Evidence of risky driving in Korean older adults: A longitudinal cohort

Gihwan Byeon[a†], Sung Ok Kwon[b†], Jin Hyeong Jhoo [a,c*] , Jae-Won Jang[d], Jong Bin Bae[e], Ji Won Han[e], Tae Hui Kim[f], Kyung Phil Kwak[g], Bong Jo Kim[h], Shin Gyeom Kim[i], Jeong Lan Kim[j], Seok Woo Moon[k], Joon Hyuk Park[l], Seung-Ho Ryu[m], Jong Chul Youn[n], Dong Woo Lee[o], Seok Bum Lee[p]., Jung Jae Lee[p], Dong Young Lee[q,r], Ki Woong Kim[e,r,s]

[a] Department of Psychiatry, Kangwon National University Hospital, Chuncheon, Republic of Korea

[b] Interdisciplinary Graduate Program in Medical Bigdata Convergence, Kangwon national university, Chuncheon, Republic of Korea

[c] Department of Psychiatry, Kangwon National University School of Medicine, Chuncheon, Republic of Korea

[d] Department of Neurology, Kangwon National University School of Medicine, Chuncheon, Republic of Korea

[e] Department of Neuropsychiatry, Seoul National University Bundang Hospital, Seongnam, Republic of Korea

[f] Department of Psychiatry, Yonsei University Wonju Severance Christian Hospital, Wonju, Republic of Korea

[g] Department of Psychiatry, Dongguk University Gyeonju Hospital, Gyeongju, Republic of Korea

[h] Department of Psychiatry, Gyeongsang National University School of Medicine, Jinju, Republic of Korea

[I] Department of Neuropsychiatry, Soonchunhyang University Bucheon Hospital, Bucheon,

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Republic of Korea

[j] Department of Psychiatry, School of Medicine, Chungnam National University, Daejeon, Republic of Korea

[k] Department of Psychiatry, School of Medicine, Konkuk University, Konkuk University Chungju Hospital, Chungju, Republic of Korea

[l] Department of Neuropsychiatry, Jeju National University Hospital, Jeju, Republic of Korea

[m] Department of Psychiatry, School of Medicine, Konkuk University, Konkuk University Medical Center, Seoul, Republic of Korea

[n] Department of Neuropsychiatry, Kyunggi Provincial Hospital for the Elderly, Yongin, Republic of Korea

[o] Department of Neuropsychiatry, Inje University Sanggye Paik Hospital, Seoul, Republic of Korea

[p] Department of Psychiatry, Dankook University Hospital, Cheonan, Republic of Korea

[q] Department of Neuropsychiatry, Seoul National University Hospital, Seoul, Republic of Korea

[r] Department of Psychiatry, Seoul National University College of Medicine, Seoul, Republic of Korea

[s] Department of Brain and Cognitive Science, Seoul National University College of Natural Sciences, Seoul, Republic of Korea

[†]These authors contributed equally to this work.

[*]**Corresponding Author**

Jin Hyeong Jhoo, MD, PhD

Department of Psychiatry, Kangwon National University School of Medicine, Chuncheon, Korea.

156, Baengnyeong-ro, Chuncheon-si, Gangwon-do, 24289, South Korea

Phone +82-33-258-9203; Fax +82-33-258-9436; E-mail: jhoojh@kangwon.ac.kr

Author emails:

Gihwan Byeon, bjy0421@hanmail.net

Sung Ok Kwon, sungok@kangwon.ac.kr

Jin Hyeong Jhoo, jhoojh@kangwon.ac.kr

Jae-Won Jang, jaewon26@gmail.com

Jong Bin Bae, jongbinbae@hotmail.com

Ji Won Han, jwhanmd@snu.ac.kr

Tae Hui Kim, gooddr@hanmail.net

Kyung Phil Kwak, drphil@dongguk.ac.kr

Bong Jo Kim, bjkim@gnu.ac.kr

Shin Gyeom Kim, redmensch@schmc.ac.kr

Jeong Lan Kim, kimjl@cnu.ac.kr

Seok Woo Moon, hessem@kku.ac.kr

Joon Hyuk Park, empath0125@gmail.com

Seung-Ho Ryu, shryu@kuh.ac.kr

Jong Chul Youn, yjc0811@yahoo.co.kr

Dong Woo Lee, dwlee@paik.ac.kr

Seok Bum Lee, bumlee@dankook.ac.kr

Jung Jae Lee, mdjjlee@gmail.com

Dong Young Lee, selfpsy@snu.ac.kr

Ki Woong Kim, kwkimmd@snu.ac.kr

Data availability statement

The dataset used and analyzed during the current study is available from the corresponding author on reasonable request.

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Conflict of interest disclosure

The authors declare that they have no competing interests.

Ethics approval and patient consent statement

This study was approved by the Institutional Review Board of Seoul National University Bundang Hospital (IRB number: B-0912-089-010), and written informed consent was obtained from each subject or caregiver after providing a complete explanation of the study.

Author contributions

GHB, SOK and JHJ Led conceptualization of the study, analysis of the data, and writing of the manuscript. JWJ, JBB, JWH and KWK assisted in conceptualization the study, interpretation of the results, and editing of the manuscript. THK, KPK, BJK, SKK, JLK, SWM, JHP, SHR, JCY, DWL, DYL assisted in acquisition, analysis and interpretation of data. All authors critically revised manuscript.

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Abstract

Objectives: The aim of this study was to determine the differences in the risk factors for dangerous driving between older adults with normal cognition and those with cognitive impairment.

Design: The driving risk questionnaire (DRQ) that was applied to a community-dwelling older adult cohort and two years of accident/violation records from the National Police Agency were analyzed. We conducted regression analyses with the presence or absence of risky driving based on records (accidents + violations) two years before and after evaluation as a dependent variable and dichotomized scores of each risky driving factor as independent variables.

Results: According to four identified factors—crash history, safety concern, reduced mileage, and aggressive driving—significant associations were found between *risky driving over the past two years* and *crash history* and for *aggressive dri*ving in the *normal cognition* group. In the *cognitive impairment* group, only *crash history* was significantly associated, although *safety concerns* showed a trend toward significance.

Conclusions: In this study, it was suggested that the factors of DRQ have a significant association with actual risky driving. Our results are expected to contribute to establishing the evidence for evaluating and predicting risky driving and advising whether to continue driving in clinics.

Keywords: risky driving, older people, impaired cognition

Key points:

· The DRQ was categorized into four factors: crash history, safety concern, reduced mileage, and aggressive driving.

· "Aggressive driving" in the normal cognition group, "safety concerns" in the cognitive impairment group, and "crash history" in both groups were associated with risky driving in the two years preceding this evaluation.

·Two factors (aggressive driving, safety concerns) shown to be associated with risky driving before the evaluation period were not significantly associated with risky driving after the evaluation period.

Introduction

In the context of global ageing, the number of older adult drivers is increasing[1]. However, cognitive functions required for driving such as memory, attention, and executive function are known to decline with age[2]. This cognitive decline has been significantly associated with reduced driving ability in actual on-road driving[3]. Thus, population ageing is increasing the possibility of risky driving accompanied by fatal accidents[4]. For this reason, awareness of risky driving among older adults is also increasing.

However, even though the driving risk increases in older adults, most people wish to continue driving[5]. Therefore, to overcome the dilemma of maintaining both public safety and individuals' ability to move about freely, it is necessary to screen and evaluate the potential for risky driving in the older adult population, although an appropriate screening tool has not been developed yet. Some studies have shown associations between the neuropsychological test battery[6,7], simulated driving[8], and actual driving function, but these instruments require the intervention of specialists or a device such as a computer, and self-report scales usually evaluate the difficulty of driving accompanying driving cessation rather than the risky driving[9,10].

The Driving Risk Questionnaire (DRQ) scale was developed in 2010 by the American Academy of Neurology[11], after reviewing previous studies and selecting the factors shown to have significant associations with risky driving; the evidence-based factors were combined and presented as DRQ items. The DRQ was created by collecting evidence that has proven to increase the risk of unsafe driving in dementia patients, especially Level A, B, and C[11]. There has been no validation study of DRQ using a solid gold standard yet. However, Carvalho et al.'s study[12] found that when factor analysis was performed, it was composed of four factors, 1) history of crashes or citations, 2) informant reported concerns, 3) reduced mileage, and 4) aggressive driving, consistent with the theory of the original study. Among these factors, safety concern and reduced mileage had a negative correlation with global cognition. Safety concern also had a significant negative correlation with initiation/perseveration and memory of the dementia rating scale. In addition, safety concerns were significantly correlated with apathy, disinhibition, and dysexecutive among behavior dysfunctions. Further, reduced mileage was significantly correlated with disinhibition and dysexecutive, and aggressive driving was significantly correlated with apathy, disinhibition, and dysexecutive[12]. However, there are no studies to date that show whether the items of DRQ can predict the actual recorded traffic law violations and accident records objectively.

In this study, we translated the DRQ into Korean and applied it to data from a large-scale, community-based older adult cohort in Korea to evaluate known risky driving factors in Korean older adult drivers.

Additionally, using the accident and violation records of the National Police Agency, we sought to compare associations between DRQ scores, each factor, and actual risky driving with two groups: *normal cognition* and c*ognitive impairment*.

Materials and Methods

Participants

A total of 6818 participants who participated in the Korean Longitudinal Study on Cognitive Aging and Dementia (KLOSCAD), a nationwide, prospective, community-based older adult cohort study, were included in this study. To construct a representative cohort of Korean older adults, we randomly sampled 30 villages and towns from 13 districts across South Korea. In October 2010, we randomly selected residents aged ≥60 years of which 10% were from urban areas and 20% from rural areas—using residential rosters. In total, 12,694 older individuals were sampled, and 6,818 (53.7%) participated in the baseline KLOSCAD assessment[13]. Between November 2012 and October 2014, initial baseline evaluations were conducted. Among the participants recruited for baseline evaluations, we excluded those who had not responded to the DRQ questionnaire, those who did not drive as of the baseline date, and those for whom there was no data in the Korean National Policy agency. (Figure 1)

Clinical & Neuropsychological assessments

Demographic data (age, gender, education level, and income) were categorized according to the overall distribution (Table 1). Regarding education, the following four categories were selected: Under elementary school, under junior high school, under high school, and upper university. Income was divided according to monthly income. Low, intermediate, and high groups were defined based on the amount presented (Table 1). Cumulative Illness Rating Score (CIRS) was used to evaluate comorbid illness[14]. The score for "psychiatric illness" was subtracted from the total CIRS score to avoid redundant adjustment (Modified CIRS). Depression was evaluated using the Korean version of the geriatric depression scale (GDS-KR)[15]. Furthermore, the Performance-Oriented Assessment of Mobility Problems (POMA) for older adult patients was used to evaluate participants' mobility problems. A total

score of 19 or lower indicates a substantial risk for falling; a score between 19 and 24 indicates a moderate risk[16].

We assessed the participants' cognitive function using the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease (CERAD-K). The CERAD-K consists of the following sub-items: J1, a verbal fluency test; J2, the Boston Naming Test; J3, the Mini Mental Status Exam for Dementia Screening (MMSE-DS); J4, a word list memory test; J5, the constructional praxis test; J6, a word list recall test; J7, a word list recognition test; J8, the constructional recall test; and J9 A/B, trail-making tests A and B[17]. The CERAD Total Score (TS) was calculated by summing J1–J7 to evaluate overall cognitive domains, according to a previous study[18].

Clinical diagnosis

Geriatric neuropsychiatrists specialized in dementia research conducted a face-to-face standardized diagnostic interview including physical and neurological examinations using the Korean version of the Consortium to Establish a Registry for Alzheimer's Disease Assessment Packet (CERAD-K) Clinical Assessment Battery (CERAD-KC)[19]. According to the principle of the clinical dementia rating, the severity of dementia was evaluated considering the premorbid function of each participant[20]. Dementia was diagnosed according to the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition diagnostic criteria[21]. Only participants with ADL impairment due to cognitive declines, such as the function of memory, orientation, and judgment, were considered to have dementia; those with deterioration due to physical disability or depression were excluded[20,21]. This evaluation result was confirmed by a consensus panel conference formed by a geriatric psychiatrist, clinical psychologist, and nurse. The subtypes of dementia were determined according to the following diagnostic criteria: AD according to the criteria of the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association[22], vascular dementia (VaD) according to the criteria of the National Institute of Neurological Disorders and Stroke-Association Internationale pour la Recherche et l'Enseigne-menten Neurosciences[23], dementia with Lewy bodies (DLB) and Parkinson's disease with dementia (PDD) according to the consensus guideline proposed by

McKeith et al[24], frontotemporal lobar degeneration (FTLD) according to the Neary criteria[25], and alcohol-related dementia (ARD) according to the diagnostic criteria proposed by Oslin et al[26]. The diagnosis of mild cognitive impairment (MCI) was according to the Consensus Criteria from the International Working Group on MCI[27]. The presence of objective cognitive impairment was ascertained when the performance of the subjects' standard deviations was 1.5 or below the age-, gender-, and education- adjusted norms in any of the neuropsychological tests. In this study, participants diagnosed with dementia and MCI were defined as cognitive impairment.

Translation of the DRQ into Korean & administration

To convert the original English version of the DRQ into Korean, a bilingual clinical neuropsychologist translated the English version into Korean. Next, the back-translation of the Korean version into English was performed by a bilingual psychiatrist; then, four psychiatrists discussed the similarity and suitability of the translated Korean version compared to the original.

DRQ is a scale used to measure a person's driving-related accidents and driving habits over the past three years. It is divided into two subdomains (accident and driving habit) and consists of three and 10 questions, respectively. The Accident subdomain is scored from 0 to 4 on a scale from "None" to "4 times" in each item, and the total score ranges from 0 to 12. The driving habit subdomain is scored on a scale of 1–5 on a from "not at all" to "clearly" scale, with a total score ranging from 10–50. Therefore, the Total DRQ score is in the range of from 10 to 62 points[11]. DRQ has not been validated in any previous study, so cut-offs and sensitivity/specificity have not yet been reported. There were originally two versions of the DRQ scale: drivers' and their caregiver's. However, in the KLOSCAD cohort, the caregiver questionnaire was rarely conducted, so only the results of the driver's scale were analyzed in this study.

Records of Accident and Violation of the Korean National Policy agency

To analyze the association between the DRQ scale and actual risky driving, the records of traffic accidents and traffic law violations of the participants registered in the Korean National Police Agency

for two years before and after the DRQ evaluation were used. Participants were defined as risky drivers if there was at least one accident or violation.

Statistical analyses

First, an exploratory factor analysis was conducted based on the results of the DRQ scale in the entire group. Principal component analysis was used, and items with factor loading over 0.40 were included. The final number of factors was derived based on the inflexion point of the Scree plot and the Eigenvalue exceeding 1.0[28]. Afterwards, the mean scores of total DRQ, each derived factor, and each item were compared in the overall, normal cognition, and cognitive impairment groups. Additionally, the predictive value of each item was evaluated by conducting logistic regression analyses using each detailed item as independent variables and the existence of risky driving two years before and after evaluation as dependent variables, respectively. The reason for using data from the National Police Agency two years prior to the DRQ evaluation was that the DRQ provided information about accidents and driving habits over the past two years. Therefore, we wanted to determine how well the DRQ reflects real-world risky driving, using records from two years prior to the assessment. In addition, the reason for using the National Police Agency data for two years after the DRQ evaluation was to determine whether the current DRQ evaluation could predict future risky driving. Next, the scores of total DRQ and each factor were dichotomized based on the mean value. Considering risky driving as a dependent variable, logistic regression analyses were conducted using the low half group as a reference of the independent variables. These analyses were conducted in the whole group, normal cognition, and cognitive impaired group, respectively. Age, sex, education, income, diagnosis (normal cognition/cognitive impairment), GDS, and CIRS scores were adjusted for whole groups (Model 1), and age, sex, education, income, GDS, and CIRS scores were adjusted for normal cognition and cognitive impairment groups. (Model 2)

Additional sensitivity analyses were implemented 1) including only men and 2) including only MCI instead of the cognitive impairment group.

Results

Demographic characteristics

The study participants included in the final analysis were 1885. Among them, 1557 and 328 were in the normal cognition and cognitive impairment group, respectively. Of the total participants in the normal cognition group, 36.1% were currently driving, and among the cognitively impaired group, only 15.9% were currently driving (Supplementary Table 1). Male drivers accounted for the majority at 81%. The impairment of mobility was not significant (POMA = 27.8) in the normal cognition and cognitive impairment groups. There were significant differences for each group in the education, CIRS, POMA, MMSE, CERAD TS, and GDS scores, but none in gender, income, and the number of accidents and violations before and after evaluation (Table 1).

Factor analysis of DRQ and Mean difference between groups

As a result of the exploratory factor analysis of 13 DRQ items, four factors were derived: crash history, safety concerns, reduced mileage, and aggressive driving (Supplementary Table 2). When the mean of individual items, DRQ total score, and each factor were compared in the normal cognition and the cognitive impairment groups; there were statistically significant differences in items 7 (Avoids driving at night.), 8 (Avoids driving in the rain.), 9 (Avoids driving in traffic), total score, and "reduced mileage." The scores of all reduced mileage were statistically significantly higher in the cognitive impairment group (10.51 ±5.22) than in the normal cognition group (9.72 ±5.01). (Table 2)

Association between DRQ and Risky driving

In this analysis of the association between each item of the DRQ and risky driving for two years before the evaluation, items 1 (Traffic tickets last three years), 2 (Accidents last three years), 3 (Faulted accidents last three years), 6 (Limited driving), 7 (Avoids driving at night), 8 (Avoids driving in the rain), 10 (Exceeds the speed limit), 11 (Drives through red lights), and 12 (Drives after drinking) were statistically significantly associated in the normal cognition group, of which items 6 (Limited driving), 7 (Avoids driving at night), and 8 (Avoids driving in the rain) were such that higher scores indicated less risky driving. However, in the cognitive impairment group, only item 1 (Traffic tickets last three

years) was statistically significant. When looking at the association between each DRQ item and risk driving for two years after the evaluation, items 1 (Traffic tickets last three years), 2 (Accidents last three years), 3 (Faulted accidents last three years), 10 (Exceeds the speed limit), and 11 (Drives through red lights) were statistically significantly associated in the normal cognition group; only item 1 in the cognitively impaired group was statistically significant (Supplementary Table 3).

Looking at the association between the scores of total DRQ, each factor, and the risky driving for two years before the evaluation, in the normal cognition group, crash history (OR = 3.65, 95% CI: 2.73–4.87), reduced mileage (OR = 0.72, 95% CI: 0.55–0.94), and aggressive driving (OR = 1.39, 95% CI: 1.09–1.81) were statistically significant. In the cognitive impairment group, there was a statistically significant association with crash history (OR = 2.90, 95% CI: 1.61−5.24), and there was a trend for significance with safety concerns (OR = 1.62, 95% CI: 0.93–2.83) (Table 3). Looking at the association between the scores of total DRQ, each factor, and the risky driving for two years after evaluation, in the cognitively normal group, crash history (OR = 1.71, 95% CI = 1.25–2.35), and aggressive driving (OR = 1.43, 95% CI = 1.04–1.97) were statistically significant. Nevertheless, only crash history (OR = 2.28, 95% CI = 1.14–4.55) was statistically significant in the cognitive impairment group (Supplementary Table 4).

Sensitivity analysis

In the sensitivity analysis conducted only on men, the overall trend was similar. However, unlike the case of whole participants, reduced mileage (OR = 0.75, 95%CI = 0.56–1.00) showed a trend for significance with risky driving two years before in the normal cognition group, while safety concerns (OR = 1.86, 95% CI = 1.02–3.41) showed statistical significance in the cognitive impairment group (Figure 2). In the sensitivity analysis conducted on MCI instead of the cognitive impairment group, the overall trend was similar (Supplementary Table 5).

Discussion

In this study, the DRQ based on the existing evidence of risky driving was applied in a large older adult

community cohort, and an exploratory factor analysis was conducted. Furthermore, the results of the scale were matched with the actual risky driving based on objectively compiled records. As a result, four factors (crash history, safety concern, reduced mileage, and aggressive driving) were derived, as presented in the previous study[12]. In individual items, "avoids driving at night," "avoids driving in the rain," and "avoids driving in traffic" showed a significant difference when each item was compared between the normal cognition and cognitive impairment group. Further, DRQ total score and reduced mileage factors showed significant differences in each group. These items also had significantly higher scores for the cognitive impairment group, which reflects a decline in the driving ability due to cognitive decline[29,30].

The association between each of the 13 DRQ items and the risky driving for two years before and after the evaluation indicates a pattern corresponding to the four previously classified factors (Supplementary Tables 2 and 3).

Among the four factors, the most statistically significant association with risky driving for two years before the evaluation was the crash history in both the cognitively normal and the cognitive impairment groups because the three items of crash history almost coincide with the outcome of this study. These items are "the number of traffic law violations," "the number of traffic accidents," and "the number of traffic accidents due to one's neglect." Since these items were in the questionnaires about the number of risky driving in the past three years, the odds ratio in risky driving for two years after the evaluation showed relative decreases, although there was still statistical significance.

Next, aggressive driving in the normal cognition group was statistically significantly associated with risky driving for two years before and after the evaluation. In cognitively normal older adults, the existing aggressive temperament is significantly associated with risky driving because cognitive functions are not significantly impaired. Previous studies have shown that aggressive driving is associated with traffic accidents and violations[31]. Subsequently, from the results of this study, when cognitive decline proceeds, the decline in driving ability might have a greater effect on risky driving than the effect of aggressive temperament.

Safety concerns showed a trend towards significance with risky driving for two years before the evaluation in the cognitive impairment group; it was also significant in the sensitivity analysis targeting only men. Safety concern reflects the deterioration of driving ability. In older Korean adults, patriarchal customs are prevalent[32], making driving the job of a man, as defined by gender role, so men usually have more driving experiences and total driving times are higher than for women. Therefore, in men who drive a lot in real life, safety concerns due to risky driving might have shown a prominent association with risky driving. However, safety concerns were not statistically significantly associated with risky driving for two years after evaluation. Therefore, we suspect that the number of risky drivers voluntarily reported safety concerns might have decreased as more participants stopped driving due to safety concerns. Actually, in participants with cognitive impairment, the number of risky driving after two years of evaluation decreased compared to the two years before evaluation (Table 1). In previous studies, especially those targeting the cognitive impairment group, safety concerns were suggested to be associated with risky driving[11].

However, reduced mileage was significantly negatively associated with risky driving for two years before the evaluation in the normal cognition group. Even in normal ageing, cognitive declines such as in judgment and processing speed are progressive and decrease driving ability[33]. In the normal cognition group, one's judgment of self-cognition—metacognition— is preserved[34], proper self-evaluation on one's driving ability and stopping or reducing driving might affect preventing risky driving. However, the reason that reduced mileage was not significantly related to risky driving for two years after the evaluation could be due to the decreased number of risky drivers for two years after the evaluation compared to two years before the evaluation (Table 1).

In summary, among the factors suggested in the DRQ, crash history, aggressive driving, and reduced mileage in the normal cognition group reflected risky driving. Moreover, crash history and aggressive driving predicted risky driving in the future. Whereas, in the cognitive impaired group, only crash history reflected risky driving and predicted future risky driving.

This study suggests that risky driving was not statistically significantly higher in the cognitive impaired

group compared to the normal cognition group when DRQ was not considered (Table 1). This might be because the maintenance ratio of driving decreases as cognitive decline progresses (Supplementary table 1). Considering this, it may be wrong to allow people with cognitive impairment to maintain their driver's license or insurance based solely on violations of traffic rules or accident records. Therefore, in determining whether to continue to permit driving in dementia patients, it is necessary to consider the evidence of DRQ, and to evaluate other aspects in addition to this.

After screening for risky driving using the evidence presented in the DRQ, a diagnostic evaluation is required. In other words, tests to determine whether to continue driving are needed. Previous studies have suggested on-road testing as the gold standard in the driving assessment of older adults[35-38]. Particularly standardized, validated road tests such as the Sepulveda Road test[39], the Washington Road Test[40], and the Test-ride for Investigating Practical fitness to drive or TRIP[41] has been developed. However, there is no cut-off point to predict risky driving in these tests. In addition, there are studies using driving simulators[42-46]. Simulators have obvious advantages, allowing detailed assessment in a safe and controlled environment; However, there are variations in the software and hardware based on the simultator[42], and there is also a disadvantage of causing motion sickness in older adults[47]. Deciding whether or not to drive for an older person is particularly important in pursuing a balance between the quality of life of an individual and the safety of the community. Hence, additional studies on diagnostic driving assessment are needed.

Limitations

First, caregivers' questionnaires were not included in the analyses. Particularly, for the cognitive impairment group, the feedback from the informants is often the most accurate[48], and in clinical practice, the patients are usually accompanied by their caregivers; thus, the caregiver reports on the patient's driving ability. Hence, the reports of caregivers have clinical importance and need to be dealt with in subsequent studies. Furthermore, in the cognitive impairment group, people tend to under-report—rather than over-report—their own performance declines[49]. Hence, safety concerns, which were

statistically significant in the sensitivity analysis, might have greater clinical predictive value for risky driving.

Second, in this study, it can be considered as a limitation that the dementia group was not analyzed separately; the group was integrated into the cognitive impairment group due to the low statistical power (low case of drivers with dementia). Dementia is associated with more significant cognitive decline, so more severe impairment occurs in driving ability than mild cognitive impairment[50]. Therefore, the factors of DRQ in each diagnostic group (MCI and dementia) may have shown different associations with risky driving. However, when we implemented sensitivity analysis restricted to the MCI instead of a cognitive impairment group, similar trends were observed. Furthermore, it is much more difficult to decide whether patients with mild cognitive impairment should continue driving than those who have progressed to dementia. Therefore, it can be considered meaningful to present more evidence related to risky driving in the cognitive impairment group.

Third, it is difficult to confirm that the violation and accident records in the National Police Agency data are fully representative of risky driving associated with cognitive impairment. There could also be accidents or traffic rule violations that are not recorded. However, despite this limitation, as a means of acquiring objective indicators of risky driving on a large scale, the National Police Agency records were used in this study. In the preceding large-scale epidemiological studies, data from the National Police Agency were used as objective indicators of outcome[51].

Conclusion

In this study, the predictive value of the evidence predicting risky driving in older adult drivers differed between the normal cognition and cognitive impairment groups. Crash history and aggressive driving were important in the normal cognition group, while, in the cognitive impairment group, crash history and safety concerns were most important. The evidence demonstrates that both clinical cognitive impairments and the evidence related to risky driving must be considered by those in clinical settings who may be in a position to judge or recommend whether a patient should or should not continue to drive. Thus, our results are expected to contribute to establishing the evidence for evaluating and

predicting risky driving and deciding whether patients should stop driving.

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Table 1. Baseline characteristics of the participants in the Korean Longitudinal Study on Cognitive Aging and Dementia (KLOSCAD)

Variables	All (*n* = 1,885)	NC (*n* = 1,557)	CI (*n* = 328)	*P**
Age (yrs.)	66.5±4.8	66.3 ±4.7	67.5 ±5.2	<.0001
Gender, *n* (%)				
Male	1522 (80.7)	1250 (80.3)	272 (82.9)	0.270
Female	363 (19.3)	307 (19.7)	56 (17.1)	
Education, *n* (%)	11.9 ±4.29	12.1 ±4.3	10.9 ±4.1	<.0001
Under elementary school	322 (17.1)	252 (16.2)	70 (21.3)	<.0001
Under middle school	295 (15.7)	223 (14.3)	72 (22.0)	
Under high school	535 (28.4)	437 (28.1)	98 (29.9)	
Upper university	733 (38.8)	645 (41.4)	88 (26.8)	
Income, *n* (%)				
Low	639 (34.0)	546 (35.1)	93 (28.6)	0.062
Intermediate	951 (50.6)	777 (50.0)	174 (53.5)	
High	289 (15.4)	231 (14.9)	58 (17.9)	
Modified CIRS	4.3 ±2.8	4.2 ±2.7	4.9 ±3.3	0.003
POMA	27.8 ±1.4	27.8 ±1.5	27.8 ±0.9	0.002
MMSE	27.5 ±1.9	27.8 ±1.7	26.4 ±2.3	<.0001
CERAD-TS	71.3 ±9.6	73.3 ±8.6	61.8 ±8.3	<.0001
GDS	8.2 ±5.9	7.7 ±5.7	10.2 ±6.5	<.0001
Traffic accidents and violations before 2 yrs.				
0	1531 (81.2)	1274 (81.8)	257 (78.4)	0.161
≥1	354 (18.8)	283 (18.2)	71 (21.6)	
Traffic accidents and violations after 2 yrs.				
0	1655 (87.8)	1372 (88.1)	283 (86.3)	0.354
≥1	230 (12.2)	185 (11.9)	45 (13.7)	

Values are means ± SDs unless stated otherwise.

*Statistically significant difference between NC and CI groups ($P < 0.05$) estimated using Wilcoxon rank sum test for continuous variables and chi-square test for categorical variables.

Abbreviations: NC; normal cognition, CI; cognitive impairment, CIRS; Cumulative Illness Rating Score, POMA; Performance-Oriented Assessment of Mobility Problems in Older adult patients, MMSE; Mini Mental Status Exam, CERAD-TS; The Consortium to Establish a Registry for Alzheimer's Disease total score, GDS; Geriatric depression scale.

Table 2 Comparison of Driving Risk Questionnaire items between NC and CI groups

Item		Question	All (n = 1,885)	NC (n = 1,557)	CI (n = 328)	P*
Q1	Traffic tickets last three years	How many times have you been stopped or ticketed for a traffic violation in the last three years?	0.76±1.09	0.76 ±1.08	0.80±1.12	0.524
Q2	Accidents last three years	How many accidents have you been in, or caused, within the last three years?	0.41±0.76	0.41 ±0.76	0.43±0.78	0.713
Q3	Faulted accidents last three years	In how many accidents were you at fault in the last three years?	0.24±0.56	0.24 ±0.55	0.28±0.61	0.304
Q4	Informant has concerns	I have concerns about my ability to drive safely.	1.99±1.28	1.96 ±1.25	2.13±1.39	0.150
Q5	Others have concerns	Others have concerns about my ability to drive safely.	1.90±1.18	1.87±1.15	2.07±1.31	0.049
Q6	Limited driving	I have limited the amount of driving that I do.	2.08±1.41	2.06 ±1.39	2.17±1.48	0.315
Q7	Avoids driving at night	I avoid driving at night.	2.73±1.59	2.69 ± 1.58	2.89±1.64	0.045
Q8	Avoids driving in the rain	I avoid driving in the rain.	2.61±1.53	2.57 ±1.51	2.80±1.59	0.019
Q9	Avoids driving in traffic	I avoid driving in busy traffic.	2.44±1.49	2.40 ±1.47	2.65±1.56	0.017
Q10	Exceeds the speed limit	I will drive faster than the speed limit if I think that I won't be caught.	2.53±1.42	2.56 ±1.42	2.42±1.42	0.101
Q11	Drives through red lights	I will run a red light if I think that I won't be caught.	1.86±1.16	1.85 ±1.14	1.91±1.23	0.885
Q12	Drives after drinking	I will drive after drinking more alcohol than I should.	1.39±0.90	1.40 ±0.91	1.36±0.88	0.375
Q13	Angry outbursts while driving	When I get angry with other drivers, I will honk my horn, gesture, or drive up too closely to them.	1.73±1.10	1.74 ±1.10	1.69±1.13	0.085
DRQ Total score			21.27±7.33	21.10 ±7.20	22.08±7.87	0.039
	Crash history		1.01±1.38	0.99 ±1.36	1.08±1.45	0.382
	Safety concern		3.89±2.17	3.83 ±2.10	4.20±2.43	0.071
	Reduced mileage		9.86±5.05	9.72 ±5.01	10.51±5.22	0.026
	Aggressive driving		7.51±3.14	7.54 ±3.14	7.37±3.15	0.282

Abbreviations: NC, normal cognition; CI, cognitive impairment

*Statistically significant difference between NC and CI groups ($P < 0.05$) estimated using Wilcoxon rank sum test for continuous variables.

Table 3 Odds rations and 95% confidence intervals for traffic accidents and violations before 2 years

	All (*n* = 1,885)			NC (*n* = 1,557)			CI (*n* = 328)		
	Crude OR(95% CI)	**Adjusted OR (95% CI)[1]**	***P***	**Crude OR(95% CI)**	**Adjusted OR (95% CI)[1]**	***P***	**Crude OR(95% CI)**	**Adjusted OR (95% CI)[1]**	***P***
Total score									
Half 1 (low, <22)	1.00 (ref.)	1.00 (ref.)		1.00 (ref.)	1.00 (ref.)		1.00(ref.)	1.00 (ref.)	
Half 2 (high, ≥22)	1.05 (0.83–1.32)	1.05 (0.83-1.33)	0.697	0.95 (0.74–1.23)	0.95 (0.73–1.24)	0.703	1.50 (0.88-2.56)	1.67 (0.95-2.93)	0.076
Crash history									
Half 1 (low, 0)	1.00 (ref.)	1.00 (ref.)		1.00 (ref.)	1.00 (ref.)		1.00 (ref.)	1.00 (ref.)	
Half 2 (high, ≥1)	3.50(2.71–4.51)	3.47 (2.68-4.50)	<0.001	3.58 (2.69–4.76)	3.65(2.73–4.87)	<0.001	3.15 (1.78-5.58)	2.90 (1.61-5.24)	<0.001
Safety concern									
Half 1 (low, <4)	1.00(ref.)	1.00(ref.)		1.00 (ref.)	1.00 (ref.)		1.00 (ref.)	1.00 (ref.)	
Half 2 (high, ≥4)	1.05(0.83–1.33)	1.08 (0.85-1.37)	0.550	0.96 (0.74–1.25)	0.99 (0.75–1.29)	0.911	1.49 (0.88-2.53)	1.62 (0.93-2.83)	0.092
Reduced mileage									
Half 1 (low, <10)	1.00(ref.)	1.00(ref.)		1.00(ref.)	1.00(ref.)		1.00(ref.)	1.00(ref.)	
Half 2 (high, ≥10)	0.82(0.65–1.04)	0.82 (0.65-1.05)	0.110	0.73(0.56–0.94)	0.72(0.55–0.94)	0.016	1.32 (0.77-2.26)	1.44 (0.81-2.55)	0.210
Aggressive driving									
Half 1 (low, <8)	1.00(ref.)	1.00(ref.)		1.00(ref.)	1.00(ref.)		1.00(ref.)	1.00(ref.)	
Half 2 (high, ≥8)	1.39(1.10–1.75)	1.33 (1.05-1.70)	0.019	1.41(1.09–1.82)	1.39(1.06–1.81)	0.017	1.30 (0.77-2.20)	1.17 (0.68-2.03)	0.565

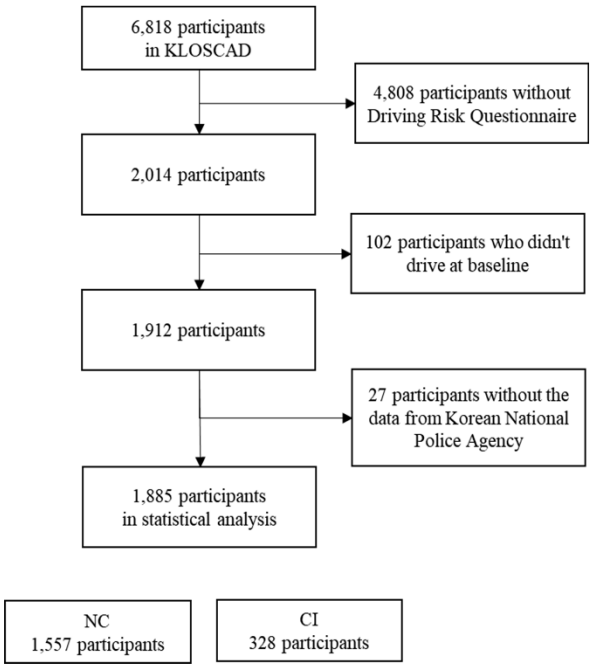
ORs were calculated using logistic regression.

[1]Models adjusted for age, sex, education, income, cognitive impairment, GDS, and CIRS.

[2]Models adjusted for age, sex, education, income, GDS, and CIRS.

Abbreviations: NC, normal cognition; CI, cognitive impairment, GDS, geriatric depression scale

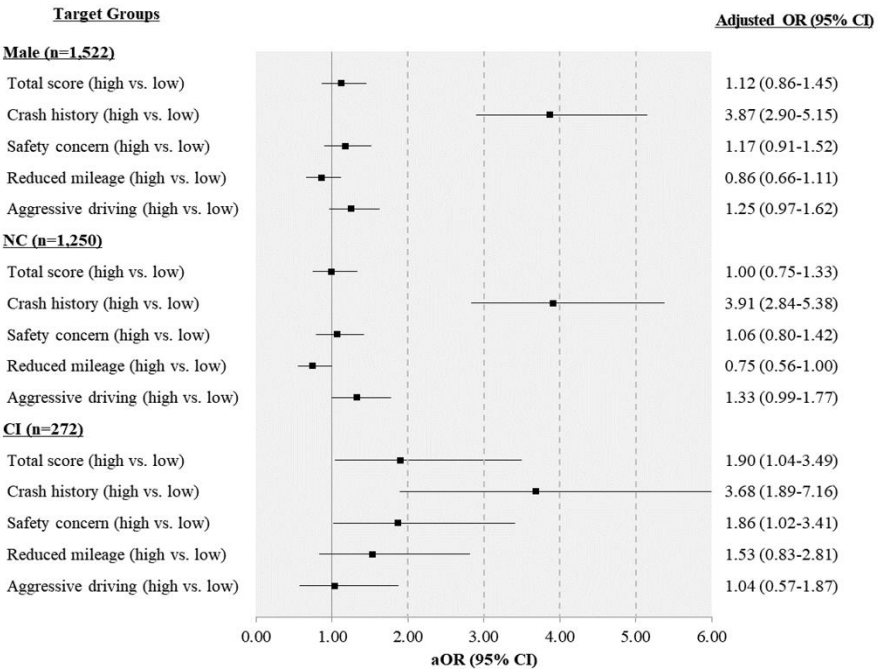
Figure 1. Schematic flowchart of study design



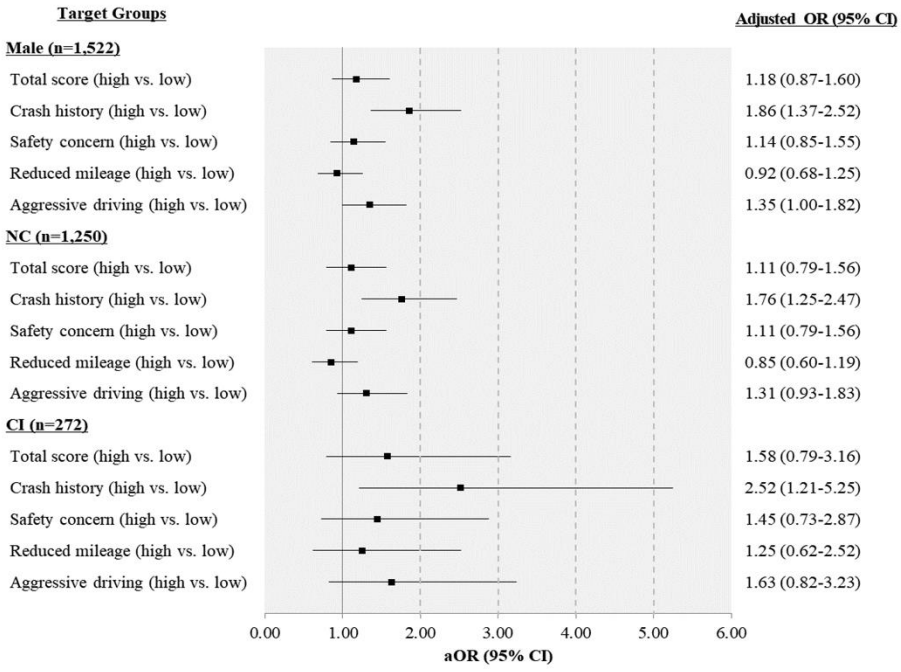
* Abbreviations: NC; normal cognition, CI; cognitive impairment

Figure 2. Odds ratios and 95% confidence intervals for traffic accidents and violations before/after 2 years in male.

(a) Odds ratios and 95% confidence intervals for traffic accidents and violations before 2 years in male



(b) Odds ratios and 95% confidence intervals for traffic accidents and violations after 2 years in male



* Abbreviations: NC, normal cognition; CI, cognitive impairment