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REVIEW

Is the Montreal Cognitive Assessment (MoCA) screening superior to the Mini-Mental State Examination (MMSE) in the detection of mild cognitive impairment (MCI) and Alzheimer's Disease (AD) in the elderly?

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ABSTRACT

Objective: To compare the accuracy of Mini-Mental State Examination (MMSE) and of the Montreal Cognitive Assessment (MoCA) in tracking mild cognitive impairment (MCI) and Alzheimer's Disease (AD).

Method: A Systematic review of the PubMed, Bireme, Science Direct, Cochrane Library, and PsycInfo databases was conducted. Using inclusion and exclusion criteria and staring with 1,629 articles, 34 articles were selected. The quality of the selected research was evaluated through the Quality Assessment of Diagnostic Accuracy Studies 2 tool (QUADAS-2).

Result: More than 80% of the articles showed MoCA to be superior to MMSE in discriminating between individuals with mild cognitive impairment and no cognitive impairment. The area under the curve varied from 0.71 to 0.99 for MoCA, and 0.43 to 0.94 for MMSE, when evaluating the ability to discriminate MCI in the cognitively healthy elderly individuals, and 0.87 to 0.99 and 0.67 to 0.99, respectively, when evaluating the detection of AD. The AUC mean value for MoCA was significantly larger compared to the MMSE in discriminating MCI from control [0.883 (CI 95% 0.855-0.912) vs MMSE 0.780 (CI 95% 0.740-0.820) $p < 0.001$].

Conclusion: The screening tool MoCA is superior to MMSE in the identification of MCI, and both tests were found to be accurate in the detection of AD.

Key words: Cognitive assessment, Alzheimer's disease, mild cognitive impairment, diagnosis and classification, early onset dementia

Introduction

Dementia is a worldwide public health problem. According to the World Health Organization, in 2012, 36 million people were diagnosed with dementia, at a prevalence rate of 4.7%. For the people older than 65, the prevalence rate practically doubled every five years. In addition to the prevalence, the impact on the economy, health, and social aid for dementia is also increasing (Alzheimer's Association, 2011; Hurd *et al.*, 2013; Prince *et al.*, 2013; Wimo *et al.*, 2013a; 2013b; Zhu *et al.*, 2015). As a result, dementia has become a priority for a coordinated action by the European Union at a global stage. Several countries have national strategies for dementia and governmental policies, which emphasize early diagnosis and intervention (Banerjee, 2010; Prince *et al.*, 2011).

Alzheimer's Disease (AD) is the main cause of dementia. It is a progressive neurodegenerative disease, clinically characterized by the impairment of cognitive abilities and functions, as well as changes in behavior (Dubois *et al.*, 2015). Another cognitive disorder which has cognitive characteristics between normal cognition and dementia is mild cognitive impairment (MCI). It is a clinical and cognitive syndrome with clear diagnostic criteria (Petersen, 2004). To diagnose MCI, the following is needed: complaint of a decline in cognitive function, obtained from the individual or an informant who

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knows the patient; the deterioration of one or more cognitive domains at a higher level than expected at the given age and education of the patient, confirmed in an objective manner by a professional through a cognitive test; independent function preserved, with no impairment in social and work abilities of the individual (Albert *et al.*, 2011).

The cognitive decline could be from a variety of cognitive domains, including memory, executive function, attention, language, and visuospatial ability. Impaired episodic memory, with a reduction in the ability to learn and retain new information, is especially seen in patients with MCI, who could later progress to dementia from AD (Albert *et al.*, 2011). The annual conversion rate of MCI to AD varies from 6% (Forlenza *et al.*, 2010), 10%–15% (Petersen *et al.*, 1999), to 31% a year (Bruscoli and Lovestone, 2004).

Therefore, identifying MCI is fundamental for the execution of preventive and therapeutic interventions in the early stages of the disease (Schönknecht *et al.*, 2005). However, the diagnosis of MCI is a complex task at times, considering that it is necessary to frequently distinguish it from the manifestations of early signs of onset dementia and the cognitive changes regarding the natural process of aging.

The accurate and early diagnosis of cognitive impairment benefits patients, families, and society (Alzheimer's Association, 2011; Tsai *et al.*, 2016). One of the main advantages is the opportunity to initiate an early effective and adequate intervention. It could also improve the access of the patient to support services and allow for future planning. An early intervention can potentially improve the quality of life of the patients and their caregivers (Boise *et al.*, 1999; De Vugt and Verhey, 2013).

Because complaints regarding memory loss are frequent during physician office visits, reliable and valid tools to discriminate healthy patients from those with impairment are necessary. The first approach for a cognitive evaluation involves administering a cognitive triage test (Hebert *et al.*, 2013). Although several triage tools are used to detect a decline in cognitive function, The Mini-Mental State Examination (MMSE) has been the most used screening instrument throughout decades (Batty *et al.*, 2013; Bos *et al.*, 2015; Folstein *et al.*, 1975; Matsumoto *et al.*, 2014; Tsoi *et al.*, 2015; Zeki Al Hazzouri *et al.*, 2014). However, it has shown not to be adequate in detecting MCI and clinical signs of dementia (Carnero-Pardo, 2014,2015; Ihl *et al.*, 1992; Petersen, 2011; Portet *et al.*, 2006; Quiroga *et al.*, 2004; Tombaugh and Mcintyre, 1992; Wind *et al.*, 1997). Thus, new triage tests, which include The Montreal Cognitive Assessment (MoCA), have been developed (Olazarán *et al.*, 2016; Velayudhan *et al.*, 2014).

MoCA was developed by Nasreddine and collaborators (2005) and has been shown as a tracking tool with a high ability to discriminate normal cognitive function and MCI and early onset dementia. The average time to administer the test is 10 to 15 minutes. The main advantage of MoCA is its sensitivity in detecting MCI and mild AD: 90% and 100%, respectively (Nasreddine *et al.*, 2005).

Studies evaluated the cognitive triage ability between MoCA and MMSE, demosntrating MoCA to be a more useful tracking tool than MMSE in detecting dementia (Freitas *et al.*, 2013; Fujiwara *et al.*, 2010; Gil *et al.*, 2015; Luis *et al.*, 2009; Tsai *et al.*, 2016; Yeung *et al.*, 2014). However, some researchers have indicated that MoCA is not superior to MMSE when evaluating patients with MCI (Kasai *et al.*, 2012; Zhou *et al.*, 2014).

Consequently, MoCA and MMSE have been used as cognitive tracking tools, including in primary care clinics, with positive results (Hanzevacki *et al.*, 2011). Nevertheless, there is no consensus as to which tool is more accurate in detecting a decline in cognitive function. Therefore, the objective of this systematic review is to evaluate the current state of the subject and assess which of the tests has been shown to be more accurate in tracking MCI and AD and which has been more recommended by researchers.

Method

This systematic review was registered on the Prospero systematic review website (PROSPERO 2017: CRD42017069349). Searches were conducted from May to July 2017, with an updated article search in March 2018, through five servers in the following data bases: MEDLINE, through Pubmed (http://www.pubmed.gov), Biblioteca Regional de Medicina (BIREME) [Literatura Latino-americana e do Caribe em Ciências da Saúde (LILACS), Indice Bibliográfico Espanhol de Ciências da Saúde (IBECS) and the Scientific Electronic Library Online (SciELO)], Science Direct, Cochrane Library and PsycInfo.

The search for articles was conducted using the following strategy and terms: "Montreal Cognitive Assessment" OR MoCA OR "Avaliação cognitiva de Montreal" OR "Evaluación Cognitiva Montreal" AND "Mini Mental State Examination" OR "Mini mental" OR MMSE OR "Mini Exame do Estado Mental" OR MEEM OR "Mini examen del estado mental".

The inclusion criteria of this systematic review were original studies that evaluated and compared the accuracy of MoCA and MMSE in discriminating cognitively healthy elderly individuals from elderly individuals with MCI and/or AD. The exclusion

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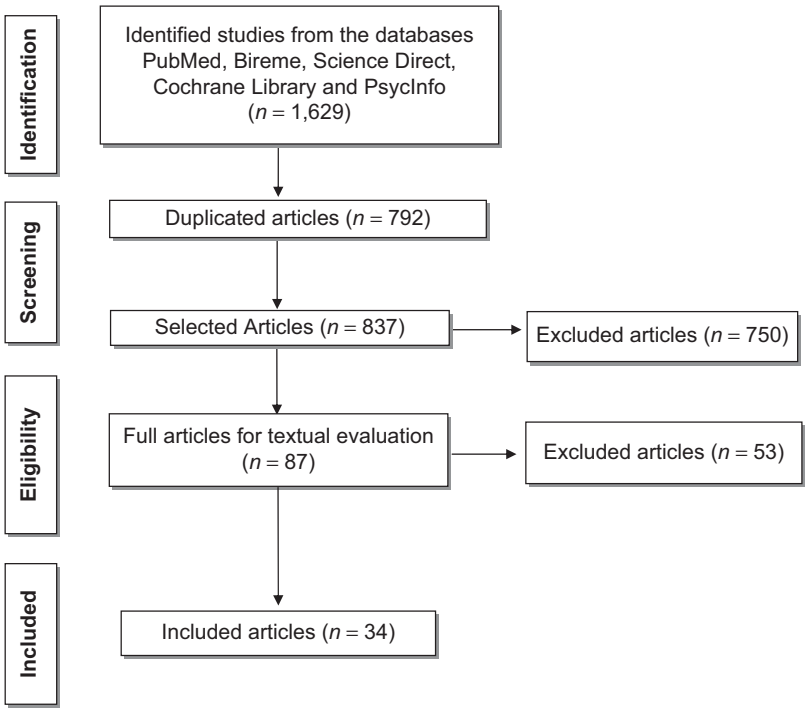

Figure 1. Flowchart of the selection of the articles used in the systematic review according to the inclusion and exclusion criteria.

criteria were review articles, case reports or a series of cases or letters to the editor, including articles which did not deal with the subject matter or contained information regarding the outcome of this review. Articles in which the research conducted was not on elderly subjects or which were not written in English, Portuguese, or Spanish were also excluded. There was no restriction regarding the publication date.

A list of the items of *Preferred Reporting Items for Systematic Reviews and Meta-Analysis* (PRISMA), developed by Liberati *et al.* (2009), were used as a guide to structure this study, since PRISMA currently constitutes a tool that provides better quality for systematic review studies.

The quality of the selected studies was evaluated through the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool (Whiting *et al.*, 2011), as recommended by Cochrane Collaboration (Davis *et al.*, 2013). The data of accuracy of MoCA and MMSE, for detection of MCI and AD, are presented as the average — considered by the sampling size in the selected studies of this systematic review — and area under the receiver operating characteristic curve (AUC) with 95% confidence intervals (CI 95%). The differences between these averages were statistically compared through the Mann-Whitney test, for a 0.05 level of significance ($p < 0.05$). All the statistical analysis was computed using the GraphPad Prism 6.0 software.

Results

The search in the data base found 1,629 publications. Microsoft Excel 2007 software was used to process the articles. After excluding duplicated references, a total of 837 studies were read and analyzed by two independent reviewers. Of the 837 articles selected through the title and abstract, 740 were excluded: 12 letters to the editor, 3 case reports, 41 review articles, 16 publications in conference annals, and 678 original articles which did not present the subject matter studied. Of the 87 selected articles for textual evaluation, 53 did not approach the subject matter studied. Therefore, after exclusion, 34 articles were selected for this systematic review. The stages of the selection of the articles are shown in Figure 1, following the PRISMA model.

More than 65% of the studies selected in this systematic review were conducted within the last five years, showing relevance and a growing interest in the scientific community on this subject matter (Table 1). Most of the studies were conducted in the Asian Continent (20/34), 24% of the research was conducted on elderly individuals from China (8/34), one of the countries with the largest population in the world aged over 60.

To determine the diagnosis of dementia, most of the studies used the diagnostic criteria from the Manual Diagnóstico e Estatístico de Transtornos Mentais (DSM IV). For the probable diagnosis of

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Table 1. Description of the studies included in the systematic review, ordered according to the publication date (n=34)

Study; country	Population (N sampling)	Age (years) average ±SD	Female gender (%)	Education (years) – average ±SD	Cut off MoCA – control vs MCI control vs AD	Accuracy of MoCA (AUC) – control vs MCI	Accuracy of MoCA (AUC) – control vs AD	Accuracy of MMSE (AUC) – control vs MCI	Accuracy of MMSE (AUC) – control vs AD	MoCA control vs MCI sensitivity/ specificity	MoCA control vs dementia sensitivity/ specificity	MMSE control vs MCI sensitivity/ specificity	MMSE control vs dementia sensitivity/ specificity	Test which presented a higher accuracy
Saleh *et al.* (2018); Egypt	Control (112) MCI (39) AD (54)	65.9 ± 5.02 67.72 ± 6.31 72.11 ± 7.64	76.8 56.4 50.0	12.8 ± 4.38 9.74 ± 5.48 4.24 ± 5.84	21/22 16/17	0.99	0.99	0.94	0.99	92.5/98.2	90.7/97.4	–	–	MoCA to MCI
Delgado *et al.* (2017); Chile	Control (104) MCI (48) Dementia (20)	72.3 ± 5.4 74.9 ± 7.8[a]	65.0 51.5[a]	11.4 ± 4.2 10.8 ± 4.4[a]	20/21 19/20	0.90	0.96	0.65	0.89	75/82	90/86	–	–	MoCA
Janelidze *et al.* (2017); Georgia	Control (46) MCI (20) AD (20)	57.7 ± 10.8 62.8 ± 11.5 70.5 ± 6.5	67.4 25.0 45.0	11.5 ± 0.5 11.6 ± 0.5 11.7 ± 0.5	21/22 –	0.88	0.95	0.43	0.67	100/69	–	–	–	MoCA
Matias-Guiu *et al.* (2017); Spain	Control (68) AD (92)	77.6 ± 7.1 78.8 ± 6.0	64.7 65.2	8.0 ± 5.4 7.1 ± 4.1	– 14/15	–	0.86	–	–	–	–	–	–	
Roalf *et al.* (2017); USA	Control (138) MCI (109) AD (340)	70.28 ± 8.99 72.95 ± 8.64 75.89 ± 8.24	66.7 52.2 64.7	16.95 ± 2.74 14.71 ± 3.96 13.39 ± 4.27	24/25 21/22	0.95	0.99	0.88	0.98	94/80	94/100	75/85	94/96	MoCA to MCI
Chen *et al.* (2016); China	Control (280) MCI (264)	Education <6 years: 68.2 ± 9.1; 68.5 ± 8.5; 67.9 ± 9.4 Education 6–12 years: 63.4 ± 6.8; 69.1 ± 8.5; 68.3 ± 8.8 Education >12 years: 65.6 ± 8.1; 71.1 ± 8.0; 73.2 ± 7.6	Education <6 years: 65.5; 69.8; 76.3 Education 6–12 years: 24.1; 38.0; 50.0 Education >12 years: 30.9; 51.1; 47.5	Education <6 years: 4.8 ± 1.7; 3.3 ± 2.4; 3.7 ± 2.5 Education 6–12 years: 9.4 ± 1.0; 10.2 ± 1.6; 10.1 ± 1.8 Education >12 years: 13.8 ± 1.9; 14.1 ± 2.0; 15.3 ± 1.1	Education <6 years: 18/19 – Education 6–12 years: 21/22 – Education >12 years: 23/24 –	Education <6 years: 0.90 Education 6–12 years: 0.95 Education >12 years: 0.92	–	Education <6 years: 0.80 Education 6–12 years: 0.74 Education >12 years: 0.72	–	Education <6 years: 87.9/81.0 Education 6–12 years: 92.9/91.2 Education >12 years: 89.8/90.9	–	Education <6 years: 86.2/60.3 Education 6–12 years: 78.6/52.2 Education >12 years: 76.4/53.4	–	MoCA
Mellor *et al.* (2016); China	Control (710) MCI (267) AD (50)	70.3 ± 7.7 76.5 ± 7.7 82.5 ± 5.5	51.9 70.0 78.0	9.1 ± 4.4 5.2 ± 4.8 3.7 ± 4.1	Education ≤6 years: 16/17 14/15 Education 7–9 years: 22/23 19/20 Education ≥10 years: 24/25 19/20	Education ≤6 years: 0.88 Education 7–9 years: 0.85 Education ≥10 years: 0.85	Education ≤6 years: 0.96 Education 7–9 years: 0.99 Education ≥10 years: 0.87	Education ≤6 years: 0.85 Education 7–9 years: 0.76 Education ≥10 years: 0.72	Education ≤6 years: 0.97 Education 7–9 years: 1.00 Education ≥10 years: 0.72	87/73	100/87	68/83	100/93	MoCA to MCI MMSE to AD

Table 1. Continued

Study; country	Population (*N* sampling)	Age (years) average ±SD	Female gender (%)	Education (years) – average ±SD	Cut off MoCA – control vs MCI control vs AD	Accuracy of MoCA (AUC) – control vs MCI	Accuracy of MoCA (AUC) – control vs AD	Accuracy of MMSE (AUC) – control vs MCI	Accuracy of MMSE (AUC) – control vs AD	MoCA control vs MCI sensitivity/specificity	MoCA control vs dementia sensitivity/specificity	MMSE control vs MCI sensitivity/specificity	MMSE control vs dementia sensitivity/specificity	Test which presented a higher accuracy
Tsai *et al.* (2016); Taiwan	Control (26) MCI (59) AD (57)	76.2 ± 8.5	49.6	Elementary school: 35.9% Junior high school: 16.2% Senior high school: 19.0% University: 28.9%	23/24 19/20	0.91	0.87	0.88	0.89	88/73	79/80	88/70	84/86	MoCA to MCI –
Chu *et al.* (2015); Hong Kong	Control (115) MCI (87) AD (64)	72.2 ± 6.1 77.2 ± 6.3 78.5 ± 5.8	75.7 63.2 60.9	6.97 ± 4.69 4.62 ± 5.19 4.56 ± 5.00	22/23 19/20	0.85	0.99	0.78	0.99	78/73	94/92	67/83	94/98	MoCA to MCI
Horton *et al.* (2015); USA	Control (124) MCI (126) AD (67)	69.6 ± 7.9 69.4 ± 7.7 74.4 ± 8.1	67 52 37	15.3 ± 2.6 14.5 ± 2.8 15.2 ± 2.7	25/26 19/20	0.88	0.93	0.79	0.95	–	–	–	–	MoCA to MCI
Hsu *et al.* (2015); Taiwan	Control (260) AD (16)	67.93 ± 6.06	50.7	11.4 ± 4.0	– 23/24	–	0.89	–	0.7	–	78/94	–	38/92	MoCA
Tan *et al.* (2015); China	Control (4150) MCI (2311) Dementia (984)	80.9 ± 4.6 82.1 ± 4.5 83.9 ± 4.9	4.9 3.6 3.9	8.5 ± 5.5 7.5 ± 5.7 6.0 ± 6.0	60–79 years: 25/26 24/25 80–89 years: 24/25 21/22 ≥90 years: 23/24 19/20	0.94	0.91	0.85	0.89	>85/>85	>80/>74	–	–	MoCA
Cecato *et al.* (2014); Brazil	Control (39) MCI (45) AD (52)	71.8 ± 6.9 76.6 ± 7.1 77.9 ± 7.0	74.4 60.0 63.5	>9 years: 58.8	24/25 22/23	0.94	0.99	0.83	0.95	82.2/92.3	98.1/100.0	80.0/82.1	92.3/82.1	MoCA
Kaya *et al.* (2014); Turkey	Control (246) MCI (114) AD (114)	68.0 ± 10.3 74.2 ± 8.8 77.2 ± 9.1	60.1 43.0 57.0	–	Elementary: 17/18 15/16 High school: 20/21 18/19 Higher education: 22/23 19/20	0.85	0.99	0.84	0.98	Elementary: 67/83 High school: 73/85 Higher education: 81/86	89/90 98/97 99/99	– – –	– – –	MoCA to MCI
Malek-Ahmadi *et al.* (2014); USA	Control (73) MCI (39) AD (34)	82.59 ± 7.67 80.54 ± 8.43 84.74 ± 6.74	45.2 46.2 38.2	14.55 ± 2.41 14.77 ± 2.53 14.56 ± 3.15	– –	0.71	0.94	0.76	0.97	–	–	–	–	–
Yeung *et al.* (2014); Hong Kong	Control (49) MCI (93) Dementia (130)	73.6 ± 7.6 76.4 ± 7.5 79.5 ± 6.8	59.0 53.0 65.0	5.61 ± 4.27 4.80 ± 4.78 3.26 ± 4.03	21/22 18/19	0.85	0.97	0.86	0.99	82.8/73.5	92.3/91.8	78.5/81.6	95.4/89.8	–

Table 1. Continued

Study; country	Population (*N* sampling)	Age (years) average ±SD	Female gender (%)	Education (years) – average ±SD	Cut off MoCA – control vs MCI control vs AD	Accuracy of MoCA (AUC) – control vs MCI	Accuracy of MoCA (AUC) – control vs AD	Accuracy of MMSE (AUC) – control vs MCI	Accuracy of MMSE (AUC) – control vs AD	MoCA control vs MCI sensitivity/ specificity	MoCA control vs dementia sensitivity/ specificity	MMSE control vs MCI sensitivity/ specificity	MMSE control vs dementia sensitivity/ specificity	Test which presented a higher accuracy
Zhou *et al.* (2014); China	Control (148) MCI (24)	67.7 ± 7.2 67.2 ± 6.6	56.1 79.2	7.0 ± 0.5 6.2 ± 1.2	20/21 –	0.72	–	0.74		75/62	–	83/56	–	–
Dong *et al.* (2013); Singapore	Control (128) MCI (83)	67.4 ± 4.8 74.3 ± 5.5	43.0 61.4	7.9 ± 5.0 3.0 ± 3.8	19/20 –	0.94		0.91		80/92	–	87/80	–	–
Freitas *et al.* (2013); Portugal	Control (180) MCI (90) AD (90)	71.34 ± 7.49 70.52 ± 7.95 69.59 ± 7.05	59.4 61.1 57.8	6.39 ± 4.31 6.50 ± 4.57 6.23 ± 4.12	21/22 16/17	0.86	0.98	0.75	0.96	81/77	88/98	67/72	85/93	MoCA
Hu *et al.* (2013); China	Control (146) MCI (84) AD (72)	67.2 ± 5.3 60.7 ± 5.0 68.4 ± 4.3	55.5 57.1 55.5	9.3 ± 2.6 9.8 ± 3.0 8.9 ± 3.1	26/27 25/26	0.93	0.96	0.74	0.98	92/85	92/96	85/53	92/100	MoCA to MCI –
Memória *et al.* (2013); Brazil	Control (41) MCI (43) AD (28)	71.7 ± 4.6 74.3 ± 5.6 76.5 ± 4.9	80.5 67.4 53.6	13.4 ± 4.4 11.4 ± 4.2 11.1 ± 5.0	24/25 21/22	0.82	0.99	0.69	–	81/77	91/100	60/68	–	MoCA
Roalf *et al.* (2013); USA	Control (140) MCI (126) AD (321)	71.2 ± 9.2 72.3 ± 8.1 75.7 ± 8.2	67.1 49.2 62.0	15.9 ± 3.0 14.9 ± 4.21 3.3 ± 4.1	28/29 27/28	0.89	0.99	0.85	0.99	84/79	94/96	82/73	96/97	MoCA to MCI –
Wang *et al.* (2013); Taiwan	Control (62) AD (67)	75.6 ± 5.12 78.19 ± 5.71	41.9 58.2	8.34 ± 4.45 6.42 ± 4.72	– 21/22	–	0.95	–	0.92	–	95.5/82.3	–	88.1/85.5	MoCA
Dong *et al.* (2012); Singapore	Control (33) MCI (61)	62.8 ± 9.9 70.1 ± 9.7	55.2	9.4 ± 3.9 7.2 ± 4.7	19/20 –	0.95	–	0.88	–	–	–	–	–	MoCA
Lifshitz *et al.* (2012); Israel	Control (80) MCI (74)	71.3 ± 4.6 76.3 ± 5.6	46.2 48.6	Elementary: 1%; 22% High school: 50%; 40% Higher education: 49%; 38%	25/26 –	0.96	–	0.86	–	94.6/76.3	–	33.8/100.0	–	MoCA
Yu *et al.* (2012); China	Control (865) MCI (115) Magierska *et al.* (2012); Poland	70.40 ± 7.13 71.45 ± 7.26 77.10 ± 8.01 Control (37) MCI (42) 71.4 ± 5.2 74.2 ± 6.4 76.3 ± 5.8	56.5 59.1 71.4 70.0 80.0 70.0	10.5 ± 5.3 8.4 ± 5.5 3.8 ± 4.7 14.3 ± 3.1 13.4 ± 4.9 9.1 ± 3.7	21/22 – 24/25 –	0.71 0.74	– –	0.7 0.61	– –	68.7/63.9 –	– –	50.4/74.5 47.6/72.9	– –	– MoCA
Tsai *et al.* (2012); Taiwan	Control (38) MCI (71) AD (98)	77.7 ± 6.0 79.2 ± 6.8 79.6 ± 6.4	35.1 50.7 38.7	10.1 ± 4.4 8.9 ± 5.1 8.4 ± 4.9	23/24 21/22	0.91	0.99	0.81	0.98	92/78	98/95	– /67	95/98	MoCA

Table 1. Continued

Study; country	Population (*N* sampling)	Age (years) average ±SD	Female gender (%)	Education (years) – average ±SD	Cut off MoCA – control vs MCI control vs AD	Accuracy of MoCA (AUC) – control vs MCI	Accuracy of MoCA (AUC) – control vs AD	Accuracy of MMSE (AUC) – control vs MCI	Accuracy of MMSE (AUC) – control vs AD	MoCA control vs MCI sensitivity/ specificity	MoCA control vs dementia sensitivity/ specificity	MMSE control vs MCI sensitivity/ specificity	MMSE control vs dementia sensitivity/ specificity	Test which presented a higher accuracy
Lu *et al.* (2011); China	Control (6283) MCI (1687)	72.0 ± 0.8 75.1 ± 0.9	52.1 56.3	6.7 ± 1.1 3.5 ± 1.0	Education 0 years: 13/14 – Education 1–6 years: 19/20 – Education >6 years: 24/25 –	0.90	–	0.84	–	80.5/82.5	–	–	–	MoCA
Fujiwara *et al.* (2010); Japan	Control (36) MCI (30) AD (30)	76.4 ± 3.3; 77.3 ± 6.3; 77.5 ± 6.0	72.0; 76.9; 63.0	12.3 ± 2.3; 11.5 ± 3.1; 12.1 ± 3.0	25/26 25/26	0.95	0.99	0.85	0.86	93/89	100/89	– /58	97/89	MoCA
Guo *et al.* (2010); China	Control (186) MCI (121)	67.58 ± 6.87 68.35 ± 7.20	53.23 52.07	12.18 ± 3.24 11.75 ± 3.54	– –	0.86	–	0.67	–	–	–	–	–	MoCA
Luis *et al.* (2009); EUA	Control (74) MCI (24) AD (20)	78.9 ± 3.7; 78.9 ± 5.3; 79.9 ± 4.3	51.3; 38.0; 60.0	14.2 ± 2.5; 14.4 ± 4.1; 13.5 ± 2.6	23/24 –	0.97	0.96	0.76	0.83	96/95	–	58/84	–	MoCA
Lee *et al.* (2008); South Korea	Control (115) MCI (37) AD (44)	69.1 ± 6.1; 71.3 ± 5.9; 70.4 ± 8.6	70.4; 62.2; 52.3	8.0 ± 3.5; 8.3 ± 3.8; 7.9 ± 3.7	22/23 22/23	0.94	0.98	0.66	0.87	89/84	98/84	59/70	86/70	MoCA
Nasreddine *et al.* (2005); Canada	Control (90) MCI (94) AD (93)	72.8 ± 7.0; 75.2 ± 6.3. 76.7 ± 8.8	60.0; 44.0; 59.0	13.3 ± 3.4; 12.3 ± 4.3; 10.0 ± 3.8	25/26 25/26	–	–	–	–	90/87	100/87	18/100	78/100	MoCA

MCI: mild cognitive impairment; AD: Alzheimer's disease; USA: United States of America; MoCA: Montreal Cognitive Assessment; Mini-Mental State Examination (MMSE); AUC: area under curve.

[a] Values reffering to the MCI and AD groups.

AD, the *National Institute of Neurological and Communicative Disorders and Stroke — Alzheimer's Disease and Related Disorders Association* (NINCDS-ADRDA) criteria (McKhann *et al.*, 1984) was used in most of the articles. Petersen's criteria (2004) was the most used for the diagnosis of MCI.

The Area under the curve (AUC) calculated from the ROC curve, was used to compare the diagnostic accuracy of MoCA and MMSE. Of the 34 studies selected, 31 showed information regarding the accuracy of MoCA and MMSE in detecting MCI. Twenty five articles (80.6%) showed superiority of MoCA to MMSE in discriminating individuals with mild cognitive impairment and no mild cognitive impairment (Cecato *et al.*, 2014; Chen *et al.*, 2016; Chu *et al.*, 2015; Delgado *et al.*, 2017; Dong *et al.*, 2012; Freitas *et al.*, 2013; Fujiwara *et al.*, 2010; Guo *et al.*, 2010; Horton *et al.*, 2015; Hsu *et al.*, 2015; Hu *et al.*, 2013; Janelidze *et al.*, 2017; Kaya *et al.*, 2014; Lee *et al.*, 2008; Lifshitz *et al.*, 2012; Lu *et al.* 2011; Luis *et al.*, 2009; Magierska *et al.*, 2012; Mellor *et al.*, 2016; Memória *et al.*, 2013; Nasreddine *et al.*, 2005; Roalf *et al.*, 2013, 2017; Saleh *et al.*, 2018; Tan *et al.*, 2015; Tsai *et al.*, 2012, 2016). In this group of articles are included the two studies with the most sample sizes of this review, with more than 7,000 elderly subjects each, with excellent methodological qualities, evaluated through QUADAS 2 tool (Lu *et al.*, 2011; Tan *et al.*, 2015). In these studies, a superiority of MoCA to MMSE in detecting MCI was shown. The remainder of the articles (19.4%) found similar accuracy between the two cognitive tests (Table 1).

On the other hand, 24 articles showed information regarding the discrimination between controlled individuals and individuals with dementia. Fourteen studies (58.3%), demonstrated similar accuracy between MoCA and MMSE in the detection of mild dementia, while the other 10 studies (41.7%) showed MoCA was superior to MMSE for this detection (Cecato *et al.*, 2014; Delgado *et al.*, 2017; Freitas *et al.*, 2013; Fujiwara *et al.*, 2010; Hsu *et al.*, 2015; Janelidze *et al.*, 2017; Lee *et al.*, 2008; Luis *et al.*, 2009; Wang *et al.*, 2013).

The AUC varied from 0.71 to 0.99 for MoCA and 0.43 to 0.94 for MMSE, when evaluating the ability to distinguish between the MCI of cognitively healthy elderly individuals. However, when calculated to evaluate the discriminative power of cognitively healthy elderly individuals from those with mild Alzheimer's Disease, the AUC of MoCA varied from 0.87 to 0.99, while the AUC of MMSE varied from 0.67 to 0.99. An analysis of Table 1, demonstrates that the cut-off point varies within the studies.

The AUC mean value for MoCA was significantly larger compared to the MMSE in discriminating MCI from control [0.883 (CI 95% 0.855–0.912) vs MMSE 0.780 (CI 95% 0.740–0.820) $p < 0.001$, obtained through the Mann-Whitney test]. The AUC mean value for MoCA was similar to the MMSE in discriminating AD from control [0.957 (CI 95% 0.939–0.974) vs. 0.917 (CI95% 0.878–0.956) p = 0.125]. When conducting a comparison of the accuracy of MoCA and MMSE in detecting MCI and AD using the AUC mean value considered by the sampling size in the selected studies of this systematic review, the superiority of MoCA to MMSE in detecting MCI [0.842 (CI 95% 0.814–0.870) vs. 0.778 (CI 95% 0.746–0.809), $p < 0.01$] was confirmed, and the good accuracy for both test in detecting AD was also confirmed [0.839 (CI 95% 0.823–0.855) vs. 0.821 (CI 95% 0.790–0.852), p = 0.328] (Figure 2).

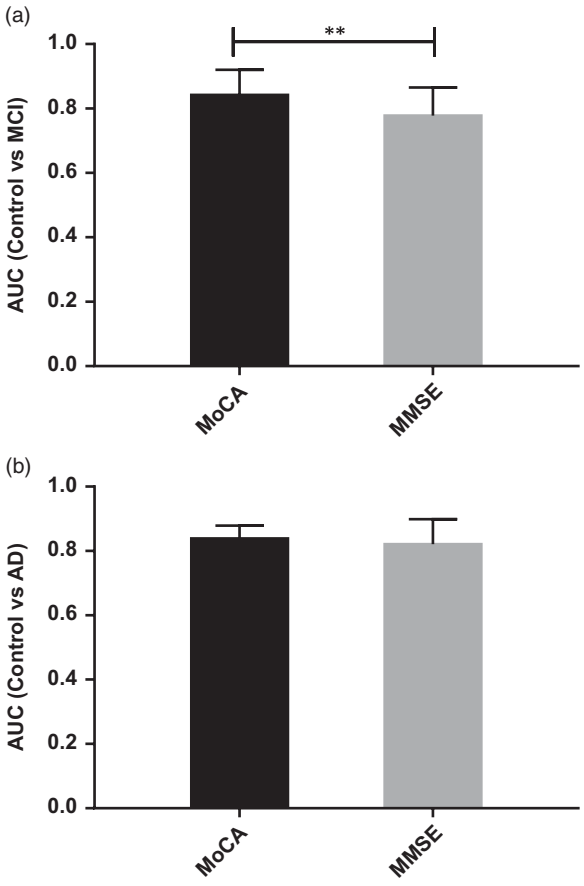

Figure 2. Comparison of the Area under the Curves (AUCs) mean values (± standard deviation) for MoCA and MMSE, considered by the sampling size in the selected studies of this systematic review, for detection of MCI (A) and AD (B). $^{**}p < 0.01$, obtained through the Mann-Whitney test.

When evaluating the quality of the studies included in this review through the QUADAS-2 tool, it is shown that the studies for the most part, have an excellent applicability, and a low risk of bias (Supplementary Table 1 and Figure 3). Only one study was considered to have a high risk of bias due

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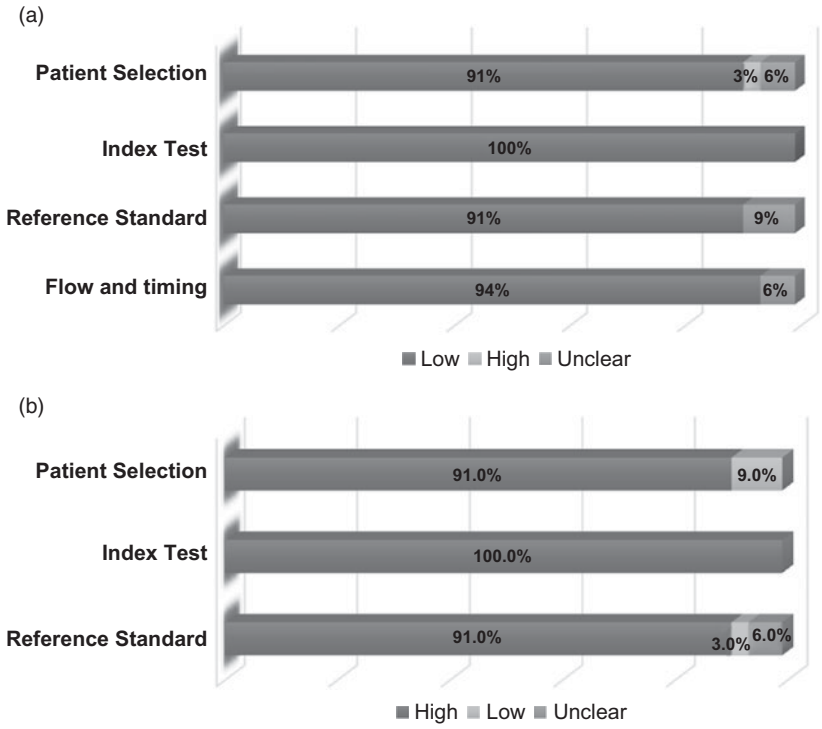

Figure 3. Evaluation of the quality of the studies included in the systematic review through Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool. A – Risk of Bias; B – Applicability.

to the way the patients were selected and consequently, low applicability in Patient Selection. In three studies, the gold standard used was unclear (Supplementary Table 1 and Figure 3). All the studies presented a low risk of bias and high applicability regarding to the index test of the QUADAS-2 tool.

Discussion

This systematic review aimed to evaluate the current state of the subject and assess which of the tests has been shown to be more accurate in tracking MCI and AD in elderly individuals. In this review, 34 articles which analyzed the ability of MoCA and MMSE in distinguishing MCI and AD among the healthy elderly population were included. The cut-off point of MoCA varied within the studies, from 13/14, in the elderly with low education (Lu *et al.*, 2011), to 28/29, in detecting MCI, in a study conducted in the U.S.A. (Roalf *et al.*, 2013). The most frequent cut-off point to detect MCI was 21/22 and 19/20 to detect AD. In general terms, in the studies conducted on elderly individuals with low formal education, lower values of the cut-off point were found to attain a more accurate diagnosis (Dong *et al.*, 2012,2013; Matías-Guiu *et al.*, 2017; Yeung *et al.*, 2014; Zhou *et al.*, 2014).

It is important to mention that the four studies that presented results stratified per education found lower cut-off points for elderly individuals who have lower formal education, highlighting the importance of considering the level of education of the patients when evaluating their cognitive performance (Chen *et al.*, 2016; Kaya *et al.*, 2014; Lu *et al.*, 2011; Mellor *et al.*, 2016). In addition, it is shown that a lower accuracy in MMSE was found in the elderly group with higher formal education. This fact is due to the ceiling effect that occurs in elderly individuals with higher education when administering MMSE. Even those with the diagnosis of MCI and mild AD are able to achieve performance similar to cognitively healthy elderly individuals, thus decreasing the accuracy of the test (Chen *et al.*, 2016; Mellor *et al.*, 2016). This fact was more evident in the Mellor and collaborators (2016) studies, in which the AUC of MMSE decreased from 0.85 to 0.72 — accuracy detection of MCI — and from 0.97 to 0.72 — accuracy detection of mild AD — when compared to elderly individuals who had ≤6 years of formal education to those who had ≥10 years of formal education, respectively.

The Yeung and collaborators (2014) study was the only study, among the studies of the groups that evaluated the three cognitive groups (control, MCI, and mild AD), in which the MoCA accuracy was similar to MMSE in the detection of MCI and also

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Table 2. Distribution of the scores of The Montreal Cognitive Assessment (MoCA) and the Mini-Mental State Examination (MMSE), according to the evaluated cognitive function

COGNITIVE FUNCTION	TASK	MoCA (PONTUATION)	MMSE (PONTUATION)
Visuospatial abilities	Copy of three-dimensional cube	1	–
	Clock drawing	3	–
	Copy of pentagons	–	1
Executive functions	Trail Making B	1	–
	Phonemic fluency	1	–
	Abstraction	2	–
Attention, concentration, and working memory	Digits forward and backward	2	–
	Tapping with hand at letter A	1	–
	Serial subtraction	3	5
Language	Repetition	2	1
	Naming	3	2
	Comprehension (3-stage command)	–	3
	Reading	–	1
	Writing	–	1
Memory	Learning	–	3
	Delayed recall	5	3
Orientation	Orientation to time	4	5
	Orientation to place	2	5

in the detection of mild AD. This is the study with elderly individuals who had the lowest formal education, among the included articles in the current literature review. Therefore, the absence of the superiority of MoCA in this study was probably due to the occurrence of the floor effect: cognitively healthy elderly individuals who had low formal education showed bad performance in the test, similar to elderly individuals with MCI and mild AD, consequently with a low accuracy in distinguishing between controlled individuals from those with cognitive impairment.

It is interesting to observe that the values of the cut-off points for MCI were superior to those defined to determine AD in practically all the studies that evaluated the detection of MCI and AD (Cecato *et al.*, 2014; Chu *et al.*, 2015; Delgado *et al.*, 2017; Freitas *et al.*, 2013; Horton *et al.*, 2015; Hu *et al.*, 2013; Kaya *et al.*, 2014; Mellor *et al.*, 2016; Memória *et al.*, 2013; Roalf *et al.*, 2013, 2017; Saleh *et al.*, 2018; Tan *et al.*, 2015; Tsai *et al.*, 2012, 2016; Yeung *et al.*, 2014). This fact is probably due to having higher cut-off points, in other words, stricter to prevent possible MCI cases from being considered normal. Thus, the higher cut-off points increase the sensitivity of the tracking tests.

It is important to highlight that since tracking tests are being used, the most important component of accuracy to be evaluated in these tests is sensitivity — in other words, the ability of the test to correctly identify, among all the evaluated individuals, those that really present the characteristics of interest, which in the tests in question, is the cognitive status — naturally, without forgetting the remainder properties of the test: specificity and positive and negative predictive value. Therefore, when the sensitivity of the cognitive tests is observed in a more detailed manner, the superiority of MoCA to MMSE becomes more apparent. This is more likely due to MoCA containing more complex items, such as cube drawing and clock drawing (Table 2). In addition, the time needed to evaluate the delayed recall is longer in MoCA, making the test more difficult, with a higher percentage of error for the elderly with impaired cognitive functions and consequently, higher sensitivity in this tracking tool.

The Chinese study of Tan and collaborators (2015), which used the second highest sample size among the studies of this review ($n = 7{,}445$), showed cut-off points stratified by age. The values decreased with the increase in age, with the MoCA cut-off points at 25/26 and 24/25 for elderly individuals between 60 and 79 years of age, 23/24 and 19/20 for the elderly in their 90s, for the detection of MCI and AD, respectively. Thus, the role age has in the cognitive performance of MoCA is noticeable.

Conclusion

Therefore, through the results of this systematic review of the literature, it is shown that despite the varying accuracy present in the studies, through statistical analysis MoCA has shown higher

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superiority to MMSE in identifying MCI, and both tests are accurate in detecting Alzheimer's Disease, with MoCA presenting a tendency towards a greater ability to achieve this diagnostic tracking, but without statistical difference. The evaluation of the accuracy of these cognitive tracking tools in the populations, as well as choosing the test with the highest diagnostic accuracy are extremely relevant where these tests will be used to facilitate the process of diagnosing impaired cognition.

Hence, it is proposed that MoCA be chosen in relation to MMSE as the test for cognitive tracking in the elderly, mainly for the tracking of MCI. Additionally, it is proposed that the cut-off points be defined considering the formal education of the population studied, aiming at a more accurate tracking of the elderly at risk of developing a decline in cognition and early onset dementia, proportionally, hence, an early diagnosis brings more benefits to the elderly, their family, and to society.

Conflict of interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Description of authors' roles

T. Pinto, M. Costa, and R. Ximenes developed the concept of the paper. T. Pinto performed the statistical analyses. All authors participated in the interpretation of the data and the writing of the paper. T. Pinto and R. Ximenes coordinated the writing. All authors have approved the final paper.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1041610218001370

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