Psychometric properties of cognitive screening for patients with cerebrovascular diseases

A systematic review

Jaqueline de Carvalho Rodrigues¹, Natália Becker², Carolina Luisa Beckenkamp³, Camila Schorr Miná⁴, Jerusa Fumagalli de Salles⁵, Denise Ruschel Bandeira⁶

ABSTRACT. Screening instruments are ideal for acute clinical settings because they are easy to apply, fast, inexpensive and sensitive for specific samples. However, there is a need to verify the psychometric properties of screening in stroke patients. Objective: This study investigated the psychometric properties (methodological procedures) of cognitive screening for patients with cerebrovascular diseases. Methods: A systematic review of papers published on PsycINFO, Web of Knowledge, PubMed and Science Direct (2005 to 2016) was performed. Results: A total of 55 articles remained after applying exclusion criteria. The samples ranged from 20 to 657 patients. Most articles evaluated elderly individuals with four to 13 years of education who had experienced ischemic or hemorrhagic stroke. There was a tendency to find evidence of validity for criteria and to analyze the sensitivity/specificity of the instruments. Although the studies frequently used the Mini-Mental State Examination (MMSE) and the Montreal Cognitive Assessment (MoCA) to seek evidence of validity and reliability, the use of these instruments among stroke patients has been criticized due to their psychometric properties and the neuropsychological functions evaluated. Conclusion: Although there is no gold standard screen for assessing adults post-stroke, instruments devised specifically for this population have shown promise. This review helps both researchers and clinicians to select the most appropriate screen for identifying cognitive impairment in adults post-stroke.

Key words: neuropsychological assessment, stroke, vascular cognitive impairment, validity, reliability.
Cognitive impairment is a common consequence following stroke, occurring in approximately 45% to 83% of subjects depending on the follow-up time, neurological characteristics and instruments used.\(^1,2\) Notably, cognitive impairment is observed in more than 50% of patients six months after stroke.\(^2,3,4\) These patients can develop vascular dementia, which affects both functional independence and quality of life.\(^4,6\)

The most common deficits in vascular cognitive impairment include reduced processing speed, executive dysfunction, hemineglect, inattention, aphasia, apraxia and amnesia.\(^3,5,7\) There is no consensus on which tests should be used to evaluate performance on these functions in post-stroke patients.\(^8\) The selection of tools usually depends on an instrument’s availability and on the neuropsychologist’s preference and familiarity with the tasks.\(^9\)

Using an extensive battery of neuropsychological assessment is impractical in many clinical settings, where evaluation with simpler cognitive screening instruments is required.\(^9\) Screening instruments are therefore ideal for an acute clinical setting because they are easy to apply, fast, inexpensive and sensitive for specific samples.\(^10,11\) Ideally, neuropsychologists should be aware of whether the selected screen has adequate psychometric properties for stroke populations in their countries. However, most neuropsychologists have based their diagnosis on instruments psychometrically tested in patients with nonvascular cognitive impairment.\(^6,12-14\) The Neuropsychological Working Group of the National Institute of Neurological Disorders and Stroke (NINDS) and the Canadian Stroke Network (CSN) have recommended three protocols (60, 30, and 5 minute protocols) for assessing vascular cognitive impairment,\(^15\) and their psychometric properties have been tested in many studies.\(^16-20\)

Regarding the instruments’ psychometric properties, neuropsychological tests should exhibit evidence of specific forms of validity: evidence based on test content, evidence based on response processes, evidence regarding internal structure (dimensionality and relationships between scores of the same test), evidence regarding relationships with conceptually related constructs (convergent and discriminant evidence), evidence regarding relationships with criteria (contrasting groups, effect size, concurrent and predictive validity), and evidence based on the consequences of testing. In addition, it is important for the tests to demonstrate reliability in the form of temporal stability and internal consistency.\(^21\)

Furthermore, the instrument should be constructed in a manner that aims to determine cognitive deficits in a specific population. Thus, we recognize the need to verify the psychometric properties of screening in stroke patients. In this context, the present systematic review aims to identify the cognitive screening with adequate psychometric properties for use in stroke patient samples. The specific aims of this review study were: (a) to analyze the quality of the methodological information reported (sample size, age and education of participants, neurological data such as cerebrovascular disease and time post-stroke); and (b) to identify cognitive screening that have adequate validity and reliability evidence. This systematic review reports the methodological limitations of psychometric studies of adults post-stroke and investigates which screening are most adequate for identifying cognitive deficits in these patients. This review article can be distinguished from other studies in this field that tend to discuss only the sensitivity and specificity of screening instruments\(^22,23\) or fail to examine the psychometric properties of the tests in stroke patient samples.\(^8\)

**METHODS**

We performed a systematic review of papers published from January 2005 to December 2016 on the following databases: PsycINFO (refined by the terms in the abstract), Web of Knowledge (refined by the terms in the subject of the article), PubMed (refined to include the terms in the title and abstract), and Science Direct (refined by the terms in the abstract, title, or keywords). The refinements varied because the databases use different advanced search tools. The following combinations of keywords were applied: “stroke”, “cerebrovascular accident”, “vascular cognitive impairment”, and “cerebrovascular disease” versus “neuropsychological assessment”, “neuropsychological evaluation”, “cognitive screening”, “neuropsychological screening”, “cognitive assessment”, and “cognitive evaluation”. These
keywords were selected from the most commonly used terms in the health databases to include all articles that reported neuropsychological evaluations in stroke patients.

After excluding repeated articles, the remaining articles were divided and analyzed by two judges. Four judges selected only empirical studies in English, Portuguese, French or Spanish that assessed adults with cerebrovascular disease using cognitive screening. If the two judges disagreed on the selection of a particular study, a third judge was recruited. The judges had experience in neuropsychological assessment post-stroke and knowledge about the instruments used.

Many studies have evaluated neuropsychological deficits in stroke patients with cognitive screening tests, but failed to explicitly report that their analysis was psychometric. In these situations, we assumed that these articles claimed to analyze validity evidence based on relations to other variables.21

RESULTS

After performing searches and excluding repeated articles, 74 studies that evaluated neuropsychological functions in stroke groups using screening instruments were selected. These articles were read in full, with a focus on the methods and results sections. Subsequently, 19 non-psychometric studies were excluded (Figure 1). The results and discussion will be presented in two sections: (1) characteristics of the samples; and (2) psychometric properties of the cognitive screening.

Characteristics of the samples

In our review, the samples ranged from 20 to 657 stroke patients, but only one study calculated the sample size.24 Most of the articles evaluated individuals between 50 and 80 years old (Table 1), and only two studies included younger samples (i.e., patients under 30 years of age).25,26 The majority of the studies evaluated patients with four to 13 years of education (9 years on average). However, 27.27% of the articles did not specify the educational levels of the participants (Table 1). With respect to cerebrovascular disease, 30.90% of studies evaluated ischemic and hemorrhagic stroke samples, 21.81% evaluated transient ischemic attack (TIA) and stroke patients, 10.90% ischemic stroke only, 9.09% cerebral small vessel diseases, 7.27% hemorrhagic stroke, 3.63% vascular dementia and 16.36% did not report this information (Table 1). The time between post-stroke onset and neuropsychological assessment varied. A total of 50.90% of studies assessed patients at 3 months post-stroke,
### Table 1. Cognitive screening and characteristics of the samples.

| Cognitive screening                                      | N (CVD) | Age (M±SD or range) | Years of education (M±SD, % or range) | Time post-stroke          |
|-----------------------------------------------------------|---------|----------------------|---------------------------------------|---------------------------|
| Addenbrooke’s Cognitive Examination-Revised (ACE-R)       | 101 (NI)| 67.0–82.5            | 9.0–11.0                              | 8-48 days                 |
| Barrow Neurological Institute Screen for Higher Cerebral Functions (BNIS) | 54 (I, H, SH) | 53.8±12.3            | 33.3% high education                  | 15.0±12.8 weeks           |
| BNS32                                                    | 295 (I) | 43.4-66              | 92 < 9; 203 > 9                       | 7 years                   |
| Birmingham Cognitive Screen (BCoS – Cantonese version)34 | 98 (I)  | >50 years            | Ni                                    | 2 weeks                   |
| Birmingham Cognitive Screen (BCoS)35                    | 657 (I and H) | 69.31±14.34, 71.38±12.60 | 11.52±2.76, 11.19±2.76 | 26.65±22.36, 20.44±17.29 |
| Brief Memory and Executive Test (BMET)37                | 196 (SVD)| 63.5±9.9             | 13.7±3.8                              | 20.5±32.3 months          |
| Brief Neuropsychological Screening (BNS)32               | 134 (NI)| 69.7±12.9            | 8.3±3.4                               | <1 month                  |
| Clock Drawing Test (CDT)1                                | 49 (I, H, SH) | 62±53.5              | Ni                                    | 36±17 days                |
| CDT33                                                   | 187 (I and H) | 49 – 80              | 0 - 29                                | 3 - 25 months             |
| Cog-44                                                  | 92 (I and TIA) | 63-83                | Ni                                    | 1-4 days                  |
| Cognistat6                                               | 49 (I, H, SH) | 62±53.5              | Ni                                    | 38±17 days                |
| Cognitive Assessment Scale for Stroke Patients (CASP)35  | 44 (I and H) | 64±15                | Ni                                    | 42±22 days                |
| CASP36                                                   | 50 (I and H) | 63±14                | Ni                                    | 40±17 days                |
| Functional Independence Measure (FIM cognitive)37        | 169 (I and H) | 56.2±11.3            | 61.2% intermediate                     | <12 months                |
| Middlesex Elderly Assessment of Mental State (MEAMS)38   | 30 (NI)  | 75.8±7.94            | Ni                                    | 20.73±24.37 days          |
| Mild Vascular Cognitive Impairment Assessment tool for Stroke (MVCI)39 | 60 (I and H) | 64.07±13.46          | Ni                                    | Ni                        |
| Mini-Mental State Examination (MMSE)40                   | 34 (I and H) | 64.7±11.5            | 1 – 7                                 | 6.5±2.9 days              |
| MMSE37                                                  | 169 (I and H) | 56.2±11.3            | 61.2% intermediate                     | <12 months                |
| MMSE38                                                  | 493 (TIA, I and H) | 69.9±12.4            | Ni                                    | 6 months or 5 years       |
| MMSE41                                                  | 80 (NI, SVD) | 65.85±6.94           | 10.00±3.35                            | 3 months                  |
| MMSE42                                                  | 239 (TIA and I) | 60.2±11.8            | 7.5±4.1                               | 3-6 months                |
| MMSE43                                                  | 327 (TIA and I) | 59.8±11.6            | 7.7±4.3                               | 3-6 months                |
| MMSE44                                                  | 60 (I and IH) | 72.1±13.9            | 10.5±3.9                              | 98.3±12.0 days            |
| MMSE45                                                  | 388 (I and TIA) | 59.8±11.6            | 7.7±4.3                               | 0-14 days, 3-6 months     |
| MMSE46                                                  | 138 (SIVD)  | 50-85                | > 6                                   | > 3 months                |
| MMSE47                                                  | 105 (I)   | 68.61±10.35          | 8.90±4.24                             | < 2 weeks                 |
| MMSE48                                                  | 83 (I and H) | 66.6±9.7             | 9.2±4.8                               | 9.0±5.4 months            |
| Montreal Cognitive Assessment (MoCA)43                   | 327 (TIA and I) | 59.8±11.6            | 7.7±4.3                               | 3-6 months                |
| MoCA47                                                  | 29 (I, H, TIA) | 68±12                | Ni                                    | 2.5±1.4 days              |
| MoCA48                                                  | 95 (I and H) | 68.2±13.7            | 79% primary                           | 6.6±3.5                  |
| MoCA49                                                  | 34 (VD)    | 73.21±7.85           | 4.97±2.74                             | Ni                        |
| MoCA42                                                  | 239 (TIA and I) | 60.2±11.8            | 7.5±4.1                               | 3-6 months                |

continues.
Table 1. Cognitive screening and characteristics of the samples (continuation).

| Cognitive screening                  | N (CVD)                         | Age (Mean ± Standard Deviation or range) | Years of education (Mean ± Standard Deviation, % or range) | Time post-stroke |
|--------------------------------------|---------------------------------|------------------------------------------|-----------------------------------------------------------|-----------------|
| MoCA (by telephone)                  | 99 (TIA and stroke)             | 73.4 ± 11.6                              | 63% < 12                                                  | 1 year          |
| MoCA                                 | 60 (I and H)                    | 72.1 ± 13.9                              | 10.5 ± 3.9                                                | 98.3 ± 12.0 days|
| MoCA                                 | 80 (I and H)                    | 68.2 ± 14.6                              | 9.2 ± 4.4                                                 | 5-9 days, 8.4 ± 2.2 months |
| MoCA                                 | 388 (I and TIA)                 | 59.8 ± 11.6                              | 7.7 ± 4.3                                                 | 0-14 days, 3-6 months |
| MoCA                                 | 136 (I and H)                   | 64.3 ± 14.3                              | NI                                                       | 11.1 ± 14.5 days |
| MoCA                                 | 108 (aSAH)                      | 21-75                                    | NI                                                       | 2-4 weeks, 1 year |
| MoCA                                 | 194 (aSAH)                      | 21-75                                    | NI                                                       | 1 year          |
| MoCA                                 | 138 (SVD)                       | 50-85                                    | > 6                                                      | > 3 months      |
| MoCA                                 | 211 (I and H)                   | 70.6 ± 1.8                               | 23/98/42 (low/medium/high)                                | 5.1 ± 4.9 days  |
| MoCA                                 | 291                             | 59.8 ± 11.6                              | 7.7 ± 4.3                                                 | 3-6 months, 1 year |
| MoCA                                 | 105 (I)                         | 68.61 ± 10.35                            | 8.90 ± 4.24                                               | < 2 weeks       |
| Mini MoCA                            | 72 (NI)                         | 68.1 ± 15                                | 11.2 ± 2                                                 | NI              |
| MoCA (by telephone)                  | 91 (I, H, TIA)                  | 72.9 ± 11.6                              | 63% < 12                                                 | 3.1 ± 1.9 years |
| MoCA BM (Bahasa Malaysia version)    | 40 (I and H)                    | 57.2 ± 10.3                              | 8.5 ± 3.9                                                 | 164-581 days    |
| MoCA Beijing version (by telephone)  | 102 (I and TIA)                 | 53.95 ± 11.43                            | 12/74/26 (low/medium/high)                                | > 14 days       |
| MoCA Beijing version (by telephone)  | 89 (NI)                         | 62.9 ± 8.6                               | 9.2 ± 4.2                                                 | > 3 months      |
| MoCA (Changsha)                      | 338 (I and VD)                  | > 40 years                               | > 2                                                      | NI              |
| MoCA (Chinese – Cantonese)           | 70 (VD)                         | 70.1 ± 7.88                              | 8.84 ± 3.20                                              | 3 months        |
| MoCA (Chinese – Cantonese)           | 206 (I)                         | 68.14 ± 10.64 (NCI), 69.24 ± 11.45 (VCIND)| 9.73 ± 5.35 (NCI), 8.65 ± 5.51 (VCIND)                  | NI              |
| Hong Kong MoCA (HK-MoCA)             | 90 (aSAH)                       | 54.0 ± 11.0                              | NI                                                       | 3 months        |
| HK-MoCA                              | 50 (I)                          | 68.8 ± 9.2                               | 5.9 ± 4.1                                                 | 6-18 months     |
| HK-MoCA (by telephone)               | 104 (I, H, and TIA)             | 68.9 ± 10.1, 70.8 ± 9.2                   | 6.3 ± 4.4, 6.0 ± 4.5                                      | 39.4 ± 7.6 months |
| HK-MoCA                              | 40 (SMD)                        | 70.08 ± 8.5                              | 5.98 ± 4.5                                                | < 3 months      |
| MoCA (Singaporean)                   | 100 (TIA, I and H)              | 61.2 ± 11.3                              | 52% ≤ primary                                            | 4.2 ± 2.4 months |
| Northwick Park Examination of Cognition (NPETC) | 166 (NI) | 69.2 ± 14.1 | NI | 5.6 ± 7.9 days |
| Oxford Cognitive Screen (OCS)        | 208 (NI)                        | 71.1 ± 14.5                              | 11.5 ± 2.7                                               | 6.6 ± 4.69 days |
| OCS                                  | 200 (I and H)                   | 70.5 ± 14.7                              | NI                                                       | 6.1 ± 4.4 days  |
| Repeatable Battery for Assessment of Neuropsychological Status (RBANS) | a) 158, b) 36 (NI) | a) 64.27 ± 14.45, b) 63.21 ± 16.19 | a) 34% < 12, b) 29% < 12 | a) 20±19.4 days, b) 12 months |
| Rotterdam CAMCOG (R-CAMCOG)          | 169 (I and H)                   | 56.2 ± 11.3                              | 61.2% intermediate                                        | <12 months      |
| Screening Instrument for Neuropsychological Impairments in Stroke (SINS) | 49 (I, IH, SH) | 62 ± 53.5 | NI | 38±17 days |
| Six-item Screener (SIS – by telephone)| 89 (NI) | 62.9 ± 8.6 | 9.2 ± 4.2 | > 3 months |
| Weigl’s Colour-Form Sorting Test (WCFT) | 105 (NI) | 73.4 ± 10.7 | 9.9 ± 1.7 | NI |
| Zürich Maxi Mental Status Inventory (ZüMAX) | 33 (NI) | 63.2 ± 14.7 | NI | 49.4±70.8 days |

N: number of participants; NI: not informed; CVD: cerebrovascular disease; MI: multiple infarcts; SVD: small vessel disease; TIA: transient ischemic attack; I: ischemic; H: hemorrhage; IH: intracerebral hemorrhage; SH: subarachnoid hemorrhage; VD: vascular dementia; aSAH: aneurysmal subarachnoid hemorrhage; SIVD: subcortical ischemic vascular disease.
Table 2. Cognitive screenings, procedures for determining validity/reliability.

| Cognitive screening                              | Procedures for determining validity/reliability with appropriate values                                                                 | Procedures for determining validity/reliability without appropriate values |
|-------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Addenbrooke’s Cognitive Examination-Revised (ACE-R) | Concurrent validity (relation with criteria), SE (relation with criteria), SE/SP (relation with related constructs), test-retest (temporal stability reliability), comparison between contrasting groups (relation with criteria) | SE/SP (relationships with appropriate values)                             |
| Barrow Neurological Institute Screen for Higher Cerebral Functions (BNISS) | Inter-rater (internal-consistency reliability), test-retest (temporal stability reliability), comparison between contrasting groups (relation with criteria), convergent validity (relation with related constructs) | SE (relation with criteria)                                              |
| Birmingham Cognitive Screen (BCoS – Cantonese version) | Comparison between contrasting groups (relation with criteria), predictive validity (relation with criteria), convergent validity (relation with related constructs) | SE/SP (relationships with criteria)                                       |
| Birmingham Cognitive Screen (BCoS)               | Comparison between contrasting groups (relation with criteria), predictive validity (relation with criteria)                               | SE/SP (relationships with criteria)                                       |
| Brief Memory and Executive Test (BMET)           | Inter-rater (internal consistency reliability), test-retest (temporal stability reliability), SE/SP (relation with criteria), comparison between contrasting groups (relation with criteria), response times (response processes) | SE/SP (relationships with criteria)                                       |
| Brief Neuropsychological Screening (BNS)         | Comparison between contrasting groups (relation with criteria), predictive validity (relation with criteria), convergent validity (relation with related constructs) | SE/SP (relationships with criteria)                                       |
| Clock Drawing Test (CDT)                         | SE/SP (relation with criteria)                                                                                                        | SE/SP (relationship with related constructs), SE/SP (relation with criteria) |
| Cog-4                                           | Convergent validity (relation with related constructs), SE/SP (relation with criteria)                                                  | SE/SP (relationship with related constructs), SE/SP (relation with criteria) |
| Cognistat                                        | Convergent validity (relation with related constructs)                                                                             | SE/SP (relationship with related constructs)                              |
| Cognitive Assessment Scale for Stroke Patients (CASP) | Convvergent validity (relation with related constructs)                                                                             | SE/SP (relationship with related constructs)                             |
| Functional Independence Measure (FIM)            | Convergent validity (relationship with related constructs)                                                                         | SE/SP (relationship with related constructs)                              |
| Middlesex Elderly Assessment of Mental State (MEAMS) | SE/SP (relation with criteria)                                                                                                        | SE/SP (relationship with criteria)                                       |
| Mild Vascular Cognitive Impairment Assessment tool for Stroke (MVCI) | Judge analysis - face validity (content-oriented evidence), convergent validity (relation with related constructs), SE/SP (relation with criteria), correlation, inter-rater (internal consistency reliability) | SE/SP (relationship with related constructs), SE/SP (relationship with criteria) |
| Mini-Mental State Examination (MMSE)             | Comparison between contrasting groups (relation with criteria), SE (relation with criteria), SE/SP (relation with criteria), predictive validity (relation with criteria), convergent validity (relation with related constructs) | SE/SP (relationship with related constructs), SE/SP (relationship with related constructs), SE/SP (relation with criteria), predictive validity (relation with related constructs) |
| Montreal Cognitive Assessment (MoCA)             | Comparison between contrasting groups (relation with criteria), SE/SP (relation with criteria), SE (relation with criteria), SE/SP (relation with related constructs), inter-rater (internal-consistency reliability), predictive validity (relation with criteria), convergent validity (relation with related constructs), test-retest (temporal stability reliability) | SE/SP (relationship with criteria), SE/SP (relationship with related constructs), SE (relation with criteria), SE/SP (relation with related constructs), SE (relation with criteria), SE/SP (relation with related constructs), SE (relation with criteria), SE/SP (relationship with related constructs), SE (relation with criteria), SE/SP (relationship with related constructs), SE (relation with criteria), SE/SP (relationship with related constructs), SE (relation with criteria), SE/SP (relationship with related constructs) |
| miniMoCA                                        | SE/SP (relation with criteria), convergent validity (relation with related constructs)                                               | SE/SP (relationship with related constructs), SE/SP (relationship with related constructs) |

continues.
Table 2. Cognitive screenings, procedures for determining validity/reliability (continuation).

| Cognitive screening                                      | Procedures for determining validity/reliability with appropriate values                                                                 | Procedures for determining validity/reliability without appropriate values                      |
|----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| MoCA (by telephone)                                      | Comparison between contrasting groups (relation with criteria), SE/SP (relation with criteria), convergent validity (relation with related constructs), concurrent validity (relation with criteria), test-retest (temporal stability reliability), inter-rater (internal consistency reliability). |                                                                                              |
| Northwick Park Examination of Cognition (NPEC)           | Comparison between contrasting groups (relation with criteria), SE/SP (relation with criteria).                                   |                                                                                              |
| Oxford Cognitive Screen (OCS)                            | Convergent and discriminant validity (relation with related constructs), SE/SP (relation with criteria), test-retest (temporal stability reliability), concurrent validity (relation with criteria), comparison between contrasting groups (relation with criteria). |                                                                                              |
| Repeatably Battery for Assessment of Neuropsychological Status (RBANS) | Convergent and discriminant validity (relation with related constructs), predictive validity (relation with criteria).            |                                                                                              |
| Rotterdam CAMCOG (R-CAMCOG)                              | Convergent validity (relation with related constructs).                                                                           |                                                                                              |
| Screening Instrument for Neuropsychological Impairments in Stroke (SINS) | Convergent validity (relation with related constructs).                                                                           | SE/SP (relation with criteria).                                                              |
| Six-item Screener (SIS – by telephone)                   | Comparison between contrasting groups (relation with criteria), SE/SP (relation with criteria).                                   |                                                                                              |
| Weigl’s Colour-Form Sorting Test (WCFT)                  | Convergent validity (relation with related constructs), comparison between contrasting groups (relation with criteria).          |                                                                                              |
| Zürich Maxi Mental Status Inventory (ZüMAX)              | Comparison between contrasting groups (relation with criteria), test-retest (temporal stability reliability).                    |                                                                                              |

SE: sensitivity, SP: specificity.

25.45% included patients who were assessed from 3 to 12 months post-stroke and 14.54% assessed patients more than 12 months post-stroke. A total of 9.09% of the articles did not report time post-stroke (Table 1).

Psychometric properties of the instruments

In the last few years, many studies have demonstrated the psychometric properties of the instruments according to the tripartite model of validity: content, criteria and construct. However, in our systematic review, we classified the evidence of validity and reliability in accordance with recently established definitions. 21 Most of the studies determined validity based on relationships with criteria (60%), relationships with related constructs (22.50%), and content-oriented evidence (0.83%) (Table 2). Only 19 articles presented data on the reliability of the instruments, 10.83% of which discussed internal consistency reliability and 5% temporal stability reliability (Table 2).

With respect to the procedures adopted to determine validity and reliability, many of the studies included a sensitivity and specificity analysis (28.33%), considered convergent validity (or relations to other tests) (21.66%), compared contrasting groups (14.16%), executed predictive validity (9.16%), performed inter-rater analysis (7.5%), considered concurrent validity (5.83%), considered test-retest reliability (4.16%), tested for correlation with other measures (3.33%) and identified effect size (2.5%). The alternate form, discriminant evidence, response times and an analytical judgment of the instrument (face validity) were investigated once for each (0.83% overall).

As can be observed in Table 2, the Montreal Cognitive Assessment (MoCA) followed by the Mini-Mental State Examination (MMSE) were the instruments most analyzed to find validity and reliability evidence (40.90% and 18.18%, respectively). Other instruments were investigated once or twice per instrument. The studies were classified according to appropriate or inappropriate values present in the Discussion section of the articles (Table 2).

We found 26 instruments whose psychometric properties had been investigated in stroke patients (Table 3). Table 3 shows the neuropsychological functions evaluated by the screening tools: episodic memory (80.77%), language (69.23%), orientation (65.38%), executive functions (61.54%), attention (53.84%), visuo-construc-
### Table 3. Neuropsychological screening and functions evaluated.

| Screening                                                                 | Episodic memory | Language | Orientation | Executive functions | Attention | Visuo-construction | Perception | Praxis | Abstraction | Arithmetic | Processing speed |
|--------------------------------------------------------------------------|-----------------|----------|-------------|----------------------|-----------|---------------------|------------|--------|-------------|------------|------------------|
| Addenbrooke’s Cognitive Examination–Revised (ACE-R)                      | X               | X        | X           | X                    | X         |                     |            |        |             |            |                  |
| Barrow Neurological Institute Screen for Higher Cerebral Functions (BNIS)| X               | X        | X           | X                    | X         |                     |            |        |             |            |                  |
| Birmingham Cognitive Screen (BCoS)                                       | X               | X        | X           | X                    | X         |                     |            |        |             |            |                  |
| Brief Memory and Executive Test (BMET)                                   | X               | X        |             |                      |           |                     |            |        |             |            |                  |
| Brief Neuropsychological Screening (BNS)                                 | X               | X        | X           | X                    | X         | X                   |            |        |             |            |                  |
| Clock Drawing Test (CDT)                                                 | X               |          |             |                      |           |                     |            |        |             |            |                  |
| Cog-4                                                                    |                 | X        | X           | X                    |           |                     |            |        |             |            |                  |
| Cognistat                                                                |                 |          |             |                      |           |                     |            |        |             |            |                  |
| Cognitive Assessment Scale for Stroke Patients (CASP)                    | X               | X        | X           | X                    |           |                     |            |        |             |            |                  |
| Functional Independence Measure (FIM Cognitive)                          | X               | X        |             |                      |           |                     |            |        |             |            |                  |
| Middlesex Elderly Assessment of Mental State (MEAMS)                     | X               | X        | X           | X                    |           |                     |            |        |             |            |                  |
| Mild Vascular Cognitive Impairment Assessment tool for Stroke (MVCI)     | X               | X        | X           | X                    | X         | X                   |            |        |             |            |                  |
| Mini–Mental State Examination (MMSE)                                     | X               | X        | X           | X                    |           |                     |            |        |             |            |                  |
| MiniMoCA - Montreal Cognitive Assessment(miniMoCA)                       | X               |           |             |                      |           |                     |            |        |             |            |                  |
| Montreal Cognitive Assessment (MoCA)                                     | X               | X        | X           | X                    |           |                     |            |        |             |            |                  |
| MoCA (by telephone)                                                      | X               |           |             |                      |           |                     |            |        |             |            |                  |
| MoCA (Hong Kong)                                                         | X               | X        | X           |                      |           |                     |            |        |             |            |                  |
| MoCA (Singaporean)                                                       | X               | X        | X           |                      |           |                     |            |        |             |            |                  |
| Northwick Park Examination of Cognition (NPEC)                           | X               | X        | X           | X                    |           |                     |            |        |             |            |                  |
| Oxford Cognitive Screening (OCS)                                          | X               | X        | X           |                      |           |                     |            |        |             |            |                  |
| Repeateable Battery for Assessment of Neuropsychological Status (RBANS)   | X               |           |             |                      |           |                     |            |        |             |            |                  |
| Rotterdam CAMCOG (R-CAMCOG)                                              | X               |           |             |                      |           |                     |            |        |             |            |                  |
| Screening Instrument for Neuropsychological Impairments in Stroke (SINS)  | X               |           |             |                      |           |                     |            |        |             |            |                  |
| Six-item Screener (SIS)                                                   |                 | X        |             |                      |           |                     |            |        |             |            |                  |
| Weigl’s Colour-Form Sorting Test (WCFT)                                   |                 | X        |             |                      |           |                     |            |        |             |            |                  |
| Zürich Maxi Mental Status Inventory (ZüMAX)                              | X               | X        | X           | X                    | X         | X                   |            |        |             |            |                  |
tion (38.5%), perception (34.61%), praxis (23.07%), abstraction (23.07%), arithmetic (19.23%) and processing speed (3.84%).

DISCUSSION
Characteristics of the samples
Regarding sample size, we identified wide variability in the number of participants, and only one study presented a sample calculation. Calculating the sample size in psychometric studies is recommended both to avoid finding differences between groups by chance and to increase the likelihood of detecting true, clinically significant differences. Therefore, the results of many papers should be interpreted with caution because they do not use representative samples of stroke patients.

It is essential to ensure the sample’s representativeness by providing a detailed description of its sociodemographic and developmental characteristics in empirical studies. Most of the investigations involved elderly stroke patients (>60 years), and the psychometric properties of the screening are shown only for this age group. An increasing number of young people affected by this injury exhibit cognitive impairment, which is present in approximately 20% to 30% of young stroke patients. Age influences patient performance on cognitive tasks. Therefore, it is important to verify whether validity and reliability evidence vary according to this variable for each test.

Educational background may influence both patient performance and test sensitivity specificity. However, several studies included in this review did not discuss the education of participants and did not control for this variable, which is a limitation. Adults with high educational levels usually have better performance on neuropsychological assessments, and the cut-off points of tests should take this into account. Years of education should always be considered in empirical studies in neuropsychology.

In relation to neurological variables, many studies did not report the cerebrovascular disease of the participants (16.36%). Patients present vascular cognitive impairment regardless of stroke type, although there are differences in the neuropsychological performance of patients with vascular dementia (VD), subcortical ischemic vascular disease (SIVD) and mild cognitive impairment (MCI). Therefore, future studies could provide validity evidence and cut-off points for the screening according to cerebrovascular disease (when differences are found between groups). This would enable clinicians to know when significant deficits are present in each case.

Lastly, the time post-stroke is important to note in empirical studies because instruments have shown different cut-off points and because patients recover some neuropsychological functions approximately six months post-stroke. Neurocognitive assessment is indicated after acute stroke. The early recognition of cognitive deficits leads to improved interventions and thus prognosis.

Psychometric properties of the instruments
Most instruments have shown validity regarding relationships with criteria, and the studies typically used age, education, stroke type and neuropsychological performance differentiations between clinical and control groups as criteria. This evidence is important in determining whether a neuropsychological instrument can predict either the performance of a specific group of individuals or whether there will be differences in the scores of contrasting groups. However, a stroke may produce different behavioral changes in individuals, thus complicating the definition of a criterion group. Although heterogeneity of performance is important for identifying the test’s psychometric properties, heterogeneity of lesions can limit the interpretation of the results for all types of cerebrovascular diseases.

Evidence based on relationships with related constructs was also one of the most common forms of validity evidence found by the screening. Correlation with other tests and measures (related constructs) is important for proving that an instrument assesses the intended cognitive domains. In general, cognitive screening have been related with other instruments in that they evaluate similar neuropsychological functions. However, the strength of the correlation between instruments varies widely due to the different characteristics of the tests. For example, the CASP showed weak correlation with MoCA and the MMSE likely because it has visual items that can be administered to patients with severe expressive aphasia, while the other screening are language-dependent. Therefore, interpreting evidence of validity based on conceptually related constructs should be carried out with caution.

Other psychometric procedures, such as seeking content validity, may not have been found frequently because most of the screening instruments were not specifically devised for stroke samples. Further evidence of validity should be found in the manuals of the tests published in each country. Our study is limited by a failure to describe these data.

Most of the studies analyzed only the validity – not the reliability – of the instruments. We suggest that
psychometric studies include analyses of reliability to enlarge their evidence and avoid measurement errors. For example, some studies with test-retest reliability (temporal stability reliability) demonstrated that patients have better performance on the reevaluation. Other studies show temporal score stability. Several studies did not specify the time of cognitive evaluation. Therefore, future studies should clarify the timing of the evaluation and show evidence in accordance with this variable.

Regarding psychometric property procedures, sensitivity and specificity analysis were the most commonly used in the studies. The sensitivity of a test relates to the percentage of individuals with deficits that the instrument is able to identify (true positive rate). In contrast, the specificity indicates the test’s ability to detect healthy people for the neuropsychological functions measured (true negative rate). According to Blake et al., a cognitive screening instrument should have values superior to 80% and 60% for good sensitivity and acceptable specificity, respectively. However, many screening instruments did not reach these values. Therefore, items need to be better studied and replaced to improve the quality of the instruments.

Notably, convergent validity and comparisons between contrasting groups were frequently executed. These procedures are important to seek evidence of validity based on relationship with criteria, as previously discussed. Differences between contrasting groups with various degrees of severity of vascular cognitive impairment were highlighted in many studies. However, studies need to improve the control of variables such as sociodemographic (age and education) and neurological data (cerebrovascular disease) that influence patient cognitive performance.

In this review article, most cognitive screening used in stroke samples were originally developed to evaluate MCI and Alzheimer dementia patients, such as the MMSE, MoCA, WCFT, R-CAMCOG, ACE and CDT. However, there is no theoretical basis to justify the use of such screening, and they do not contain specific tasks for stroke patients. The application of neuropsychological instruments with a theoretical base is important both to justify patient deficits and plan their rehabilitation.

The NINDS and the CSN recommended the use of the MoCA to evaluate vascular cognitive impairment as an alternative to the MMSE. These instruments are correlated. However, one advantage of the MoCA is that the ceiling effects were substantially less evident than for the MMSE in stroke patients. Although both instruments are commonly investigated, the applicability to stroke samples has been discussed.

Some studies support the high sensitivity of the MoCA, but reveal its low specificity. Chan et al. found that 77% of patients were classified as cognitively intact on the MoCA but were impaired for one or more cognitive domains on a neuropsychological assessment (intellectual functioning, processing speed, and visual memory) not evaluated by the screen. The MoCA also failed to identify patients without problems in daily life functioning after mild stroke and discharge destination; however, a relationship between the MoCA and functional measures was found post-stroke.

The MoCA has demonstrated wide validity and reliability in several languages. However, researchers should exercise caution with MoCA cut-off points in each country because this test is influenced by educational level, age, cerebrovascular disease and time post-stroke. Additionally, deficits in language (comprehension and expression) and perception (hemineglect), which are common post-stroke, may negatively affect the performance of participants on MoCA tasks.

A limitation of the studies on the MoCA is that the cut-off point for elderly samples without vascular disease, as well as cut-off points from different countries generally, to classify cognitive impairment patients, underestimate the possible deficits post-stroke. It is also important to show cut-off points by subtest (cognitive function), which could contribute to understanding the impact of brain injury on specific skills.

The MMSE is more specific than the MoCA but is less sensitive for stroke patients. This instrument can show differences between clinical and control groups and between various cerebrovascular diseases but underestimates cognitive impairment post-stroke. However, the MMSE has shown low prediction ability for functional outcomes.

According to Pendlebury et al., the MMSE showed a ceiling effect in many subtests (namming, registration, reading and writing reaching near maximal scores) in amnestic, TIA and stroke groups. Moreover, the MMSE is insensitive for evaluating abstract reasoning, executive functioning, and visual perception/constructive deficits that are present in subcortical lacunar strokes. Compared to a detailed neuropsychological battery of tests, the MMSE did not present adequate levels of sen-
However, most neurologists discriminate acute stroke patients when evaluating post-stroke cognitive impairments, but these functions are not developed for vascular cognitive impairments, which justifies the construction of specific instruments. Moreover, the majority of the studies may underestimate patient deficits.

In summary, the psychometric properties of neuropsychological screening for stroke patients have been explored by initial analyses that did not use representative samples. Although the studies most frequently used the MMSE and the MoCA to find evidence of validity and reliability, the use of these instruments in stroke patients, which justifies the construction of specific instruments. Moreover, more studies involving specific instruments for stroke patients are necessary to confirm the validity and reliability of the cognitive screening.

**Authors contributions.** All authors drafted and critically revised the manuscript.

**Acknowledgements.** The research reported in this paper has been made possible through support from the Fundação de Amparo à Pesquisa do Rio Grande do Sul (FAPERGS) and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

**REFERENCES**

1. Jokinen-Salmela H, Melkas S, Ylikoski R, Pohjasvuori T, Kaiste M, Erkinjuntti T, et al. Post-stroke cognitive impairment is common even after successful clinical recovery. Eur J Neurol. 2015;22(8):1288-94.
2. Delavan H, Jönsson A-G, Lökvist H, Ivarsson S, Ernstähn S, Norving B, et al. Cognitive function in stroke survivors: a 10-year follow-up study. Acta Neurol Scand. 2016;133(3):1-8.
3. Schaapmeesters P, Maaswijk NAM, Van Dijk EJ, Rutten-Jacobs LCA, Arntz RM, Schroderwaldt HC, et al. Long-term cognitive impair-
ment after first-ever ischemic stroke in young adults. Stroke. 2013; 44(6):1621-8.
4. Ferreira MGR, Moro CHC, Franco SC. Cognitive performance after ischemic stroke. Dement Neuropsychol. 2015;9(2):165-75.
5. Barker-Collo S, Starkey N, Lawes CMM, Feigin V, Senior H, Parag V. Neuropsychological profiles of 5-year ischemic stroke survivors by oxfordshire stroke classification and hemisphere of lesion. Stroke. 2012; 43(1):50-5.
6. Nys GMS, Van Zandvoort MJ, De Kort PLM, Jansen BPW, Kappele LJ, De Haan EHF. Restrictions of the Mini-Mental State Examination in acute stroke. Arch Clin Neuropsychol. 2005;20(5):623-9.
7. Nakebey K, Boland E, Bergersen H, Schanke A-K, Farner L, Wagle J, et al. Scoring for cognitive deficits after stroke: a comparison of three screening tools. Clin Rehabil. 2008;22(12):1095-104.
8. Lees R, Fearon P, Harrison JK, Brookfield NM, Quinn TJ. Cognitive and mood assessment in stroke research. Stroke. 2012;43(8):1678-80.
9. Dement Neuropsychol 2019 March;13(1):31-43
Rodrigues et al.

Wong GKC, Lam SW, Wong A, Mok V, Su D, Ngai K, et al. Early MoCA-assessed cognitive impairment after aneurysmal subarachnoid hemorrhage and relationship to 1-year functional outcome. Transl Stroke Res. 2014;5(2):296-91.
10. Boosman H, Visser-Meily JMA, Post MWM, Duits A, van Heuven GM. Validity of the Barrow Neurological Institute (BNI) screen for higher cerebral functions in stroke patients with good functional outcome. Clin Neuropsychol. 2013;27(4):687-80.
11. Redfors P, Hotgren C, Eriksson I, Holmegaard L, Samuelsson H, Jood K. The Barrow Neurological Institute screen for higher cerebral functions in cognitive screening after stroke. J Stroke Cerebrovasc Dis. 2014;23(4):349-55.
12. Pan X, Chen H, Bickerton WL, Lau JKL, Kong APH, Rotstein P, et al. Preliminary findings on the reliability and validity of the cantonese Birmingham Cognitive Screen in patients with acute ischemic stroke. Neuropsychiatr Dis Treat. 2015;11:337-90.
13. Bickerton W-L, Dementyev N, Francis D, Kumar V, Remoundou M, Balani A, et al. The BCoS cognitive profile screen: utility and predictive value for stroke. Neuropsychology. 2015;29(4):638-48.
14. Brookes RL, Holloocks MJ, Khan U, Morris RG, Markus HS. The Brief Memory and Executive Test (BME) for detecting vascular cognitive impairment in small vessel disease: a validation study. BMC Med. 2015;13(1):290.
15. Lunardelli A, Mengotti P, Pesavento V, Sverzut A, Zadini A. The Brief Neuropsychological Screening (BNS): valuation of its clinical validity. Eur J Phys Rehabil Med. 2009;45(1):85-91.
16. Yoo DH, Lee JS. Clinical usefulness of the clock drawing test applying rasch analysis in predicting of cognitive impairment. J Phys Ther Sci. 2016;28(7):1492-3.
17. Lees R, Selvarajah J, Fenton C, Pendlebury ST, Langhorne P, Stott DJ, et al. Test accuracy of cognitive screening tests for diagnosis of dementia and multidomain cognitive impairment in stroke. Stroke. 2014;45(10):3008-18.
18. Barnay J-L, Wauquiez G. Feasibility of the Cognitive Assessment scale for Stroke Patients (CASp) vs. MMSE and MoCA in aphasic left hemisphere stroke patients. Ann Phys Rehabil Med. 2014;57(6-7):422-35.
19. Benaim C, Barnay JL, Wauquiez G, Bonnin-Koang HY, Anquetil C, Pérennoud D, et al. The Cognitive Assessment scale for Stroke Patients (CASp) vs. MMSE and MoCA in non-aphasic hemisphere stroke patients. Ann Phys Rehabil Med. 2015;58(2):78-85.
20. Te Winkel-Witlox ACM, Post MWM, Visser-Meily JMA, Lindeman E. Efficient screening of cognitive dysfunction in stroke patients: comparison between the CAMCOG and the R-CAMCOG, Mini Mental State Examination and Functional Independence Measure-cognition score. Disabil Rehabil. 2008;30(18):1386-91.
21. Cartoni A, Lincoln NB. The sensitivity and specificity of the Middlesex Elderly Assessment of MEASAS for detecting cognitive impairment after stroke. Neuropsychol Reabil. 2005;15(1):55-67.
22. Oh HS, Kim JS, Shm EB, Seo WS. Development and clinical validity of a mild vascular cognitive impairment assessment tool for Korean stroke patients. Asian Nurs Res (Korean Soc Nurs Sci). 2015;9(3):225-34.
23. Pendlebury ST, Cuthbertson FC, Welch SJ V., Mehta Z, Rothwell PM. Underestimation of cognitive impairment by Mini-Mental State Examination versus the Montreal Cognitive Assessment in patients with transient ischemic attack and stroke: a population-based study. Stroke. 2010;41(8):1290-3.
24. Zhou A, Jia J. A screen for cognitive assessments for patients with vascular cognitive impairment no dementia. Int J Geriatr Psychiatry. 2009;24(12):1295-7.
25. Dong Y, Venketasubramanian N, Chan BP-L, Sharma VK, Slavin MJ, Collinson SL, et al. Brief screening tests during acute admission in patients with mild stroke are predictive of vascular cognitive impairment 3-6 months after stroke. J Neurol Neurosurg Psychiatry. 2012;83:580-5.
26. Dong Y, Slavin MJ, Chan BP-L, Venketasubramanian N, Sharma VK, Collinson SL, et al. Improving screening for vascular cognitive impairment at three to six months after mild ischemic stroke and transient ischemic attack. Int Psychogeriatrics. 2014;26(5):787-93.
stroke and transient ischaemic attack: an observational study. BMJ Open. 2013;3(9):e003105.
45. Xu Q, Cao WW, Mi JH, Yu L, Lin Y, Li YS. Brief screening for mild cognitive impairment in subcortical ischemic vascular disease: a comparison study of the Montreal Cognitive Assessment with the Mini-mental State Examination. Eur Neurol. 2014;71(3-4):106-14.
46. Shen YJ, Wang WA, Huang FD, Chen J, Liu HY, Xia YL, et al. The use of MMSE and MoCA in patients with acute ischemic stroke in clinical. Int J Neurosci. 2016;126(5):442-7.
47. Van Der Wijst E, Wright J, Steultjens E. The suitability of the Montreal Cognitive Assessment as a screening tool to identify people with dysfunction in occupational performance after mild stroke. Br J Occup Ther. 2014;77(10):526-32.
48. Godfrey O, Fick A, Roussel M, Aurnaut C, Bugnicourt JM, Lamy C, et al. Is the Montreal Cognitive Assessment superior to the Mini-mental State Examination to detect poststroke cognitive impairment?: A study with neuropsychological evaluation. Stroke. 2011;42(6):1712-6.
49. Salvadori E, Paati M, Poggesi A, Chiti G, Inziani D, Panton L. Predictive value of MoCA in the acute phase of stroke on the diagnosis of mid-term cognitive impairment. J Neurol. 2013;260(9):2220-7.
50. Geubbelis HJB, Nusselein BAM, Van Heughten CM, Valentin SAM, Rasquin SMC. Can the Montreal Cognitive Assessment predict discharge destination in a stroke population in the hospital? J Stroke Cerebrovasc Dis. 2015;24(5):1094-9.
51. Campbell N, Rice D, Friedman L, Speechley M, Teasell RW. Screening and facilitating further assessment for cognitive impairment after stroke: application of a shortened Montreal Cognitive Assessment (miniMoCA). Disabil Rehabil. 2016;38(8):601-4.
52. Pendlebury ST, Welch SJ V, Cuthbertson FC, Mariz J, Mehta Z, Rothwell PM. Telephone assessment of cognition after transient ischemic attack and stroke: modified telephone interview of cognitive status and telephone Montreal Cognitive Assessment versus face-to-face Montreal Cognitive Assessment and neuropsychological battery. Stroke. 2013;44(1):227-9.
53. Sahathevan R, Ali KM, Ellery F, Mohamad NF, Hamdan N, Ibrahim NM, et al. A Bahasa Malaysia version of the Montreal Cognitive Assessment: validation in stroke. Int Psychogeriatr. 2014;26(5):781-6.
54. Zuo L, Dong Y, Zhu R, Jin Z, Li Z, Wang Y, et al. Screening for cognitive impairment with the Montreal Cognitive Assessment in Chinese patients with acute mild stroke and transient ischaemic attack: a validation study. BMJ Open. 2016;6(7):e011310.
55. Tu Q-Y, Jin H, Ding B-R, Yang X, Lei Z-H, Bai S, et al. Reliability, validity, and optimal cutoff score of the Montreal Cognitive Assessment (Changsha version) in ischemic cerebrovascular disease patients of hunan province, China. Dement Geriatr Cogn Dis Extra. 2013;3(1):25-36.
56. You J-S, Chen R-Z, Zhang F-M, Zhou Z-Y, Cai Y-F, Li G-F. The chinese (cantonese) montreal cognitive assessment in patients with subcortical ischemic vascular dementia. Dement Geriatr Cogn Dis Extra. 2011;1(1):276-82.
57. Wong GKC, Lam SW, Wong A, Ngai K, Poon WS, Mok V. Comparison of Montreal Cognitive Assessment and Mini-Mental State Examination in evaluating cognitive domain deficit following aneurysmal subarachnoid haemorrhage. PLoS One. 2013;8(4):1-7.
58. Wu Y, Wang M, Ren M, Xu W. The effects of educational background on Montreal Cognitive Assessment screening for vascular cognitive impairment, no dementia, caused by ischemic stroke. J Clin Neurosci. 2013;20(10):1406-10.
59. Wong GKC, Lam S, Ngai K, Wong A, Mok V, Poon WS. Evaluation of cognitive impairment by the Montreal Cognitive Assessment in patients with aneurysmal subarachnoid haemorrhage: prevalence, risk factors and correlations with 3 month outcomes. J Neurol Neurosurg Psychiatry. 2012;83(11):1112-7.
60. Wong A, Nyenhuis D, Black SE, Law LS, Lo ESK, Kwan PWL, et al. Montreal Cognitive Assessment 5-Minute protocol is a brief, valid, reliable, and feasible cognitive screen for telephone administration. Stroke. 2015;46(4):1059-64.
61. Wong A, Xiong YY, Kwan PWL, Chan AY, Lam WWM, Wang K, et al. The validity, reliability and clinical utility of the Hong Kong Montreal Cognitive Assessment (HK-MoCA) in patients with cerebral small vessel disease. Dement Geriatr Cogn Disord. 2009;28(1):81-7.
62. Dong Y, Sharma VK, Chan BPL, Venketasubramanian N, Teoh HL, Seet RCS, et al. The Montreal Cognitive Assessment (MoCA) is superior to the Mini-Mental State Examination (MMSE) for the detection of vascular cognitive impairment after acute stroke. J Neurol Sci. 2010;299(1-2):15-8.
63. Williams PM, Johnson C, Swan S, Barber C, Murphy P, Devine J, et al. The Northwick Park Examination of Cognition: a brief cognitive assessment tool for use in acute stroke services. Int J Ther Rehabil. 2016;23(7):314-22.
64. Demerye N, Riddoch MJ, Slavkova ED, Jones K, Reckless I, Mathieson P, et al. Domain-specific versus generalized cognitive screening in acute stroke. J Neurol. 2016;263(2):308-15.
65. Larson E, Kirschner K, Bode P, Heinemann A, Goodman R, Construct and predictive validity of the repeatable battery for the assessment of neuropsychological status in the evaluation of stroke patients. J Clin Exp Neuropsychol. 2005;27(1):16-32.
66. Hobson P, Meara J, Taylor C. The Weigl Colour-Form Sorting Test: A quick and easily administered bedside screen for dementia and executive dysfunction. Int J Geriatr Psychiatry. 2007;22(9):909-15.
67. Tobler-ammann BC, de Brun ED, Brugger P, de Bie RA, knolhs RH. The Zürich Maxi Mental Status Inventory (ZüMAX): test-retest reliability and discriminant validity in stroke survivors. Cogn Behav Neurol. 2016;29(2):78-90.
68. Walter SD, Elasizm B, Donner A. Sample size and optimal designs for reliability studies. Stat Med. 1998;17(1):101-10.
69. Lees R, Lua J, Melling E, Miaow Y, Tan J, Quinn TJ. Cog-4 has limited diagnostic test accuracy and validity for cognitive assessment in stroke survivors. J Stroke Cerebrovasc Dis. 2014;23(8):1604-10.
70. Blake H, McKinney M, TREECE K, lee E, Lincoln NB. An evaluation of screening measures for cognitive impairment after stroke. Age Ageing. 2002;31(8):451-6.