE and MoCA scores (47,48). In general, studies among elderly people with low education levels, lower values of cutoff point for a more accurate diagnosis were found (49,50).

Although the cutoff scores provide a good indication of the sensitivity and specificity for differentiation of the clinical group from the control group, they are not able to control the effect of confounders that increase the likelihood of incorrect classification. Therefore, the main advantage of using a normative approach over a cutoff score approach is that the means and standard deviations are classified by a number of different factors that allow for a more accurate estimate of cognitive performance.

Taken together, these results highlight the use of demographically adjusted MoCA and MMSE scores may provide clinicians with a more accurate estimate of the severity of cognitive impairment, thus improving the clinical utility of the instrument.

There were strengths and limitations to this study. Among its strengths is the relatively large sample size of patients. This study utilized the MoCA rather than gold standard measures (e.g., DSM-111, NINCDS-ADRDA, and clinical record) to evaluate cognitive function, and thus we were unable to diagnose MCI. Also, there might be more measurement bias comparing the MoCA with gold -standard measures. Still, the reliability and validity of the MoCA have been well assessed among different populations, including older adults.

Abbreviations

NeLSA (Neyshabour Longitudinal Study on Ageing); MMSE: Mini-Mental State Examination); MoCA (Montreal Cognitive Assessment); MCI (Mild Cognitive Impairment); ROC (Receiver Operating Characteristics)

Declarations

Acknowledgement

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Author Contributions

Nayyereh Aminisani, Morteza Shamshirgaran, Ali Javadpour and Chris Stephens involved in study design and conduct, and editing the manuscript. Rasoul Alimi performed the analysis and prepared the manuscript draft. Mozghan Jourian contributed to data collection and

manuscript writing. Mohhammad Asghari-Jafarabadi, NA and SMS reviewed the analysis and manuscript results. All Authors approved the final draft.

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Availability of data and materials

All collected source data are maintained and stored at the study research office, in the Healthy Ageing Research Centre, Neyshabur University of Medical Sciences, Iran. A backup of the dataset is stored in the PERSIAN study's central server, Tehran, Iran. Data is not open-accessed, but may be obtained with the permission following requests and submission of specific proposals. Information on study details and data access forms be found on the study website, <https://nelsacohort.num.s.ac.ir>, <https://persiancohort.com>, or you could send an email through email to Nelsa@num.s.ac.ir or principle investigator Dr Nayyereh Aminisani (aminisanin1@num.s.ac.ir).

Ethics approval and consent to participate

The NeLSA has been approved by the Ethical Committee of Neyshabur University of Medical Sciences (record number IR.NUMS.REC, 1394.35). Ethical approval for the current study was obtained from ethical board of Neyshabur University of Medical Sciences (IR.NUMS.1398.047). Written informed consent was obtained from all participants and they were free to leave the study at any time and for any reason, without any consequences. All procedures performed in this research were in accordance with Helsinki Declaration.

Consent for publication

Not applicable.

Competing interests

None to declare.

Author details

¹ Healthy Ageing Research Centre, Neyshabur University of Medical Sciences, Neyshabur, Iran

² Shiraz Geriatric Research Centre, Shiraz University of Medical Sciences, Iran

³ Road Traffic Injury Research Center, Department of Epidemiology and Biostatistics, Faculty of Health, Tabriz University of Medical Sciences, Tabriz, Iran

⁴ School of Psychology, Massey University, Palmerston North, New Zealand

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Figures

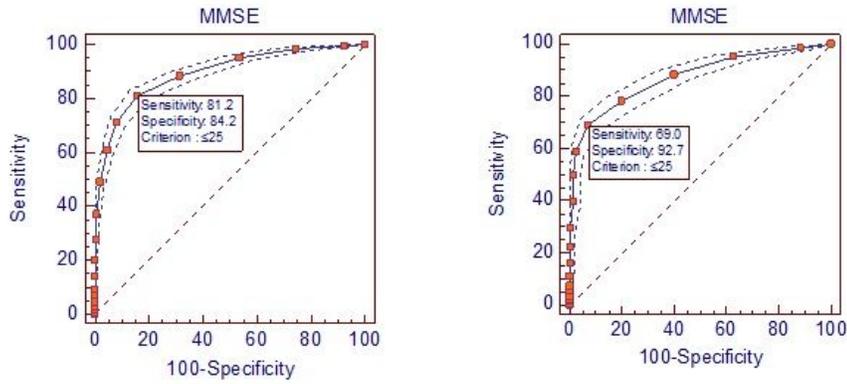


Figure 1

Receiver operating characteristic curve analysis. Left: The cutoff points for the MMSE in discrimination between MCI and healthy basis of MOCA<23 as a gold test. Right: The cutoff points for the MMSE in discrimination between MCI and robust basis of MOCA<26 as a gold test. Hint. MOCA: Montreal Cognitive Assessment, MMSE: Mini-Mental State Examination