

Clinical application of the Polish adaptation of the Montreal Cognitive Assessment (MoCA) test in screening for cognitive impairment

Zastosowanie polskiej adaptacji Montrealskiego Testu do Oceny Funkcji Poznawczych (MoCA) w przesiewowej ocenie funkcji poznawczych

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Abstract

Background and purpose: The Montreal Cognitive Assessment (MoCA) test is a brief cognitive screening tool with high sensitivity and specificity for detecting mild cognitive impairment (MCI). The aim of this study was to evaluate the usefulness of MoCA and compare it with the Mini-Mental State Examination (MMSE) in the early detection of cognitive decline in MCI.

Material and methods: A group of 115 subjects (36 meeting DSM-IV criteria for Alzheimer disease (AD) [Clinical Dementia Rating (CDR) = 1], 42 meeting Petersen's criteria for MCI [CDR = 0.5], and 37 cognitively intact controls [CDR = 0]) was recruited for the study in the university-based Alzheimer out-patient clinic. All participants underwent general medical, neurological, and psychiatric examinations. The MoCA, the MMSE, CDR and the short (15-item) version of the Geriatric Depression Scale were also applied.

Results: Both MCI and AD groups exhibited impaired performance on MoCA compared to controls. Polish versions of the MMSE and MoCA tests were comparable in discriminating mild dementia from both MCI and control groups. The Polish version of the MoCA test performed marginally better than MMSE in discriminating MCI from controls. We propose to use the MoCA test to screen for MCI

Streszczenie

Wstęp i cel pracy: Montrealski Test do Oceny Stanu Poznawczego (*Montreal Cognitive Assessment* – MoCA) jest narzędziem do przesiewowej oceny stanu poznawczego i cechuje się dużą czułością oraz swoistością w wykrywaniu łagodnych zaburzeń poznawczych (*mild cognitive impairment* – MCI). Celem pracy była ocena przydatności testu MoCA oraz porównanie z Krótką Skalą Oceny Stanu Psychicznego (*Mini-Mental State Examination* – MMSE) we wczesnym wykrywaniu łagodnych zaburzeń poznawczych.

Materiał i metody: Przeprowadzono badanie z użyciem polskiej wersji testu w grupie 115 osób, w tym 36 chorych na chorobę Alzheimera o nasileniu łagodnym wg DSM-IV [*Clinical Dementia Rating* (CDR) = 1], 42 pacjentów z MCI (CDR = 0,5) oraz 37 zdrowych osób w grupie kontrolnej (CDR = 0) – pacjentów poradni przyklinicznej o profilu psychogeriatrycznym. U wszystkich uczestników projektu przeprowadzono ocenę ogólnego stanu somatycznego, badanie neurologiczne i psychiatryczne oraz dokonano oceny z użyciem MoCA, MMSE, CDR oraz 15-punktowej wersji Geriatrycznej Skali Depresji (*Geriatric Depression Scale*).

Wyniki: Zarówno pacjenci z MCI, jak i z chorobą Alzheimera wykonali test MoCA gorzej w porównaniu z osobami z grupy kontrolnej. W badanej populacji testy MMSE i MoCA okazały się porównywalne w odróżnianiu otępienia

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using an optimal cut-off score of 24 and to screen for dementia using a cut-off score of 19.

Conclusions: The Polish version of the MoCA seems effective in the detection of deteriorated cognitive performance and appropriate for differentiating impaired from preserved cognitive function in a Polish population.

Key words: screening, mild cognitive impairment, Montreal Cognitive Assessment, MoCA.

Introduction

A dramatic increase in the incidence of Alzheimer disease (AD) in the near future is predicted. Therefore, there is a growing interest in identifying adults at high risk for developing cognitive decline. The concept of a transitional state between normal aging and AD or other dementia subtypes has been present in the literature for many years [1,2]. Mild cognitive impairment (MCI) is a condition characterized by an acquired cognitive impairment without significant functional decline in the activities of daily living, constituting an intermediate stage between normal aging and dementia. Mild cognitive impairment is a heterogeneous clinical syndrome for which no DSM (Diagnostic and Statistical Manual of Mental Disorders) Fourth Edition (DSM-IV) or ICD (International Statistical Classification of Diseases and Related Health Problems) criteria have yet been established. The criteria by Petersen *et al.* are currently the most frequently applied in everyday clinical practice [3,4], but revisions and other propositions also exist [5,6]. The diagnosis of MCI requires considerable clinical judgment. Neuropsychological testing with standardized tests is often used to assess and characterize MCI patients, but many clinicians lack easy and timely access to such assessments or to tertiary care memory clinics. For that reason, there is a need for sensitive but user-friendly cognitive screening tests for clinicians, such as the Montreal Cognitive Assessment (MoCA) test [7]. Moreover, clinical and neuropsychological studies are needed that can better characterize which screening methods are the most efficacious in the process of diagnosing MCI cases.

The Mini-Mental State Examination (MMSE) was published in 1975 as a practical means of evaluating cognitive functions [8]. The Mini-Mental State Exa-

mination has been considered the 'gold standard' and is currently one of the most widely used tools for the assessment of cognitive impairment in both clinical practice and research [9]. The Mini-Mental State Examination was suggested as a useful MCI screening tool in the guidelines of the American Academy of Neurology [10], but it may not adequately capture early cognitive deficits associated with dementia [8]. Moreover, a number of issues were raised regarding the sensitivity of some MMSE subtests and the impact of age, education, ethnic differences and gender on the final score [11-13].

There is a need for a tool detecting individuals who will subsequently develop AD and now score within the normal range on the MMSE. The Mini-Mental State Examination and other popular dementia screening tests lack sensitivity owing to ceiling effects, especially in highly educated subjects [14]. Interpretation of the MMSE score is further hampered by the need for complicated age and education adjustments [15].

A growing number of novel cognitive screening tests are being developed. A major focus is on increasing sensitivity, covering more domains than MMSE, addressing frontal/executive functioning, and decreasing susceptibility to cultural and educational biases [16].

Increasing doubts on the applicability of MMSE for MCI screening resulted in the preparation of alternative tools, including the MoCA test. The MoCA test is a short (usually it can be administered within 10 minutes), one-page, paper-and-pencil screening test [7]. The test consists of tasks assessing the following domains: short-term memory, visuospatial abilities, executive functions, phonemic fluency, verbal abstraction, attention, concentration, working memory, language, and, finally, orientation to time and place. A comparison of cognitive domains covered by the MMSE and MoCA is presented in Table 1.

Słowa kluczowe: badanie przesiewowe, łagodne zaburzenia poznawcze, Montrealski Test do Oceny Stanu Poznawczego, MoCA.

Table 1. Comparison of cognitive functions assessed during Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA) examination

Cognitive function/item		MMSE (No. of points/task)	MoCA (No. of points/task)
Orientation		10 items (10)	6 items (6)
Memory	learning	learning of 3 words (1 trial allowed) (3)	learning of 5 words (2 trials allowed) (no points)
	delayed recall	3 words (3)	5 words (5)
	cued recall (optional)	not present	5 words (no points)
	recognition (optional)		5 words (no points)
Naming		2 objects (2)	3 pictures (3)
Visuospatial functions		copy of pentagons (1)	copy of cube (1) clock drawing (3)
Comprehension		3-stage command (3)	not present
Attention		serial 7 subtracting (5)	forward Digit Span (1) backward Digit Span (1) serial 7 subtracting (3)
Vigilance		not present	tapping with hand at letter A (1)
Language		repetition of sentence (1)	repetition of 2 sentences (2) letter fluency (1)
Reading		sentence (1)	not present
Abstract thinking		not present	similarities (2)
Writing		patient's sentence (1)	not present
Alternating Trail Making		not present	1 trial (1)

The total possible score in MoCA is 30; a score of 26 or above is considered normal. A score below 26 points in subjects demonstrating no functional impairment is suggestive of MCI. The early stage of dementia is indicated by a score below 26 with concomitant functional impairment. One extra point is added in cases with less than 12 years of formal education.

Montreal Cognitive Assessment is a cognitive screening tool with high sensitivity and specificity for detecting MCI in subjects performing within the normal range on the MMSE [7]. It is argued that most patients meeting clinical criteria for MCI score above 26 points on the MMSE, which is also the 'healthy' range for cognitively intact elderly. The Montreal Cognitive Assessment might be particularly useful in this context, as it turned out to be more sensitive than the MMSE for the detection of MCI and mild AD in the general population. An MoCA score below 26 was considered the optimal cut-off threshold for the diagnosis of cognitive impairment even in individuals performing well on the MMSE. Moreover, compared to MMSE, MoCA covers a broader range of cognitive domains and can be

useful in evaluating cognitive decline of various aetiologies [17-21].

The origins of the test, content details and scoring rules were described by Nasreddine and colleagues [7]. Initially, only French and English versions of the MoCA were prepared and evaluated. Currently, the MoCA is being translated and validated in several other languages [22-24].

The Polish version of the MoCA test was prepared in the Department of Old Age Psychiatry and Psychotic Disorders, Medical University of Lodz [25]. English, Polish and versions in other languages are available at www.mocatest.org.

The objective of this study was to evaluate the usefulness of the MoCA versus the MMSE in the early detection of cognitive decline in MCI.

Material and methods

The study was conducted in a university-based AD out-patient clinic. In the pilot study, the Polish version

of the MoCA was prepared. In the current study, the comparative usefulness of the MoCA test versus the MMSE in the early detection of cognitive decline in MCI was evaluated.

Written informed consent for the study was obtained from all subjects before inclusion. The study was approved by the Ethics Committee of the Medical University of Lodz (RNN/598/07/KB).

Study participants

A group of 115 participants matched for age, gender and years of formal education was recruited for the current study and divided into three groups: patients with mild AD, patients meeting criteria for MCI, and cognitively intact elderly controls.

The main inclusion criterion was the final CDR score: 0 for controls, 0.5 for MCI and 1 for AD cases. Subjects meeting that criterion were further evaluated clinically and psychometrically.

The AD group consisted of 36 cases with probable AD diagnosed according to the DSM-IV criteria [26]. The diagnosis of dementia was based on the clinical and neuropsychological assessments and given before inclusion in this study. The MoCA test was applied independently of the MCI or AD diagnostic process. All demented subjects had an informant who provided an adequate clinical history.

The MCI group consisted of 42 elderly participants. Mild cognitive impairment was diagnosed based on clinical evaluation and previously established criteria [3]. Accordingly, the group comprised subjects with subjective complaints of gradual memory loss over at least 6 months reported by the patient or family members.

Individuals demonstrated objective evidence of memory loss confirmed by the clinician, general preservation of other cognitive domains and normal level of functioning in activities of daily living. The group of MCI cases was heterogeneous and consisted of different subtypes of MCI. The inclusion process was based solely on the CDR score and general Petersen's criteria, without specifically focusing on selecting the amnesic-type MCI subjects. Nevertheless, the majority of recruited cases met criteria for amnesic MCI and some could be classified as mixed MCI. Subjects with other obvious medical, neurological, or psychiatric causes of memory loss were excluded. The MCI patients showed no psychiatric comorbidity as well.

The control group consisted of 37 healthy elderly volunteers recruited from the community, without subjective cognitive complaints and normal baseline neuropsychological performance. The control subjects also underwent a clinical psychiatric examination to exclude psychiatric comorbidity.

Demographic characteristics of the study participants are presented in Tables 2 and 3.

The proportion of women in each group was similar. The control subjects were significantly younger than both MCI and AD patients; the latter two groups were matched for age. Patients with AD were significantly less educated than both MCI and controls, while MCI subjects and controls had a comparable level of education ($p = 0.4$).

Due to differences in age and education of study participants, linear regression was used to perform adjustment for those variables significantly correlated with MoCA and/or MMSE scores.

Table 2. Demographic characteristics of study participants. Post-hoc testing of between-group comparisons was performed for statistically significant results of analysis of variance (ANOVA)

Variable	AD (N = 35)	MCI (N = 42)	Controls (N = 37)	ANOVA F (p)	Between-group comparisons (p values)		
					AD vs. MCI	AD vs. controls	MCI vs. controls
Gender (proportion of women)	0.7	0.8	0.7	NA	No difference between the groups		
Age [years]; mean $\pm$ SD	76.3 $\pm$ 5.8	74.2 $\pm$ 6.4	71.4 $\pm$ 5.2	6.3 ($p = 0.002$)	0.29	0.002	0.11
Education [years]; mean $\pm$ SD	9.1 $\pm$ 3.7	13.4 $\pm$ 4.9	14.3 $\pm$ 3.1	17.40 ($p < 0.0001$)	0.0002	0.0001	0.62

SD – standard deviation, AD – Alzheimer disease, MCI – mild cognitive impairment, NA – not applicable

Table 3. Clinical characteristics of study participants. Post-hoc testing of between-group comparisons was performed for statistically significant results of analysis of variance (ANOVA)

Variable	AD (N = 35)	MCI (N = 42)	Controls (N = 37)	ANOVA F (p)	Between-group comparisons (p values)		
					AD vs. MCI	AD vs. controls	MCI vs. controls
MMSE [total points]; mean ± SD	23.1 ± 2.4	27.7 ± 1.7	28.9 ± 1.0	39.85 (p < 0.0001)	0.0001	0.0001	0.29
MoCA [total points]; mean ± SD	15.1 ± 2.6	22.1 ± 3.0	25.1 ± 2.8	57.83 (p < 0.0001)	0.0001	0.0001	0.0004
GDS [total points]; mean ± SD	3.7 ± 3.1	3.4 ± 2.6	2.4 ± 2.4	2.31 (p = 0.1038)	NS	NS	NS

MMSE – Mini-Mental State Examination, MoCA – Montreal Cognitive Assessment, GDS – Geriatric Depression Scale, SD – standard deviation, AD – Alzheimer disease, MCI – mild cognitive impairment, NS – not significant

Instruments

Montreal Cognitive Assessment (MoCA)

The Polish version of the MoCA was demonstrated previously [25]. It has officially been approved by the constructors of the test (available at www.mocatest.org) and administered during the current study.

The scale was adapted through translation and back translation to guarantee semantic equivalence. The Polish version of the MoCA is identical to the English version except for two sentences used in the repetition task, having been replaced by Polish equivalents carrying the same meaning. The second obstacle while preparing the Polish adaptation was the need to modify the letter fluency item. The letter fluency test, called FAS (using the initial letters F, A and S) is probably the most commonly used letter fluency task. Various letters are used in different languages depending on their relative frequencies; however, normative data are available for these versions. The standardization of the test is essential as clinicians may administer many alternate versions when no normative data exist. For example, letters K, S, P or M and W are used in Polish but normalization of these versions in practice is lacking. Moreover, the FAS fluency test is frequently used for clinical and research purposes in Poland as well as in many other countries. Taking that into account we decided to apply the letter F taken from the original FAS test. Finally, there were some doubts considering the choice of words for the learning task. Like the authors of other local versions of

the MoCA, we decided to use the list of words directly from the English version, translated into Polish. In our opinion this guarantees the semantic equivalence of the testing task.

General assessment

All subjects underwent general medical, neurological and psychiatric investigations. The testing battery applied included the MoCA [7,25], MMSE [8], CDR scale [27], and the short (15-item) version of the Geriatric Depression Scale (GDS) [28]. The choice of applied tools was to guarantee diagnostic precision and correct attribution to study groups.

None of the participating subjects had any signs of neurological or unstable somatic disease.

Examination procedure

The first stage comprised the recruitment of cases. For that purpose, the CDR scale was applied (R.M.). Subjects meeting the main inclusion criterion (CDR score, as mentioned above) were further evaluated clinically with the clinical criteria for AD and MCI (R.M.) and battery of instruments. All participants were administered the MMSE test, MoCA test, and GDS (J.M.). The second rater performed general clinical assessment (R.M.). The tests were administered in the same order and the same standardized instructions were given.

Some tasks overlap between the MMSE and MoCA tests; therefore the MoCA test was performed at the be-

ginning, followed by the MMSE. The orientation scores and serial 7s trial score were copied onto the MMSE sheet. The serial 7s task acts as a distracter for the recall of three words. While applying the MMSE, we decided to perform comprehension tasks at this point.

Data management and statistical analysis

Continuous variables are presented as means and standard deviations. To determine differences between the analysed groups, analysis of variance (ANOVA) with post-hoc verification using Tukey's test was performed. Categorical variables are presented as fractions. Differences of such characteristics between the groups were calculated using Pearson's chi-square test. The Mini-Mental State Examination and MoCA raw scores were adjusted for age and years of education using a linear regression model. ROC curves were used to compare the diagnostic performance of MMSE and MoCA in discriminating dementia from MCI and controls as well as MCI versus controls. A p -value threshold of 0.05 was imposed as the statistical significance level for chi-square tests and ANOVA with the same threshold applica-

ble for post-hoc testing. For ROC curves, 95% confidence intervals not including the value 0.5 were considered statistically significant.

Results

The data of 115 subjects were collected for this study, including 36 with mild AD dementia (CDR = 1), 42 with MCI (CDR = 0.5) and 37 controls (CDR = 0). Both MMSE and MoCA scores were significantly different in all between-the-group comparisons (AD vs. controls, AD vs. MCI, MCI vs. controls; data presented in Table 3). The GDS scores were comparable in all study groups (data presented in Table 3).

A pairwise comparison of areas under the ROC curves was performed to compare the clinical applicability of the MMSE and MoCA tests in separating the groups. Different cut-off scores were tested and likelihood ratios, sensitivity and specificity were calculated both for MMSE and MoCA (results are presented in Tables 4-7).

As MMSE is supposed to be a screening test, it is much more important not to miss any case of dementia

Table 4. Psychometric characteristics of Mini-Mental State Examination (MMSE) in detecting Alzheimer disease (AD) dementia ($N = 36$) versus combined groups of mild cognitive impairment (MCI) and controls ($N = 79$). Optimum cut-off based on ROC curve with area under the curve (AUC) 0.86 (95% CI 0.78-0.92) equalled 26 and is marked with an asterisk

Test and cut-off score used	Sensitivity	Specificity	+ Likelihood Ratio	- Likelihood Ratio	Number needed to diagnose
MMSE ≤ 23	40.0 (23.9-57.9)	98.7 (93.1-99.8)	31.6	0.6	2.6
MMSE ≤ 24	48.6 (31.4-66.0)	94.9 (87.5-98.6)	9.6	0.5	2.3
MMSE ≤ 25	60.0 (42.1-76.1)	92.4 (84.2-97.1)	7.9	0.4	1.9
MMSE $\leq 26^*$	80.0 (63.1-91.5)	77.2 (66.4-85.9)	3.5	0.3	1.7
MMSE ≤ 27	88.6 (73.2-96.7)	62.3 (50.4-72.7)	2.3	0.2	2.0

Table 5. Psychometric characteristics of Mini-Mental State Examination (MMSE) in differentiating patients with mild cognitive impairment (MCI) ($N = 42$) from controls ($N = 37$). Optimum cut-off based on ROC curve with area under the curve (AUC) 0.61 (95% CI 0.50-0.72) equalled 27 and is marked with an asterisk

Test and cut-off score used	Sensitivity	Specificity	+ Likelihood Ratio	- Likelihood Ratio	Number needed to diagnose
MMSE ≤ 24	0.0 (0.0-8.5)	100.0 (90.4-100.0)	—	1.0	—
MMSE ≤ 25	14.3 (5.5-28.6)	100.0 (90.4-100.0)	—	0.9	7.0
MMSE ≤ 26	28.6 (15.7-44.6)	83.7 (68.0-93.8)	1.8	0.8	8.1
MMSE $\leq 27^*$	47.6 (32.0-63.6)	72.9 (55.9-86.2)	1.8	0.7	4.9
MMSE ≤ 28	76.2 (60.5-87.9)	40.5 (24.8-57.9)	1.3	0.6	6.0

Table 6. Psychometric characteristics of the Montreal Cognitive Assessment (MoCA) test in differentiating patients with dementia ($N = 36$) from controls or individuals with mild cognitive impairment (MCI) ($N = 79$). Optimum cut-off based on ROC curve with area under the curve (AUC) 0.91 (95% CI: 0.85-9.6) equalled 19 and is marked with an asterisk

Test and cut-off score used	Sensitivity	Specificity	+ Likelihood Ratio	– Likelihood Ratio	Number needed to diagnose
MoCA ≤ 17	62.9 (44.9-78.5)	92.4 (84.2-97.1)	8.3	0.4	1.8
MoCA ≤ 18	77.1 (59.9-89.5)	86.1 (76.4-92.8)	5.5	0.3	1.6
MoCA $\leq 19^*$	85.7 (69.7-95.1)	82.3 (72.1-90.0)	4.8	0.2	1.5
MoCA ≤ 20	91.4 (76.9-98.1)	72.1 (60.9-81.7)	3.3	0.1	1.6
MoCA ≤ 21	94.3 (80.8-99.1)	64.6 (53.0-75.0)	2.7	0.1	1.7

Table 7. Psychometric characteristics of the Montreal Cognitive Assessment (MoCA) test in differentiating patients with mild cognitive impairment (MCI) ($N = 42$) from controls ($N = 37$). Optimum cut-off based on ROC curve with area under the curve (AUC) 0.74 (95% CI: 0.63-0.83) equalled 24 and is marked with an asterisk

Test and cut-off score used	Sensitivity	Specificity	+ Likelihood Ratio	– Likelihood Ratio	Number needed to diagnose
MoCA ≤ 22	54.8 (38.7-70.1)	67.6 (50.2-82.0)	1.7	0.7	4.5
MoCA ≤ 23	71.4 (55.4-84.3)	62.2 (44.8-77.5)	1.9	0.5	3.0
MoCA $\leq 24^*$	80.9 (65.9-91.4)	54.0 (36.9-70.5)	1.8	0.3	2.9
MoCA ≤ 25	88.1 (74.4-96.0)	40.5 (24.8-57.9)	1.5	0.3	3.5
MoCA ≤ 26	90.5 (77.4-97.3)	37.8 (22.5-55.2)	1.5	0.2	3.5

than to have a false positive result. The best parameters in terms of likelihood ratios and false negative results were achieved with a cut-off score of 26 (results are presented in Table 4). Interestingly, a commonly recommended cut-off score of 24 yielded a highly unacceptable result of 40% false negatives. Therefore, we propose a cut-off score of 26 as the best for dementia detection, with a false negative rate of 20% and a false positive rate of 23%.

The Mini-Mental State Examination proved to perform poorly in discriminating MCI from healthy controls. Even for MMSE ≤ 27 the rate of false negative MCI attributions was as high as 52.5%, while using MMSE ≤ 28 gave an unacceptable 59.5% rate of false positives (results are presented in Table 5). Thus, MMSE could not be reliably used in our sample for the detection of MCI.

The optimal MoCA cut-off score for differentiating dementia from MCI/controls was 19, providing decision-making level likelihood ratios (results are presented in Table 6). A cut-off score of 19 for MoCA turned out to be comparable to a cut-off of 27 for MMSE. The MoCA test showed no advantage over MMSE in dementia detection.

During MCI versus controls comparison, MoCA cut-off scores of 25 or 26 were characterized by good sensitivity with false negative rates of 11.9 and 9.5%, respectively. However, there were quite high false positive ratios, namely 69.5 and 62.16%. The optimum cut-off based on an ROC curve analysis, with best positive and negative likelihood ratios, proved to be 24 (results are presented in Table 7). As the false positive rate still equals 46%, the MoCA test may not be considered an ideal tool to discriminate MCI from healthy elderly; nevertheless, it is still considerably better than the MMSE in terms of sensitivity (compare with Table 5).

In conclusion, we propose to employ the MoCA cut-off score of 24 to screen for MCI and a cut-off score of 19 to detect dementia with optimal precision.

There were no detectable differences in terms of diagnosing AD when using either test, with a slight tendency towards superiority of the MoCA (difference of area under the curve [AUC] 0.05; 95% CI: 0.02 to 0.13; $p = 0.14$). In terms of detecting MCI, the difference between the tests was greater, though again it did not reach statistical significance (difference of AUC 0.13; 95% CI: 0.01 to 0.26; $p = 0.08$). However, as the AUC for detecting MCI using the MMSE was dri-

ven mostly by specificity and for MoCA by sensitivity, the latter test seems to be a better option when screening for MCI. This assumption, however, needs further validation.

Discussion

The MMSE remains the most frequently used cognitive screening instrument. It is appreciated as the best tool for ruling out a diagnosis of dementia in the community and primary care. However, its sensitivity to detect early AD and, in particular, MCI cases is inadequate [29]. In our study, the commonly recommended MMSE cut-off score for diagnosing dementia (24 points) yielded a highly unacceptable result of 40% false negatives (for the Polish version of the MMSE). The best parameters in terms of likelihood ratios and false negative results were achieved with a cut-off score of 26.

The MoCA test seems to be an ideal tool for diagnosing suspected MCI cases, sensitive for individuals performing well on MMSE, resistant to educational bias. Nasreddine *et al.* compared the psychometric properties of the MMSE and MoCA in the original paper and reported high sensitivity and specificity for detecting MCI, as currently conceptualized, in patients performing in the normal range on MMSE [7]. Using a cut-off score of 26, the MMSE had a sensitivity of 18% to detect MCI, whereas the MoCA correctly attributed 90% of MCI subjects. The analysis of mild AD cases demonstrated a sensitivity of 78%, whereas MoCA detected 100% of cases. Specificity was excellent for both the MMSE and MoCA (100% and 87%, respectively).

Our preliminary data [25], consistently with findings of others [15,30], proved that lowering the cut-off score from the originally proposed 26 to 24 points significantly improved test accuracy. The use of the MoCA cut-off score of 26 showed good sensitivity of detecting cognitively impaired subjects (0.94 [95% CI: 0.87-0.98]), but with unacceptably low specificity (0.35 [95% CI: 0.2-0.44]). Overall accuracy of the test was found to equal 0.76 (95% CI: 0.66-0.82). On the other hand, when a cut-off score of 24 was selected, the test performance in correctly detecting cognitively impaired subjects improved significantly. Sensitivity declined marginally compared with the original 26-point threshold (0.90 [95% CI: 0.82-0.96]) while specificity was increased to 0.65 (95% CI: 0.48-0.78), providing an overall accuracy of 0.81 (95% CI: 0.7-0.89).

In the current study, we found MMSE to perform poorly in discriminating MCI versus normal controls. False negative screening for MCI was as high as 52.5% even for $MMSE \leq 27$, while using $MMSE \leq 28$ gave an unacceptable 59.5% rate of false positives.

As mentioned above, the MoCA seems to perform better in this area, but the ideal cut-off threshold is open to debate. Luis *et al.* showed that using the recommended cut-off score of 26, the MoCA detected 97% of cognitively impaired subjects but specificity was fair (35%) [15]. Lowering the cut-off score to 23 excellently improved sensitivity (96%) and specificity (95%) of the MoCA test. In our study, MoCA cut-off scores of 25 or 26 were characterized by good sensitivity, with false negative rates of 11.9 and 9.5%, respectively. However, there were quite high false positive rates of 69.5 and 62.16%, respectively. The optimum cut-off based on an ROC curve analysis proved to be 24. The Polish version of the MoCA test performed marginally better than the MMSE in discriminating MCI from controls (but not reaching statistical significance; $p = 0.08$). The detection of MCI using the MMSE was driven mostly by specificity (72.9 for 27 points) and for the MoCA by sensitivity (80.9 for 24 points), making the latter test a better choice when screening for MCI. It can be explained by the low number of subjects participating in our study. Smith *et al.* studied a comparable number of cases, reporting MMSE and MoCA sensitivities comparable to the study by Nasreddine; however, specificity of the test was significantly lower (50% vs. 87%) [30].

Several methodological issues limit the interpretation of the results of this study. Firstly, the diagnosis relied solely on the clinical picture, without pathological confirmation. Secondly, a limited number of cases were included in this study. Due to the low number of studied subjects, assumptions on the utility of the MoCA as compared to the MMSE should be interpreted with caution. The cut-off thresholds should be verified in some independent samples. Thirdly, during preparation of the Polish version of the MoCA test, some problems arose. As mentioned above, the scale was adapted through translation and back translation to guarantee semantic equivalence. The Polish version of the MoCA is identical to the English version. We decided to replace two sentences used in the repetition task with their Polish equivalents carrying the same meaning. The second obstacle while preparing the Polish adaptation was the need to modify the letter fluency item (compare with the Spanish version) [31]. The letter F is used as part of

the MoCA in many other (non-English-speaking) countries [7,32,33]. As mentioned above, the choice of letters depends on their relative frequencies in different languages; however, normative data are available for these versions. For example, letters K, S, P or M and W are used in Polish in routine clinical practice but the normalization of this variant is still lacking. Moreover, these letters are used for research purposes and publications alongside the 'FAS' version. The standardization of the test is essential as – in the absence of normative data – clinicians may administer many alternative versions. In this study, the importance of the letter F for the interpretation of results is marginal (1 point per 30 points for the complete test). Those arguments supported the use of the letter F in our version of the test. However, because of rational doubts regarding its use, other variants of the Polish MoCA test (employing alternative letters) are planned. Finally, there were some doubts considering the choice of words for the learning task. We decided to use the list of words directly from the English version, translated into Polish for the guaranteed semantic equivalence. The same strategy was chosen by many authors of other European versions of the MoCA (available at www.mocatest.org). Further studies with modified variants of the MoCA test are planned.

The differences in age and education level between the compared groups were significant, which could potentially bias analyses of diagnostic efficacy. To minimize this risk, mathematical adjustments were introduced allowing the evaluation of the MoCA and MMSE scales independently of the confounding variables.

The main applicability of the study is the finding that the Polish version of the MoCA can be used in everyday clinical practice in a Polish population for the detection of cognitive impairment.

We have demonstrated that the Polish versions of the MMSE and MoCA tests are comparable in discriminating mild dementia from both MCI and control groups. Further research is required to reliably determine sensitivity and specificity of the MoCA test, and its ability to discriminate MCI from normal cognitive functioning should be validated in longitudinal studies.

Conclusions

1. The Polish versions of the MMSE and MoCA tests are comparable in discriminating mild dementia from both MCI and control groups.
2. We propose to apply the MoCA test for MCI screening using an optimal cut-off score of 24 and for

dementia detection using a cut-off score of 19. The cut-off thresholds should be verified in other independent samples.

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Disclosure

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