Development of a Novel Self-administered Cognitive Assessment Tool and Normative Data for Older Adults

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Background: Preexisting cognitive impairment in surgical patients is one of the leading risk factors for adverse cognitive outcomes such as postoperative delirium and postoperative cognitive dysfunction. We developed a self-administered tablet computer application intended to assess the individual risk for adverse postoperative cognitive outcomes. This cross-sectional study aimed to establish normative data for the tool.

Materials and Methods: Healthy volunteers aged 65 years and above were administered the Mini-Mental State Examination, Geriatric Depression Scale, and Consortium to Establish a Registry for Alzheimer's Disease-Neuropsychological Assessment Battery to assess cognitive health. All subjects completed the tablet computer application without assistance. Primary outcome measure was the test performance. Regression models were built for each cognitive domain score with the covariates age, sex, and education in cognitively healthy subjects. Demographically adjusted standard scores (*z*-scores) were computed for each subtest.

Results: A total of 283 participants (155 women, 128 men) were included in the final analysis. Participants' age was 73.8 ± 5.2 years (mean ± SD) and their level of education was 13.6 ± 2.9 years. Mini-Mental State Examination score was 29.2 ± 0.9 points, Geriatric Depression Scale score was 0.4 ± 0.7 points, and Consortium to Establish a Registry for Alzheimer's Disease-Neuropsychological Assessment Battery total score was 98.7 ± 5.7 points. Older age was associated with poorer performance in the visual recognition task and in Trail Making Test B ($P < 0.05$ after Bonferroni-Holm adjustments).

Conclusions: This study provides normative data for a novel self-administered tablet computer application that is ultimately designed to measure the individual risk for adverse postoperative cognitive outcomes in elderly patients.

Key Words: cognitive function, assessment, postoperative delirium, postoperative cognitive dysfunction, tablet computer application, normative data

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In light of a growing geriatric patient population,[1] health care professionals are increasingly faced with specific challenges of elderly patients in the primary care and hospital setting. The need for surgical procedures increases with patient age.[2] Elderly patients undergoing surgery are more vulnerable to adverse postoperative outcomes due to advanced age, frailty, and concomitant medical conditions.[3] Adverse cognitive outcomes such as postoperative delirium (POD) and postoperative cognitive dysfunction (POCD) are frequently encountered in older surgical patients and are associated with increased morbidity and mortality.[4–6] An early identification of risk factors is useful for the targeted prevention of cognitive disorders in hospitalized patients.[7] While most predictors for POD and POCD may be detected in the medical history, clinical examination, or laboratory investigations, some may be missed in the absence of a specific assessment. Preexisting cognitive impairment in surgical patients is one of the strongest risk factors for further postoperative cognitive decline including POD[8–11] and POCD.[12,13] However, it tends to be underdiagnosed,[14,15] because an objective evaluation of the cognitive performance is time-consuming and usually requires trained personnel. Therefore, it may be challenging to implement the routine

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This report describes a cross-sectional study. The authors state that the report includes the items in the STROBE checklist for cross-sectional studies.

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assessment of cognitive status in all geriatric patients presenting for surgery.[16] Besides, most cognitive screening tools available to date are not specifically intended for preoperative use in surgical patients.[17] Some current risk prediction models for POD do not include the assessment of cognitive functions at baseline.[18,19]

Our goal was to create a new tool to assess individual baseline cognition as a major risk factor for adverse postoperative cognitive outcomes in surgical patients. Key requirements for the design of the CogCheck application were self-administration, user-friendliness, language-free content (pictures), conciseness (ie, administration time <30 min), and automated scoring. These may facilitate routine use in clinical practice (eg, during preoperative evaluation for anesthesia) and offer potential advantages over other screening tools. Eventually, the purpose of the CogCheck application is to simplify and standardize preoperative cognitive testing in the elderly. Compared with CogCheck, other preoperative cognitive assessments do not use computerized testing,[17] which may be beneficial regarding test reliability and scoring. In addition, the self-administrative character of CogCheck and the possibility of remote and parallel testing may reduce personnel and resource costs.

The development of such tool involves several steps: (1) identification of relevant cognitive domains, (2) choice of task to assess these domains, (3) computer programming of the tasks, (4) pilot study to assess applicability of the tool, and (5) collection of normative data in a group of individuals with established cognitive health.[20] Once these steps have been carried-out successfully, the new tool may be used in a series of validation studies. The objective of this cross-sectional study was to collect normative data in cognitively healthy individuals, and find the adjustment necessary to eliminate the influence of demographic characteristics (age, sex, and education).

MATERIALS AND METHODS

Study Design

We conducted a cross-sectional study to acquire normative data for the tablet computer-based application, CogCheck. Ethical approval for this study (protocol No. EKNZ BASEC. 2016-00393) was provided by the institutional ethics board (Ethikkommission Nordwest- und Zentralschweiz) on April 12, 2016. A substantial amendment to the study protocol was approved on November 11, 2016. All study participants provided written informed consent. The study was conducted in respect of the most recent version of the Declaration of Helsinki and registered on ClinicalTrials.gov (NCT02708823) before data acquisition. This manuscript adheres to the applicable EQUATOR network guidelines.

Participants and Setting

All study participants were healthy nonsurgical volunteers recruited from the Registry of Individuals Interested to Participate in Research established by the Memory Clinic, University Center for Medicine of Aging Basel, Felix Platter Hospital, in Basel, Switzerland. Only subjects who had previously filled out a standardized medical questionnaire were considered. Data from eligible participants were screened for inclusion and exclusion criteria. Inclusion criteria were: (1) aged 65 years and above, (2) education ≥7 years, (3) fluency in the German language, and (4) written informed consent. Exclusion criteria were: (1) history of cognitive impairment, (2) signs of depression, (3) severe sensory or motor impairment interfering with cognitive testing, (4) serious somatic disease, disease or event affecting the central nervous system (head trauma with loss of consciousness >5 min, any brain surgery, general anesthesia within the last 3 mo, alcoholism, intoxication with neurotoxic substances), (5) cerebrovascular disease, (6) regular medication with psychoactive drugs except for benzodiazepines, and (7) participation in any cognitive study within the last 3 months or previous participation in a study using CogCheck.

In order to ensure cognitive health of participants, only those with at least 27/30 points[21] in the Mini-Mental State Examination (MMSE)[22] and >85.89 points[23] in the German version of the Consortium to Establish a Registry for Alzheimer's Disease-Neuropsychological Assessment Battery (CERAD-NAB)[24] were included. Subjects with >5/15 points on the brief version of the Geriatric Depression Scale (GDS),[25] indicating signs of depression, were excluded. Optimal homogeneity of the study population was achieved by stratification of participants according to age and sex categories.

Design of CogCheck

The CogCheck application was developed in a joint project by the Department of Anesthesia at University Hospital Basel and the Memory Clinic at Felix Platter Hospital in Basel, Switzerland. As objective assessment of a patient's cognitive status is highly resource-dependent,[26] our goal was to create a computerized risk-stratification tool for adverse postoperative cognitive outcomes in surgical patients that is easy to use and does not require trained personnel. Previous investigations showed that even persons without computer experience were able to perform well using computer-based tests.[27] Moreover, study subjects were more successful when using a tablet computer with touch screen instead of a computer with a mouse or a keyboard.[26,28] Thus, we designed a tablet computer application in which all subtests are language-free. Instructions—which can be easily translated into other languages—are provided in writing and are complemented with short videos. This also allows for the assessment of patients with hearing impairment.

We compared existing preoperative risk scores[29–31] to decide which predictors should be included in our new tool. The final version of CogCheck (see Fig., Supplemental Digital Content 1, http://links.lww.com/JNA/A58, which shows translated screenshots of the application) used for test standardization included: (1) demographic and medical data (sensory impairment,[32] age,[33] medications,[34] education,[35] and language skills), (2) cognitive self-assessment,[33] (3) temporal orientation,[17,22] and

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(4) a set of 7 automated subtests of cognitive functions (visual recognition,[36] picture learning and recognition,[26] digit span,[37] spatial span,[38] reaction time and attention,[26] and Trail Making Tests [TMT] A and B[39]). The automated scoring system for CogCheck is based on the Diagnostic and Statistical Manual of Mental Disorders (DSM-5)[40] definitions for neurocognitive disorders.

At an initial stage, user-friendliness of CogCheck was evaluated in a pilot project[41] with 20 cognitively healthy volunteers (10 women, 10 men; mean age: 71.8 ± 3.4 y; mean Montreal Cognitive Assessment[42] score: 28.0 ± 0.9 points) and 13 cognitively impaired patients (5 women, 8 men; mean age: 76.5 ± 4.5 y; mean Montreal Cognitive Assessment score: 22.3 ± 2.6 points) of the Memory Clinic. Twenty-seven pilot study participants (82%) privately owned and used a computer, 7 (21%) a tablet computer, and 9 (27%) a smartphone. The majority of cognitively healthy and impaired subjects were successfully able to complete the assessment without or with minimal help (95% and 85%, respectively). The CogCheck application received high overall quality and acceptance ratings (clear layout: 97%; easy navigation: 88%). Successively, some practical features of the application were improved (eg, font size, color-coding, and touchscreen sensibility).

Variables and Data Sources

Study participants were examined by one of 4 individually trained psychology master's students in a quiet room, seated at a table. After obtaining consent, the examiner first updated the individual's medical questionnaire and medication list. Second, the MMSE and GDS were administered. Subjects then performed CogCheck on an iPad Air tablet computer with 9.7-inch display using iOS 10.2 or 10.3 (Apple Inc., Cupertino, CA). Although the examiner remained in the room during CogCheck testing, he or she was not allowed to interact in any way with the subject. Finally, the extended German version of the CERAD-NAB[43] was administered.

Data from CogCheck were sent in real-time to a secure server at University Hospital Basel using a locked Wireless Local Area Network connection. Examiners were blinded to application data. Paper-based study data were recorded directly onto the case report form and later transferred into an electronic database using FileMaker Pro (FileMaker Inc., Santa Clara, CA).

Statistical Analysis

We evaluated the effects of common demographic characteristics on test performance and examined the distribution of scores. First, 20 regression models for each cognitive subtest (see Table, Supplemental Digital Content 2, http://links.lww.com/JNA/A59, which displays the content and structure of the CogCheck application) were calculated with the covariates age, sex, education, their interactions, and their potential nonlinear relationships using quadratic terms.[44] The optimal model was determined by leave-one-out cross-validation, that is, minimizing the Prediction Residual Sums of Squares statistics among the 20 regression models for each response variable.[44] Second, if necessary, optimal transformations (Box-Cox family or arcsine) were applied to achieve normality and homoscedasticity of the residuals. Third, step 1 was repeated with transformed variables determining an optimal model from the 20 models. This was always the same or a similar model as in step 1, which speaks for a certain robustness of the analysis. Finally, formulae for demographically adjusted standard scores (z-scores) were computed based on the final regression model. The Bonferroni-Holm method for multiple testing was applied in order to estimate the hypothetical effects of age and education in all subtests.

In order to estimate the fifth and 95th percentile with a maximum deviation of 2% for the normative data,[45] at least 171 subjects were needed. Age, sex, and education were predefined as predictor variables, and 3 additional predictor variables with interactions and quadratic terms were anticipated. Ten subjects per predictor variable were included to account for adjustments in the regression models. Hence, the minimum sample size was 231. All statistical analyses were performed using R, version 3.4.1 (R Foundation, Vienna, Austria).

RESULTS

Participants

All study-related examinations took place between December 2016 and April 2017. At the time of the study, the Registry of Individuals Interested to Participate in Research counted 2162 volunteers, including 794 subjects who had filled out a standardized medical questionnaire. Of 487 eligible subjects who were contacted by letter, 334 were included in the study. The final sample for analysis consisted of 283 cognitively healthy volunteers (155 women, 128 men). Figure 1 shows the process of recruitment and inclusion in detail. For the final sample (n = 283), mean subject age was 73.8 ± 5.2 (range, 65 to 91) years, and mean education was 13.6 ± 2.9 (range, 7 to 20) years. Each age category was represented by at least 21 subjects per sex. The study population comprised nearly equal numbers of men and women in each age category. Demographic characteristics, medical comorbidities, and neuropsychological test results of participants are summarized in Table 1. There was no missing data on the key variables in our main analysis.

Results of CogCheck

Demographic data, self-assessment of cognitive functions, and testing of temporal orientation originating from CogCheck are summarized in Table 2. The mean time necessary to complete the application was 21.7 ± 2.2 minutes. All participants were able to complete the assessment without help.

Older participants performed poorer in the visual recognition task ($P < 0.001$), TMT-A ($P < 0.001$), and TMT-B ($P < 0.001$), with the most distinct effect observed in TMT-B. Participants with a lower level of education obtained lower scores in the visual recognition ($P = 0.006$), picture recognition ($P = 0.026$), and digit span ($P = 0.036$)

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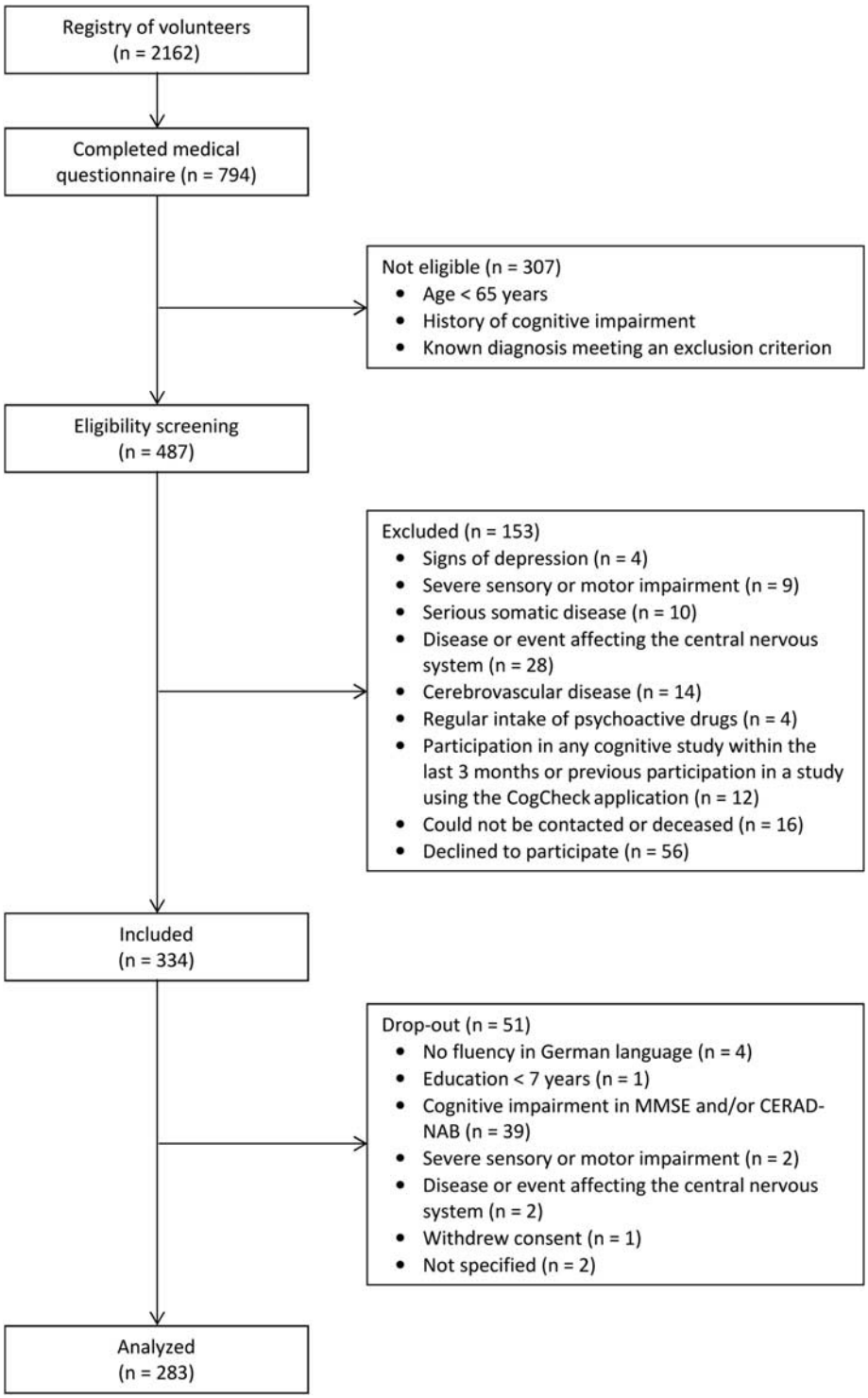

FIGURE 1. Study flow chart. CERAD-NAB indicates Consortium to Establish a Registry for Alzheimer's Disease-Neuropsychological Assessment Battery; MMSE, Mini-Mental State Examination.

tasks, as well as in TMT-B ($P = 0.005$). Men performed better than women in the digit span task ($P < 0.001$). The influence of age, sex, and education on other subtests was not uniformly negative or positive due to interactions and quadratic effects. When applying the Bonferroni-Holm adjustment to test the effect of age and education in 6 subtests ($\alpha = 0.05$), the age effect was significant in the visual recognition task and TMT-B. The education effect

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TABLE 1. Participant Characteristics According to Age Category

	All Participants (n = 283)	65-69 y (n = 68)	70-74 y (n = 102)	75-79 y (n = 68)	> 79 y (n = 45)
Demographics					
Age (y)	73.8 ± 5.2	67.6 ± 1.4	72.2 ± 1.3	76.5 ± 1.4	82.6 ± 2.4
Female sex	155 (55)	42 (62)	58 (57)	34 (50)	21 (47)
Education (y)	13.6 ± 2.9	13.2 ± 2.7	14.0 ± 2.8	13.7 ± 3.1	13.3 ± 2.8
Medical comorbidities*					
Heart disease†	54 (19)	5 (7)	13 (13)	17 (25)	19 (42)
Arterial hypertension	112 (40)	20 (29)	36 (35)	31 (46)	25 (56)
Hypercholesterolemia	60 (21)	14 (21)	14 (14)	18 (26)	14 (31)
Diabetes type II	14 (5)	4 (6)	6 (6)	1 (1)	3 (7)
Chronic lung disease‡	14 (5)	1 (1)	3 (3)	8 (12)	2 (4)
Gastrointestinal disease§	23 (8)	4 (6)	11 (11)	2 (3)	6 (13)
Urologic disease	27 (10)	3 (4)	8 (8)	9 (13)	7 (16)
Thyroid disease‖	30 (11)	8 (12)	12 (12)	7 (10)	3 (7)
Arthrosis	35 (12)	8 (12)	11 (11)	13 (19)	3 (7)
Osteoporosis	34 (12)	4 (6)	14 (14)	10 (15)	6 (13)
Chronic pain	27 (10)	5 (7)	9 (9)	9 (13)	4 (9)
History of head trauma	25 (9)	5 (7)	11 (11)	5 (7)	4 (9)
Prior general anesthesia	239 (84)	59 (87)	85 (83)	56 (82)	39 (87)
Regular alcohol consumption	181 (64)	45 (66)	61 (60)	49 (72)	26 (58)
Neuropsychological test scores					
MMSE score (points)	29.2 ± 0.9	29.4 ± 0.7	29.3 ± 0.9	29.0 ± 0.9	28.9 ± 1.0
GDS score (points)	0.4 ± 0.7	0.3 ± 0.8	0.4 ± 0.7	0.3 ± 0.6	0.4 ± 0.7
CERAD-NAB total score (points)¶	98.7 ± 5.7	97.9 ± 5.5	98.6 ± 5.2	99.5 ± 5.9	99.0 ± 6.5

Data are presented as mean ± SD or n (%).
*Evaluation of medical comorbidities was based on medical history and/or medication list.
†Including coronary, valvular, hypertensive, and rhythmic heart disease.
‡Including asthma, chronic obstructive pulmonary disease, and lung fibrosis.
§Including gastroesophageal reflux and peptic ulcer disease.
‖Including hypothyroidism and hyperthyroidism.
¶Adjusted for age, sex, and education.
CERAD-NAB indicates Consortium to Establish a Registry for Alzheimer's Disease-Neuropsychological Assessment Battery; GDS, Geriatric Depression Scale; MMSE, Mini-Mental State Examination.

was significant in the visual recognition task and fell just short of significance in TMT-B (adjusted $P = 0.054$). Because of modifying effects (interactions and quadratic terms), uniform effects of age and education could not be tested in the other four subtests.

Calculation of Standard Scores

For each cognitive subtest of CogCheck, we chose the best predictive model and computed demographically adjusted standard scores (z-scores). The basic formula for the calculation of standard scores [z = (transformed score – expected score)/residual SE] was applied for each cognitive subtest (Table 3). The Figure in Supplemental Digital Content 3 (http://links.lww.com/JNA/A60), provides the detailed analysis of all CogCheck subtests.

DISCUSSION

The CogCheck application is a completely self-administered cognitive assessment and screening tool intended for use in surgical patients. This cross-sectional study provides demographically adjusted normative data for the CogCheck tool. Taking into account age, sex, and education, we calculated standard scores for 6 cognitive subtests that, in combination, may provide an indication of the overall cognitive status. A previous pilot study independently demonstrated the user-friendliness and applicability of CogCheck in cognitively healthy and cognitively impaired subjects.

Preexisting cognitive impairment is reported to have a significant impact on the incidence of adverse postoperative cognitive outcomes. In earlier studies, the odds ratio for delirium ranged from 6.3 (95% confidence interval [CI], 2.9-13.7) up to 11.5 (95% CI, 6.1-20.1) in patients suffering from cognitive impairment.[33] For POCD, the odds ratio was 2.4 (95% CI, 1.1-5.5).[13] After validation of CogCheck in surgical patients, the tool may eventually screen for cognitive impairment as a major risk factor for adverse postoperative cognitive outcomes via self-administered testing on a tablet computer.

Participants of the current normative study were cognitively healthy volunteers, and relatively strict exclusion criteria (cut-off scores for MMSE, CERAD-NAB, and GDS) were applied. This eliminates potential confounders (presence of mild cognitive impairment, dementia, or depression) and leads to almost ideal normative data. Hence, clinicians may better interpret test results of patients affected by conditions associated with poor cognitive performance. Subjects with medical comorbidities commonly found in the elderly (Table 1) were deliberately not excluded from the study for a better representation of the geriatric population.

We used a regression-based analysis to calculate normative data for each subtest of the assessment application. This approach considers specific demographical data that are critical for an appropriate estimation of the individual performance and does not rely on categories

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TABLE 2. CogCheck Test Results

	All Participants (n = 283)	65-69 y (n = 68)	70-74 y (n = 102)	75-79 y (n = 68)	> 79 y (n = 45)
Demographic and medical data					
Sensory impairment					
Use of vision aids	272 (96)	66 (97)	95 (93)	66 (97)	45 (100)
Presence of hearing impairment	121 (43)	22 (32)	34 (33)	32 (47)	33 (73)
Daily drug intake					
No drugs	60 (21)	18 (26)	25 (25)	11 (16)	6 (13)
1-3 drugs	172 (61)	46 (68)	62 (61)	40 (59)	24 (53)
4-7 drugs	42 (15)	4 (6)	12 (12)	15 (22)	11 (24)
> 7 drugs	9 (3)	0 (0)	3 (3)	2 (3)	4 (9)
Age entered correctly*	245 (87)	60 (88)	92 (90)	60 (88)	33 (73)
Education entered correctly	137 (48)	33 (49)	48 (47)	31 (46)	25 (56)
Language					
Native German speaker	277 (98)	68 (100)	100 (98)	66 (97)	43 (96)
Other, but fluent in German	6 (2)	0 (0)	2 (2)	2 (3)	2 (4)
Cognitive self-assessment†					
Memorizing new things	2.6 ± 0.5	2.7 ± 0.5	2.6 ± 0.5	2.6 ± 0.6	2.4 ± 0.5
Remembering names	2.4 ± 0.6	2.5 ± 0.6	2.4 ± 0.6	2.4 ± 0.6	2.3 ± 0.6
Multiple simultaneous tasks	2.8 ± 0.4	2.9 ± 0.4	2.8 ± 0.5	2.7 ± 0.5	2.7 ± 0.4
Financial issues	3.1 ± 0.3	3.0 ± 0.2	3.1 ± 0.4	3.0 ± 0.3	3.0 ± 0.4
Remembering appointments	3.0 ± 0.3	3.0 ± 0.3	3.0 ± 0.3	3.0 ± 0.2	2.9 ± 0.3
Temporal orientation‡					
Weekday entered correctly	281 (99)	68 (100)	101 (99)	67 (99)	45 (100)
Date entered correctly	231 (82)	56 (82)	81 (79)	58 (85)	36 (80)
Automated subtests of cognitive functions					
Visual recognition (raw score)§	12.0 ± 1.9	12.3 ± 1.7	12.2 ± 1.7	12.0 ± 1.7	10.8 ± 2.3
Picture recognition (raw score)§	27.5 ± 2.1	28.1 ± 1.8	27.5 ± 2.1	26.7 ± 2.3	27.5 ± 2.0
Spatial span (raw score)§	7.0 ± 1.7	7.2 ± 1.7	7.1 ± 1.7	7.2 ± 1.6	6.2 ± 1.8
Digit span (raw score)§	8.4 ± 2.0	8.7 ± 2.1	8.4 ± 2.1	8.6 ± 1.9	7.5 ± 1.8
TMT-A; number of line connections/min	21.9 ± 5.9	23.4 ± 6.1	22.2 ± 6.2	21.7 ± 5.6	19.3 ± 3.7
TMT-B; number of line connections/min	15.1 ± 4.1	16.5 ± 3.3	15.7 ± 3.9	14.8 ± 4.2	12.3 ± 3.9

Data are presented as mean ± SD or n (%).
*Error analysis showed that 97% of subjects, who had entered an incorrect age, had rounded their age up to the next year.
†Cognitive functions were self-assessed on a 5-point Likert scale (1 = much worse, 2 = somewhat worse, 3 = no change, 4 = somewhat better, 5 = much better) compared with 2 years ago.
‡Error analysis showed that 1% of subjects entered the weekday incorrectly, 18% entered the day incorrectly, none entered the month incorrectly, and 1% entered the year incorrectly.
§Possible range of values is 0 to 15 for visual recognition, 0 to 30 for picture recognition, 0 to 16 for spatial span, and 0 to 18 for digit span.
TMT indicates Trail Making Test.

(eg, age groups) which are somewhat arbitrary. This increases the diagnostic accuracy in subjects at the extremes of such groups.

The composition of different cognitive tests in CogCheck may result in a more adequate assessment, as cognitive impairment and dementia may affect different domains of cognition. Assessing a smaller number of domains for the benefit of time may not capture the complete picture of cognitive impairment. The CogCheck application, in turn, has a multidimensional character.

Limitations of our study include the potential selection bias resulting in super-optimal normative data. Participants included in this study were recruited from an existing registry of nonsurgical volunteers. These individuals might have a higher intellect or display a greater motivation to perform well in cognitive testing than the average population. This bears the risk of overestimating cognitive impairment if interpretation of individual performance is missed. Therefore, our normative data must be considered as a guideline, and test results of patients

TABLE 3. Formulae for Demographically Adjusted Standard Scores

Cognitive Subtest	Standard Score Formula
Visual recognition	$z = [(RS-2)^{1.5}-(54.694-0.398\times A+0.479\times E)]/8.308$
Picture recognition	$z = [\text{asin (sqrt (RS/30.5))}-(1.460-0.0042\times A+0.0055\times E+0.056\times G+0.0006\times(A-A_{mean})\times G)]/0.115$
Spatial span	$z = [RS^{1.4}-(31.811-0.245\times A+0.141\times E-0.964\times G+0.185\times(A-A_{mean})\times G+0.050\times(E-E_{mean})^2)]/5.031$
Digit span*	$z = [RS-(11.736-0.053\times A+0.087\times E-0.811\times G-0.0079\times(A-A_{mean})^2)]/1.923$
TMT-A	$z = [RS^{0.75}-(18.48-0.0912\times A-0.136\times E+0.064\times G+0.241\times(E-E_{mean})\times G+0.026\times(E-E_{mean})^2)]/1.998$
TMT-B	$z = [RS^{1.5}-(153.17-1.488\times A+1.2636\times E)]/21.653$

The basic formula for the calculation of standard scores is z = (transformed score − expected score)/residual SE.
*No transformation was necessary to receive normal distribution for the digit span score.
A indicates age; E, education; G, gender; RS, raw score; TMT, Trail Making Test.

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from very different cultural backgrounds or individuals with very low education require cautious interpretation. It was decisive to include only individuals with established cognitive health, as their scores serve as starting points for the interpretation of scores from actual patients. This healthy normative sample will not be representative of older adults requiring surgery in all aspects, and expected differences will have to be explained on clinical grounds. Finally, as CogCheck was envisioned as a one-time screening test, we did not study the possibility of repeated/longitudinal assessment and tracing of a perioperative cognitive trajectory in individual patients, as well as the test-retest reliability.

Normative data are essential for any assessment tool, even when a traditional examiner-administered test is programmed for use on a computer, as it becomes a new and different test.[46] The general question arises whether computerized assessment is appropriate for use in the elderly. One could assume that elderly people who are used to electronic devices may achieve better test results than those who are not, or do not feel comfortable using computers. However, previous findings suggest that the level of computer experience among older adults is not associated with the performance in a computerized test.[27] Moreover, a recent literature review showed that people with dementia are able to independently use touchscreen technology.[47] A disadvantage of computerized testing is the absence of an opportunity to motivate the patient, as an examiner would be able to do. Nevertheless, self-administration is more resource-efficient and eliminates potential rater-related bias.

Traditional neuropsychological assessment batteries such as the CERAD-NAB are strongly based on verbal language. In contrast, the cognitive subtests in CogCheck are entirely language-free. A number of automated tools to assess cognitive functions also require the presence of a bedside examiner, include tests with a computer-generated voice (which can be difficult for patients with impaired hearing), or need handling of hardware (stylus, computer mouse, or keyboard). Some high-quality computerized applications[48] like COGNIGRAM (CogState Ltd),[49] CANTAB Mobile (Cambridge Cognition Ltd),[50] or the NIH Toolbox (Health Measures)[51] require the purchase of a license. However, considering recent health care resource cuts, paid single assessments may hinder the broad use of these tools in clinical practice.[48,52] We plan to make the CogCheck application available for free to any interested clinician and researcher. While some assessment tools take longer, the average time of 21.7 minutes needed to complete CogCheck seems reasonable. In addition, our tool screens for preoperative risk factors beyond preexisting cognitive impairment (eg, polymedication).

The current European and American guidelines on adverse postoperative cognitive outcomes recommend preoperative screening for risk factors including mental status for any patient without known history of cognitive impairment.[53,54] Preoperative screening may not only help to identify vulnerable patients but also guide preventive strategies. A standardized cognitive evaluation before surgery may offer important baseline information in patients experiencing postoperative cognitive decline. Still, the implementation of routine screening for cognitive impairment in surgical patients may be challenging in daily practice.[55]

As this study first provides normative data for an elderly nonsurgical population, CogCheck application data may not yet be used in a risk prediction model of adverse postoperative cognitive outcomes in surgical patients. Validation of the CogCheck application with postoperative outcome data is necessary before it may fully enter clinical routine. We plan to investigate the association of CogCheck performance and POD incidence in a follow-up study of patients undergoing cardiac surgery. Succeeding validation of the tool, CogCheck opens a wide field of research. Identifying vulnerable patient populations may simplify the study of targeted preventive measures to reduce the incidence of adverse postoperative cognitive outcomes (eg, nonpharmacological multicomponent strategies,[7] cognitive or physical prehabilitation, prophylactic medication, and perioperative anesthetic considerations). Automatic data integration with digital records (eg, medical history, medication lists, laboratory values, type of surgery) is conceivable in the future.

CONCLUSIONS

This study in healthy nonsurgical volunteers provides normative data for the CogCheck cognitive assessment tool. The CogCheck application measures the individual cognitive performance adjusted for demographic influences. However, clinical implementation of CogCheck to identify surgical patients with a high risk for adverse postoperative cognitive outcomes will only be possible after validation of the tool. In future research directed at the targeted prevention of adverse postoperative cognitive outcomes, this simple self-administered assessment tool may provide important information regarding the preoperative cognitive status.

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