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ORIGINAL ARTICLE

Older patients' driving safety with the help of DRIVING SIMULATOR: Which cognitive test can predict better driving safety?

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ABSTRACT

Introduction: Being able to drive is an important parameter of independence and self-sufficiency. The continued use of cars, which plays an important role in maintaining the mobility of the older individuals, is very important for the protection of the individual's activity performance.

Methods: Driving skills of 31 participants were tested with the help of a driving simulator and cognitive tests were applied to each participant. The study was aimed to reveal the relationship between the cognitive functions and safe driving skills of older patients using the driving simulator and to determine the cognitive test that predicts the safe driving skill best.

Results: 31 participants was included in the study. All participants were male. The average age was 72.5±6.The median of MMSE was 29 (IQR; 28-30),the mean of MOCA was 25.52±2.6,the mean value of QMCI was 62.68±9.57, the median of trail making test A was 42.5 sec(22-97), and the median of trail making test B was 98.31 sec(38-313).MOCA test score correlated positively with "the skills expected before starting the vehicle "and driving parameters on the highway("p: 0.0024, r:0.46";"p:0.0024, r:0.46",respectively).The QMCI test was found to have a statistically positive and significant correlation with operational skills and the skills expected before starting the vehicle("p:0.041, r:0.43"; "p:0.015 r:0.50",respectively).When the factors affecting operational skills and safe driving skills were analyzed by linear regression analysis, both skills were influenced by the QMCI-orientation step(p:0.001;CI:1.59-3.9).

Conclusion: In our study, it is shown that driving skills decrease with aging. QMCI and MOCA, which are easy to apply in clinical practice, will be useful in patients driving vehicles aged 65 and over with the demonstration of a significant relationship with total driving score, safe driving and operational skills.

Keywords: driving, simulator, cognitive, older.

INTRODUCTION

Aging is a process that negatively affects many systems. Mobility is an integral part of these systems and is an indispensable element of the independence and quality of life of older individuals. The limitation of mobility causes problems in the daily living activities of older individuals and these problems also negatively affect their mental and cognitive functions [1,2]. Being able to drive is an essential parameter of independence and self-sufficiency in today's conditions. In this sense, the continued use of cars, which plays an important role in maintaining the mobility of older individuals, is crucial for protecting the individual's activity performance [3].

It has been shown in studies that the decrease in visual, motor, and cognitive functions has an influence on the reduction in driving safety [4]. The gold standard method that will best test driving safety is the test in which driving abilities are evaluated in a real vehicle. However, performing a real driving test is technically difficult and has some safety problems [4]. Driving simulators offer an option to assess both safety and deficiencies in this regard. Driving simulators are safe alternatives used to evaluate the driving skills of people at risk in terms of safe driving skills without being exposed to risks [5]. Simulation devices can also be used in the rehabilitation/training of drivers at risk [5].

The aim of our study was to reveal the relationship between the cognitive functions and safe driving skills of older patients using the driving simulator and to determine the cognitive test that predicts safe driving skills best.

METHOD

Subjects

Patients aged 65 years or older who applied to the Geriatric medicine outpatient clinic and who were active drivers in the last 6 months were included in the study. Informed consent was obtained from each patient before inclusion in the study. Exclusion criteria were patients;

- who did not have a driver's license,
- had diagnosed with conditions that legally restricts driving such as dementia, diplopia, epileptic seizures etc
- had comorbidities such as hearing and visual deficits or neurological diseases that might affect driving,
- had been using of sedatives or psychiatric drugs
- did not drive in the last 6 months despite having a driver's license were excluded from the study.

Components of the comprehensive geriatric assessment were applied to all participants. The independence levels of all patients in their daily lives were evaluated with Katz index of activities of daily living (ADL) test and Lawton Brody Instrumental activities in daily living scales (IADL) [6]. For cognitive assessment, Mini-Mental State Examination test (MMSE), Montreal Cognitive Assessment Test (MOCA test), Quick Mild Cognitive Impairment Screen (QMCI test), Forward and backward digit span Test, Trail Making Test A and B, and clock drawing test (6 points) were performed. Risk of falls were assessed by Timed up and go test and Alternating foot tap test.

Assessment of Activities of Daily Living

The Katz scale evaluates everyday activities that are fundamental. The Katz ADL scale is sensitive to changes in deteriorating health status. It helps healthcare professionals involved in the patient's holistic care to speak the same language about their function [7]. The Katz ADL assesses a person's dependence or independence with regard to six ADL areas: dressing, using the restroom (sponge, shower, or bathtub), bathing (shower, bathtub), transference, continence, and feeding. Every activity is divided into three categories on the original scale: independence, partial dependency, and complete dependence. In accordance with this classification, as independence increases the score of the scale increases [8].

Cognitive assessment

The MMSE is the most commonly used screening test for dementia screening [9]. The MMSE is evaluated out of 30 points and below 24 points indicate cognitive impairment and indicates the need for further evaluation. It is an easy and fast scale that tests orientation, memory, attention, calculation, recall, language, motor function, perception, and visuospatial abilities [10].

Another cognitive assessment test is the MOCA test [11]. It was developed as a rapid screening test for mild cognitive impairment. MOCA assesses different cognitive functions. These conditions are attention and concentration, executive functions, memory, language, visual construction skills, abstract thinking, calculation, and orientation. The highest total score that can be obtained from the test is 30. Accordingly, a score of 21 points or more is considered normal [10]. Turkish validity and reliability study was conducted [12].

The Q-MCI test is a scale that is more sensitive than the MMSE in distinguishing mild cognitive impairment from subjective forgetfulness and early-stage dementia [13]. In the study, in which the Turkish validity and reliability were evaluated, it was shown that the Q-MCI is superior to MMSE and similar with MOCA in distinguishing mild cognitive impairment [14]. The test consists of 6 different subtests. The first subtest relates to testing orientation. The patients are asked questions such as the day, month, year, and name of the country in which they are living. The second subtest relates to testing word recording. The patients are told 5 words and asked to repeat these 5 words. The third subtest is the clock drawing test. It is different from the clock drawing test mentioned above in terms of calculation. In total, the maximum score to be obtained from the clock drawing test is 15. The fourth subtest is delayed recall. In the fourth subtest, the patients are asked how many of the 5 words they remember. The fifth subtest is verbal fluency. In one minute, the patients are asked to name as many animals as possible. The sixth and the last subtests is related to logical memory. A short story is read to the patient. When the story is over, it is questioned how many of the words used in the storytelling are remembered. The total of six subtests is scored on 100 points [10]. For the QMCI test, the closer the score is to 100 points, the better cognitive performance can be considered.

As quick clinical assessments of WM, the Wechsler Memory Scale—Third Edition's Digit Span subtest have been widely used [15]. The tasks contain a forward and a backward component and call for the recall of the stimulus (digits or spatial locations) in the examiner's order, or in the opposite order. It has been suggested that the forward digit span is a measurement of the phonological loop's capacity, and that the forward spatial span is a comparable indicator of the visuospatial sketchpad [16]. It has been suggested that successful completion of the backward component of these tasks is a test of central executive function due to the additional demand of manipulating information in temporary storage [17].

Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered between 1–25, and the patient is required to draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the patient draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters [18]. The scoring of the both tests are based on time elapsed for completion; for the part A, a completion time longer than 32 seconds [19] and for part B completion time longer than 79 seconds considered as problematic in terms of driving safety [20].

Another test that shows deterioration starting from the early stages of dementia is the clock drawing test [21,22]. The patient is asked to draw the face of the clock as a round shape in which he can write the numbers. The patient, who is asked to place the numbers as they are on the wall clock, gets 3 points from the correct placement of the circle and the number 12. Placing other numbers in appropriate places is 1 point. Drawing the hands of the clock is 1 point. Correct placement of the hour and minute hands according to the desired time is again 1 point. In this way, the patient is evaluated over 6 points. With this test, constructional praxis, understanding, and planning ability are tested [21,22].

Motor functioning

Another test we applied to our patients was the "timed up and go test". The patient should sit in a standard chair, lean back against the chair, and rest his arms on the arms of the chair. The patient should walk in a line 3 meters (9.8 feet) away, then walk back to the chair and sit down. The test ends when the patient's hip touches the seat. A stopwatch should be used to time the test [23]. According to Physician's guidelines [24] to assessing and counseling older drivers, scores over 9 seconds are linked to a higher risk of motor vehicle tasks that are negligent [25].

The last test we applied to the patients was "alternating foot tap test". This test is an alternative test that allows the driver to measure the time it takes to move their right foot from the accelerator pedal to the brake pedal. The driver sits in a chair for this test. The test administrator opens a 2-inch 3-ring folder and places it on the floor with the 3 rings diagonally in front of the participant and 16 to 24 inches from the front edge of the chair. Following the instructions, the tested patient will touch the ground alternately with their right foot 5 times on either side of the open file and move from side to side with each touch. The total number of hits will be 10. The examiner records the time to complete the foot tapping task with a stopwatch [26]. The Alternate Foot Strike test is a test that measures a person's ability to quickly move their leg/foot from the accelerator pedal to the brake. Elevated traffic conviction rates (1.5 times age-matched controls) were found in those with response times exceeding 12.75 seconds [27].

Driving safety assessment

AutoSim AS1000 Driving Simulator, Norway [28] was used for driver evaluation in a simulated environment. This simulator has a real car cockpit and the image is able to provide a 180-degree viewing angle through 3 combined widescreen monitors. With its software containing different traffic situations, the simulator provides the evaluation of older patients in various environments and situations that require sudden decisions. In our study, compliance with traffic rules and accurate driving behavior were evaluated observationally during the application. During the observational evaluation, the task list was prepared by making use of the car driving requirements in the literature [29-31]. Driving was evaluated under the headings of "the use of vehicle operational parts and safe driving behavior". A detailed representation of what participants are expected to do in the driving test are given in Table 1. In the context of the use of operational parts, skills such as adjusting the mirror and seat settings, fastening seat belts, learning the location of vehicle operation controls, gear control, pressing the brake pedal, and operating the car properly were included. In the content of the safe driving behavior part, the signal, control of the lane to be exited, stopping the vehicle in the right lane and on the ground, signal, deceleration, protecting the lane, awareness pedestrian priority, noticing danger, signal, mirror control, changing lane, control of signals, vehicle positioning, and safe tracking distance were examined. The skill parameter(s) that individuals made wrong were marked as 0 points and correct behaviors marked as 1 points. Before the evaluation, individuals

Table 1. Skills that participants are expected to perform in the driving test.

THE USE OF VEHICLE OPERATIONAL PARTS	**The skills expected before starting the vehicle**	adjusting the mirror and seat settings	Fastening seat belts	learning the location of vehicle operation controls,	
	Start the vehicle	gear control,	pressing the brake pedal	operating properly	
SAFE DRIVING BEHAVIOR	**Movement**	the signal	Lane control		
	Stopping	stopping the vehicle in the right lane and right side			
	Turns	The signal	deceleration, protecting the lane	knowing pedestrian priority,	noticing danger
	Changing lane	signal	Mirror control,	Changing lane	
	Safety behavior	Mirror control	control of signals and lamps	vehicle positioning	safe tracking distance
DRIVING PARAMETERS ON THE HIGHWAY		Adjusting the speed,	Lane tracking		
TOTAL					

used a simulation environment for 10 minutes to get used to the simulation environment without any orientation. The application was started from the beginning for evaluation and the patient was informed about observation. In two-way city traffic, a driving assessment was performed on the 30-minute track, which included unexpected 3 sudden stops, lane change, lane return, parallel parking, and driving uphill. Participants were then told to move to the highway section, and it was observed whether they complied with the highway traffic rules and speed limits, and the record was obtained. The driving points of the participants were calculated according to the observation form.

Visual and hearing deficits

Whisper test was performed on each patient from 6-7 meters and hearing dysfunction was determined. Likewise, with the vision test, the patients' visual functions were evaluated and they were asked to bring visual aids such as glasses, if any.

Statistical analyses

Statistical analyses were performed using IBM SPSS version 22 software. The conformity of the variables to normal distribution was examined with histogram and probability graphs and Kolmogorov-Smirnov/Shapiro-Wilk tests. For descriptive analysis, mean and standard deviation were used for normal variables. For the non-normally distributed variables, the median and minimum-maximum values were used. Pearson test was used to evaluate the correlations of normally distributed numerical variables with each other. Spearman test was used for numerical variables that were not normally distributed. Correlation relationships between cognitive tests scores and driving tests scores were analyzed by Spearman correlation analysis. The independent effects of different predictors on driving safety tests were investigated using a multiple regression model. Factors affecting driver behavior were analyzed by linear regression analysis. Model fit was examined using the required residual and fit statistics. The suitability of the regression model and residual analyzes were performed. The variables included in the model were evaluated by colinarity analysis. Cases with a type-1 error level below 5% were interpreted as statistically significant.

RESULTS

Fifty participants were included in the study initially. Nineteen did not want to attend the driving simulation due to personal reasons. These participants didn't come because they did not want to spare time for the study. Finally, the study was conducted with 31 patients. All of the participants were male. The mean age was 72.5 ± 6.0 years. Participants were driving license holders for 40.9 ± 11.3 years. Considering the education levels of the participants, the median was 11 years (IQR, 11-15 years). Other demographic results and cognitive test results are shown in Table 2.

The median number of accidents of the participants was 0 (IQR, 0-1). Nineteen patients had no previous history of an accident. It was learned that none of the accidents were fatal accidents.

The median of MMSE of the participants was 29 (IQR, 28-30), the mean of MOCA was 25.5 ± 2.6, the mean value of QMCI was 62.68 ± 9.57, the median of the trail-making test A was 42.5 sec (22-97), and the median of the trail-making test B was 98.3 sec (38-313 sec). It was observed that the MOCA test score correlated positively moderately with "the skills expected before starting the vehicle" and driving parameters on the highway ("p: 0.0024; r: 0.46"; "p: 0.0024; r: 0.46"; respectively). The QMCI test had a statistically significant, positive, and moderate correlation with operational skills and the skills expected before starting the vehicle ("p: 0.041, r: 0.43"; "p: 0.015 r: 0.50", respectively). The relationship between driving parameters and these cognitive scales is shown in Table 3. The QMCI test was found to have a statistically significant and strong correlation with safety behavior parameters (mirror and seat adjustment, seat belt wearing, and learning the location of vehicle operating controls before starting the vehicle) (p: 0.041, r: 0.70). With increasing age, there was a decrease in operational skills, skills that were expected to be signaled and control of the lane to be exited, and skills expected to be carried out before starting the vehicle. This negative relationship was statistically significant ("p: 0.012 r: -0.50"; "p: 0.002 r: -0.60", "p: 0.005 r: -0.55" respectively). It was seen that as the education level increased, lane control skills and signaling skills increased accordingly (p: 0.042, r: 0.40). These correlations are shown in Table 4. It was seen that

Table 2. Cognitive test scores and comorbid diseases of the participants included in the study with demographic data.

Age	72.5 ± 6.0	**Number of using drugs**	2 (0-7)
Education Level			
Primary School	1 (3.2%)		
Junior High School	4 (12.9 %)		
High School	12 (38.7%)		
University	13 (41.9%)		
Diabetes Mellitus	10 (32.3%)	**vehicle use experience (years)**	42 (24-68)
Hypertension	13 (41.9%)	**Daily Living Activities**	6
Coronary artery disease	7 (22.6%)	**Instrumental daily living activities**	8
Cerebrovascular event	1 (3.2%)	**Previous traffic accident**	12 (38.7%)
Chronic Obstructive Lung Disease	1 (3.2%)	**MMSE**	29 (IQR ; 28-30)
Atrial Fibrilation	1 (%3.2)	**MOCA**	25.52 ± 2.6
Hyperlipidemia	8 (25.8%)	**QMCI**	62.68 ± 9.57
Hypothyroidism	3 (9.7%)	**Trail Making Test A**	42.5 sec (22-97)
Osteoporosis	0	**Trail Making Test B**	98.31 sec (38-313)
		Alternate Foot Tap Test	5.3 (3-9)
		Up and Go Test	11.87 ±2.4

Table 3. Correlation relationship between MOCA and QMCI tests and driving parameters.

	MOCA P value and CC	QMCI P value and CC
the skills expected before starting the vehicle	P: 0.0024 r: 0.46	p: 0.015 r: 0.50
driving parameters on the highway	P: 0.0024 r: 0.46	-
operational skills	-	p:0.041 r: 0.43
safety behavior parameters	-	p: 0.041, r: 0.70

*CC: Correlation Coefficient, MOCA: Montreal Cognitive Assesment Test, QMCI : Quick Mild Cognitive Impairment Test

Table 4. Correlation of age and education level with driving skills.

	Operational skills	Skills that were expected to be signaled and control of the lane to be exited	The skills expected before starting the vehicle
Age	p: 0.012; r: -0.50	p: 0.002; r: -60	p: 0.005; r: - 0.55
Education level	**Lane control skill** p: 0.042, r: 0.40		**Signaling skills** p: 0.042, r: 0.40

the backward digit span test, which is very simple and practical to apply in clinical practice, correlates positively with operational skills. In the unadjusted model, QMCI was found to be associated with operational skills (p: 0.025; OR: 0.36 CI: 1.14-1.70)

When the factors affecting the total scores obtained after simulation was analyzed by multivariate linear regression analysis; age, backward digit span test, and MOCA- naming step were found to be factors affecting the simulation total score (p: 0.005 CI: -1.2 / -0.3; p: 0.001 CI: 0.6 / 0.9; p: 0.002 CI: -6 / - 2). The result of the regression analysis is shown in Table 5. Multivariate linear regression analysis was performed to determine the factors affecting the skills expected before starting the vehicle. When QMCI, MOCA, age, MOCA-orientation step, and year of education were included in the model, it was seen that the orientation step in the MOCA test was a factor affecting “the skills expected before starting the vehicle” (p: 0.0001 CI: 1.969-3.728). When the factors affecting operational skills and safe driving skills were analyzed by linear regression analysis, it was seen that both skills were influenced by the QMCI-orientation step (p: 0.001 CI: 1.59-3.9).

Table 5. Factors affecting driving score with multiple regression analysis.

	Unstandardized Coefficients		Standardized Coefficients	t	P value
	B	Std. Err	Beta		
Age	-0.840	0.175	-0.455	-4.807	p: 0.005
MOCA- naming step	-4.295	0.702	-0.596	-6.121	p: 0.001
Backward digit span test	1.045	0.145	0.693	7.205	p: 0.002

*MOCA: Montreal Cognitive Assesment Test

DISCUSSSION

Older adults consider driving an important activity for their independence and self-confidence [32,33]. Older adults who are forced to stop driving become more dependent on their families, often become depressed, and, as a result, reduce their social activities. Ultimately, the risks of being placed in a nursing home are high [34]. For this reason, it is important to detect the decline in driving abilities in the early period in order to maintain the independence of the older adult. In this study, we wanted to examine the usability of the driving simulator device and the relationship between the driving skills that this device can predict and cognitive functions in order to ensure the continuation of the gains necessary for our patients to maintain their independence.

Physiological limitations and decreases in activities of daily living can be seen with aging. In today's conditions, the use of a vehicle for transportation from one place to another is considered one of the basic needs. The deprivation of this basic need of older people or the fact that they can no longer use the vehicles they used to do in their youth may cause a fragility, which will negatively affect their independence in daily life in many aspects, especially in social participation and independence in outdoor activities. In this study it was found that safe driving is highly associated with cognitive functions, education level, and age.

As the proportion of the older population increases, the proportion of older drivers also increases. A 2018 study showed that there are 29 million drivers over the age of 70 in the United States [35]. According to statistical data, more than 8,000 drivers over the age of 65 died in 2018, and more than 250,000 older drivers were hospitalized and treated in hospitals. [36]. When this rate is calculated on a daily basis, it should be considered that 20 older drivers lose their lives due to accidents almost every day.

It is difficult to understand, determine or measure whether an older driver can drive safely. Chronological age cannot be the only indicator of driving ability. It is hard to consider that driving abilities, brake time, or the ability to make decisions in risky situations of a 70-year-old, non-sarcopenic older individual without any chronic disease and an older individual with the opposite clinical condition are the same. Due to this complex side of driver evaluation, there are no easy-to-administer test or set of tests to assess driving proficiency [37-39]. For this reason, cognitive test methods that can be used to predict effective and safe driving ability were investigated in our study. It has been observed that there is a direct relationship between total driving scores and cognitive test scores, and between some other driver ability parameters and cognitive tests.

Older drivers have a higher death rate in vehicle accidents than other driver age groups. Among the older drivers, the group over the age of 85 has the highest number of fatal accidents [40]. Fatal accident rates begin to increase after age 70 [35]. It has been observed that the probability of being at fault in fatal intersection accidents is generally higher in older drivers [41]. Among the most common mistakes are incorrect assessment of vehicle distance and speed, medical events, daydreaming, and inadequate surveillance [41]. In our study, we did not have any patients who participated in an accident that would pose a life-threatening risk or an accident that resulted in death. Since a control group was not selected as the young patient profile that we can compare, it would be assertive to suggest that the age factor increases the risk of accidents. However, it has been shown in our study that the safe driving skills score has a negative correlation with age.

Aging negatively affects muscle strength especially in the neck, shoulder, and wrist, and brake reaction time [42]. As a result of reduced muscle strength, operational aspects of driving are negatively affected. Restrictions in the neck, shoulder, and wrist movements can limit vision and the ability to control the steering wheel. Sensory and/or motor neuropathy is common in older adults and may impair brake and accelerator pedal use [43]. In addition to age-related changes such as visual disturbances and reduced psychomotor abilities, older people are more likely to have medical illnesses that may affect their ability to drive. Studies have identified specific medical conditions associated with vehicle accidents or events that may adversely affect driving safety in the older population. History of falling in the last 1-2 years [44], disorders in cognitive and visual functions [45-49], history of previous accidents [45,50], presence of opioids, benzodiazepines, and tricyclic antidepressant groups among drug use [51,52], age-related diseases such as dementia, Parkinson's disease [53,54] are among the risk factors. More than a third of all prescribed benzodiazepines are written for people 60 years and older. Traffic accident risk increases by 50 percent in the first week after benzodiazepine treatment [55]. In a different study examining hospitalizations of older patients after vehicle accidents, it was found that the risk of serious accidents associated with the use of benzodiazepines increased fivefold. It has also been shown that antidepressants increase the risk 1.8 times, and opioids 1.5 times [56]. In our study, it was not shown that the chronic diseases of our patients were a risk factor that would reach statistical significance in terms of driving safety or driver score. The reason for this is the low number of patients, which is another limitation of our study. Since we did not have the usage record of benzodiazepines and tricyclic antidepressants, no evaluation was made in this respect. Since dementia and Parkinson's disease diagnoses were also determined as exclusion criteria in our study, risk assessment was not performed.

The incidence of dementia increases with the prolongation of the average lifespan. According to the research conducted by the Alzheimer's Association, the number of patients with AD, which was 5.2 million in 2014, is expected to increase to 13.8 million in 2050 [57]. In a study examining the effect of cognitive functions on driving abilities, it was shown that patients with very mild or mild dementia were more likely to fail the driving test than patients without dementia [58]. In other similar studies evaluating driving abilities, it was revealed that patients with dementia performed worse in comparison with their own age groups [59,60]. One of the cognitive tests, MMSE test can be used to evaluate unsafe driver. The American Academy of Neurology states that individuals with an MMSE score of ≤24 may be useful in identifying those at high risk for unsafe driving [58]. In our study, besides the MMSE test, MOCA, QMCI, the forward-backward digit span test, and the clock drawing test were applied to the patients. The MOCA and QMCI tests were shown in our study to correlate with driving skills in different areas of driving assessment. The MMSE test score was above the population average in the patients in our study. MOCA and QMCI tests are relatively more complex than the MMSE test, which is widely used all over the world and whose validity and reliability have been proven many times and also it was shown that the Q-MCI is superior to MMSE and similar with MOCA in distinguishing mild cognitive impairment [14]. The median MMSE of the patients included in our study was found to be 29, and it was found that there was no statistically significant relationship with driving parameters. This is due to the low number of our patients and the high MMSE scores of the patients included in the study. MOCA and QMCI tests, on the other hand, have been shown to predict driving safety better in some areas, if not in all areas. These tests, which are easy to apply, can be used in daily life in terms of widespread context and at least may give an idea about driving safety in patients who drive.

CONCLUSIONS

Driving simulation is a popular and useful method in recent years, as it provides practical applicability and rehabilitation, although it does not replace the actual driving test. In our study, it is shown that driving skills decrease with aging while risky driving increases with aging. QMCI and backward digit span tests, which are very easy to apply in clinical practice, will be useful in patients driving vehicles aged 65 and over with the demonstration of a significant relationship with the total driving score, safe driving, and operational skills. Future studies should focus on real-environment on-the-wheel assessments in terms of providing an assessment of driving in real-life situations. Furthermore, other studies should investigate the minimum required tests to determine safe driving or risky driver without needing an on-the-wheel test to provide safer assessment environment.

Author contribution

Study conception and design: ME, CB, BBD, OTA, BT MU; data collection: ET, SC, MK, AOB, OA; analysis and interpretation of results: MU, MH, MC ; draft manuscript preparation: ME, OTA. All authors reviewed the results and approved the final version of the manuscript.

Ethical approval

The study was approved by the Hacettepe University Hospital Local Ethics Committee (Protocol no. 22/775).

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Conflict of interest

The authors declare that there is no conflict of interest.

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