Review Article

Comparison of Computerized and Paper-and-Pencil Memory Tests in Detection of Mild Cognitive Impairment and Dementia: A Systematic Review and Meta-analysis of Diagnostic Studies

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A B S T R A C T

Objectives: To compare the diagnostic performance of computerized and paper-and-pencil memory tests in detection of mild cognitive impairment (MCI) and dementia.

Design: Diagnostic studies comparing computerized or paper-and-pencil memory tests with the standard diagnostic criterion for MCI or dementia were identified from OVID databases. The primary outcome was the diagnostic performance of memory tests for detection of MCI, and detection of dementia was the secondary outcome. Risk of bias and reporting quality in included studies was assessed.

Setting and Participants: Participants with MCI and dementia in any kind of setting.

Measures: Bivariate random-effects models were used to combine the diagnostic performance of memory tests and presented with a summary receiver-operating characteristic curve.

Results: A total of 58 studies with 18,450 participants with mean age ranging from 55 to 84 years were included. For the verbal memory tests on patients with MCI, computerized tests showed diagnostic accuracy of 0.89 sensitivity (95% confidence interval [CI] 0.69—0.97) and 0.82 specificity (95% CI 0.70—0.90), whereas paper-and-pencil tests showed diagnostic accuracy of 0.86 sensitivity (95% CI 0.82—0.90) and 0.82 specificity (95% CI 0.76—0.86). For the visual memory tests on MCI patients, computerized tests showed diagnostic accuracy of 0.79 sensitivity (95% CI 0.71—0.84) and 0.80 specificity (95% CI 0.71—0.86), whereas paper-and-pencil tests showed diagnostic accuracy of 0.80 sensitivity (95% CI 0.67—0.89) and 0.68 specificity (95% CI 0.51—0.81). The findings were also comparable to those with dementia.

Conclusions/Implications: Both verbal and visual computerized memory tests showed comparable diagnostic performance to the paper-and-pencil tests. Computerized cognitive tests show a great potential to use as an alternative to paper-and-pencil tests. When the records can be digitalized, long-term monitoring of cognitive function will be feasible for better management of dementia.

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Mild cognitive impairment (MCI) and dementia are global disease burdens due to the aging population. The prevalence of MCI is approximately 10% to 20%,[1] and dementia is approximately 5% to 7% in people older than 60 worldwide.[2] A recent meta-analysis showed promising results that computerized cognitive training is effective in improving cognitive function for people with MCI.[3] Therefore, early detection of MCI can facilitate proactive planning of potential intervention.

Traditionally, we use paper-and-pencil cognitive tests for MCI and dementia screening. Previous meta-analyses showed that cognitive tests have good diagnostic performance for detection of MCI and dementia.[4,5] In the recent decade, the use of computerized cognitive tests has become common. More than 17 computerized cognitive tests are identified in previous systematic reviews.[6–10] There are different advantages of using computerized cognitive tests, such as standardized administration procedures and presentation of stimulus, accurate measurement of response time, and automatic calculation of participant's performance with taking age, education, and gender into the

results calculation formula.[6,8–10] However, most of the computerized tests are more expensive than paper-and-pencil tests. Therefore, whether the changes and advancement in computerized cognitive tests are good enough to be an alternative for paper-and-pencil tests is an important concern for the clinicians choosing between different cognitive tests. However, the diagnostic performance of computerized and paper-and-pencil cognitive tests has not been compared in previous systematic reviews; therefore, it is still unclear whether there are any differences between computerized and paper-and-pencil cognitive tests in diagnostic performance for detection of MCI and dementia. Although different cognitive tests have different designs, most of the computerized and paper-and-pencil cognitive tests contain a memory test, such as 3-word recall test in the Mini-Mental State Examination[11] and 3-word recall test in a computerized test battery MPS-1000.[12] Some memory tests are solely verbal or visual memory tests, such as the Hopkins Verbal Learning Test[13] and Rey Complex Figure.[14] Some studies showed that verbal and visual memory tests are sensitive for MCI and dementia screening,[15–18] because deterioration of the ability to learn and remember new information is one of the earliest signs and symptoms for MCI and Alzheimer disease.[19,20] So, assessment of memory deterioration is one of the major focuses in MCI and dementia screening. Therefore, we focused on comparison of computerized and paper-and-pencil memory tests in this systematic review. The aim of this study was to compare the diagnostic performance of computerized and paper-and-pencil memory tests for detection of MCI and dementia.

Methods

This study was performed according to the standard guidelines for systematic review of diagnostic studies, including Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA)[21] and guidelines from the Cochrane Diagnostic Test Accuracy Working Group.[22,23]

Search Strategy

Literature searches were performed in the electronic databases of MEDLINE, EMBASE, PsycINFO, and CINAHL, from the earliest available dates stated in each database until October 15, 2017. Searching keywords included computerized test, computerized assessment, cognitive screen, memory test, visual test, cognitive impairment, Alzheimer's disease, and dementia. A list of computerized and paper-and-pencil memory tests for MCI and dementia was identified from some review articles,[4–10] and all the tests were searched independently again among the databases. Our academic searches were extended to the Digital Dissertation Consortium database and Google Scholar. The Digital Dissertation Consortium database is a platform to identify unpublished theses. Google Scholar searches literature with a combined ranking algorithm on citation counts in addition to the keyword relevancy. The first 10 pages in Google Scholar were scanned. Manual search was also performed of the bibliographies of review articles and any research studies cited in the eligible studies.

Inclusion and Exclusion Criteria

Cross-sectional studies were included if they met the following criteria:

1. Evaluated the diagnostic accuracy of a verbal memory test or visual memory test for the detection of MCI or dementia with healthy participants as control; either a full-test or a sub-test was accepted.
2. Used standard criteria reference as the gold standard for MCI or dementia. The gold standard for MCI and dementia included

the Petersen criterion,[24] the report of International Working Group on Mild Cognitive Impairment,[25] the Clinical Dementia Rating scale,[26] the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association,[27] The Diagnostic and Statistical Manual of Mental Disorders (DSM), such as DSM-IV-TR,[28] and standardized neuropsychological test or clinician consensus diagnosis. Studies that used mild or major neurocognitive disorder in DSM-V[29] were also accepted.
3. Reported the diagnostic accuracy, included sensitivity and specificity of a memory test for MCI or dementia.

Studies were excluded if (1) the study evaluated the predictive validity of a test, (2) the result of a computerized or paper-and-pencil memory test could not be separated from a whole cognitive test, and (3) the study examined a retrograde memory test, such as asking the participants about the current president of United States.

Data Extraction

Two investigators (JYC and JSK) independently extracted data using a pre-standardized data extraction form. Data collection included year of publication; study location; mean age; proportion of male individuals; number of participants with MCI, dementia, and healthy controls; and name of the memory tests. The primary outcome of this study was the diagnostic performance of the computerized and paper-and-pencil memory tests for detection of MCI, and the secondary outcome was the diagnostic performance of memory tests for detection of dementia. Therefore, we recorded the sensitivity and specificity, or true-positive, false-positive, true-negative, and false-negative values of each memory test. When a study presented several cutoff values to define a patient with MCI or dementia, only the result from a recommended cutoff value by the authors of the article was selected. When discrepancies were found regarding study eligibility or data extraction, a third investigator (KKT) would make the definitive decision.

Classification of Memory Tests

We classified the memory tests into verbal memory test and visual memory test, and both with computerized and paper-and-pencil versions. In the paper-and-pencil verbal memory test, the examiner presents a list of words to the participants, asks the participants to remember the words, and after a short period of time the participants are asked to recall the list of words. In the computerized verbal memory test, the presentation of the word list and instructions are automated by the computer program. Some computerized verbal memory tests were adopted from paper-and-pencil verbal memory tests, such as the MCI screen[18] which was adopted from the CERAD 10-word recall test.[30] In the paper-and-pencil visual memory test such as the Rey Complex Figure, the examiner presents some pictures or images to the participants and asks the participants to remember the images, and after a short period of time the participants are asked to draw the picture or identify the image.[14] In computerized visual memory tests such as the Visuo Spatial memory test, the visual stimulus and instructions are presented by a computer program.

Risk of Bias and Reporting Quality in Included Studies

Potential risks of bias in each included study were assessed by QUADAS (Quality Assessment of Diagnostic Accuracy Studies)-2 tool,[32] which evaluated 4 key domains: (1) selection of participants; (2) procedures to run the index tests; (3) procedures to conduct the reference standard; and (4) presentation on the patient flow and timing to have the reference standard. In addition, the quality of the study was assessed according to the methodology section of STARD statement (Standards for Reporting of Diagnostic Accuracy).[33] An 8-point scale