International Journal of Gerontology 16 (2022) 218–223
https://doi.org/10.6890/IJGE.202207_16(3).0010

International Journal of Gerontology

journal homepage: http://www.sgecm.org.tw/ijge/

Review Article

A Scoping Review of the Effectiveness of Driving Training in People with Mild Cognitive Impairment

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ARTICLE INFO

Accepted 22 September 2021

Keywords:
automobile driving,
cognitive dysfunction,
aged,
safety,
education

SUMMARY

Maintaining driving ability of individuals with mild cognitive impairment (MCI) is important for both health and quality of life. The aim of this scoping review was to synthesize the current peer-reviewed research articles on the effectiveness of driving training in individuals with MCI. The review included articles published in English since the commencement of the four selected databases till March 2, 2021. We included studies in which individuals with clearly defined MCI were studied and underwent driving training. Three articles met the inclusion criteria, out of the 2,559 articles that were identified through the database search. The review found that individuals with MCI can benefit from driving training, exhibiting short-term positive effects on the driving simulator (DS) performance as a result of the DS training alone, in addition to long-term positive effects on their on-road performance using multiple training. The review also identified few issues: small sample size and variations in subtypes, cognitive tests used, outcome measures, data schedules, complications, and basic functions (including visual acuity, auditory function, physical function) among studies. In conclusion, individuals with MCI have a potential to improve their driving ability; therefore, we recommend that future studies should describe at least subtypes including cognitive tests used.

1. Introduction

Mobility refers to the ability to move independently and autonomously in one's environment and is attributed particularly to driving ability. Driving ability includes coordination of multiple physical and cognitive functions and is affected by aging and medical conditions. Maintaining one's driving ability has been acknowledged as important for both health and quality of life,[1,2] therefore, the fact that people aged 65 years and above continue driving has been a critical public health concern worldwide.

Recently, with the rapid expansion in the number of licensed drivers aged 65 years and above, mild cognitive impairment (MCI), an abnormal clinical state and a transitional phase between normal aging and dementia, has been receiving greater attention in driving literatures. Studies have been conducted for the purpose of predicting and/or identifying the driving performance of individuals with MCI by means of cognitive tests, driving simulator (DS), and on-road evaluation. In DS studies with cognitive tests, individuals with MCI, as defined by the clinical dementia rating scores of 0.5 (CDR = 0.5), showed shorter time-to-collision (TTC), –the time to contact the preceding vehicle– compared to a cognitively normal age-matched control group. The shorter TTC was attributed to general cognitive functioning (as evaluated by the Mini Mental State Examination, MMSE), and not to a simple reaction time.[3] Kawano et al. reported that individuals with amnestic MCI, as defined by the criteria of CDR = 0.5, demonstrate poorer car-following ability compared to the control with normal cognition; moreover, the Trail Making Test (TMT) and Stroop task significantly predict poorer DS performance.[4] Hird et al. investigated the driving performance of different types of amnestic MCI, diagnosed based on the National Institute on Aging-Alzheimer's Association (NIA-AA) criteria. They found that individuals with multi-domain MCI had more stop signs misses and more center line crossings and spent a greater amount of time out of the legal driving lane compared to control and single-domain MCI. They also revealed the association with useful fields of view (UFOV) processing speed and DS errors among single-domain MCI and between TMT and DS errors among multi-domain MCI.[5] Delvin et al. reported that individuals with MCI, identified by the score of MMSE above 23 and symptomology for MCI, did not show a statistical difference compared to age-matched drivers despite the fact that individuals with MCI had a lower score of MMSE.[6] Moreover, individuals with MCI (defined as CDR = 0.5) did not differ in DS performance compared to a cognitively normal control despite the significant difference in the score of cognitive tests; however, individuals with MCI who have depression showed worse DS performance compared to those without depression.[7] Considering on-road driving studies, Eramudugolla et al. classified patients with MCI, diagnosed by the Winblad criteria,[8] into the four MCI subtypes (amnestic single-/multi-domain MCI, non-amnestic single-/multi-domain MCI) and then evaluated their on-road driving performance. Results showed that irrespective of whether they have memory impairment, the multi-domain subtype exhibited a higher proportion of unsafe driving behavior.[9] Vardaki et al. asked individuals with amnestic MCI diagnosed by the Petersen

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criteria[10] to report driving difficulties in a typical driving environment and found that they exhibited slowed response to relevant hazards and switched attention from automatic to conscious processing for long durations.[11] Anstey et al. also found that while individuals with MCI diagnosed by the Winblad criteria[8] had a significantly lower safety rating score for on-road driving, the range of the scores was the same as the cognitively normal control.[12] Further, studies consistently reported that individuals with MCI defined by the Petersen criteria[10] tended to overestimate their driving abilities,[13] moreover, the difference in driving performance in the real environment were not at the level of frank impairments.[14]

In sum, as reported earlier,[15] driving studies on individuals with MCI have considerable variations in the definition/diagnosis, subtypes, probably etiologies, and their cognitive status. It is plausible that although driving performance of individuals with MCI may be lower than that of cognitively normal individuals, they should not be considered unsafe drivers simply due to the diagnosis of MCI. In this context, we pose the question whether individuals with MCI can benefit from driving training and whether individuals with different subtypes and etiology of MCI respond differently to driving training. Although the effectiveness of driving training for older driver,[16] medically at-risk drivers,[17] and stroke drivers[18] has been systematically reviewed, to the best of our knowledge, no systematic or scoping review on the effectiveness of driver training programs for individuals with MCI has been reported. The aim of this scoping review was to synthesize the current peer-reviewed research articles on the effectiveness of driving training in individuals with MCI.

2. Methods

We applied the scoping review framework proposed by Tricco et al.[19] This review included articles published in English till March 2, 2021 since the commencement of the four selected databases, namely PubMed, PsycInfo, CINAHL, and Web of Science. The following search terms were used, as appropriate, for each database: "driving" OR "drive" OR "vehicle" OR "car" OR "automobile" OR "vehicle driving" OR "automobile driving" OR "car driving" OR "driving ability" OR "driving behavior" AND "MCI" OR "mild cognitive impairment" OR "cognitive dysfunction" OR "dementia" AND "training" OR "intervention" OR "education" OR "care" OR "program" OR "exercise".

As there is considerable variation in definition/diagnosis, subtypes, etiologies of MCI, and cognitive test used, the present review accepted any research articles if they defined MCI in terms of any criteria, which would be optimum for comprehending a variety of studies in this fields. The inclusion criteria were studies on individuals with clearly defined MCI who also underwent driving training. Articles were excluded if they were (i) duplicates, (ii) not research article, that is, editorials, commentaries, books, and congress abstracts, and if (iii) the terms MCI/mild cognitive impairment and driving were not specified in the title, abstract, and/or full-text, and (iv) training and related search terms, that is, intervention, education, care, program, and exercise, were not addressed. Three authors independently screened the citations and discrepancies were resolved through discussion. Figure 1 illustrates the review process.

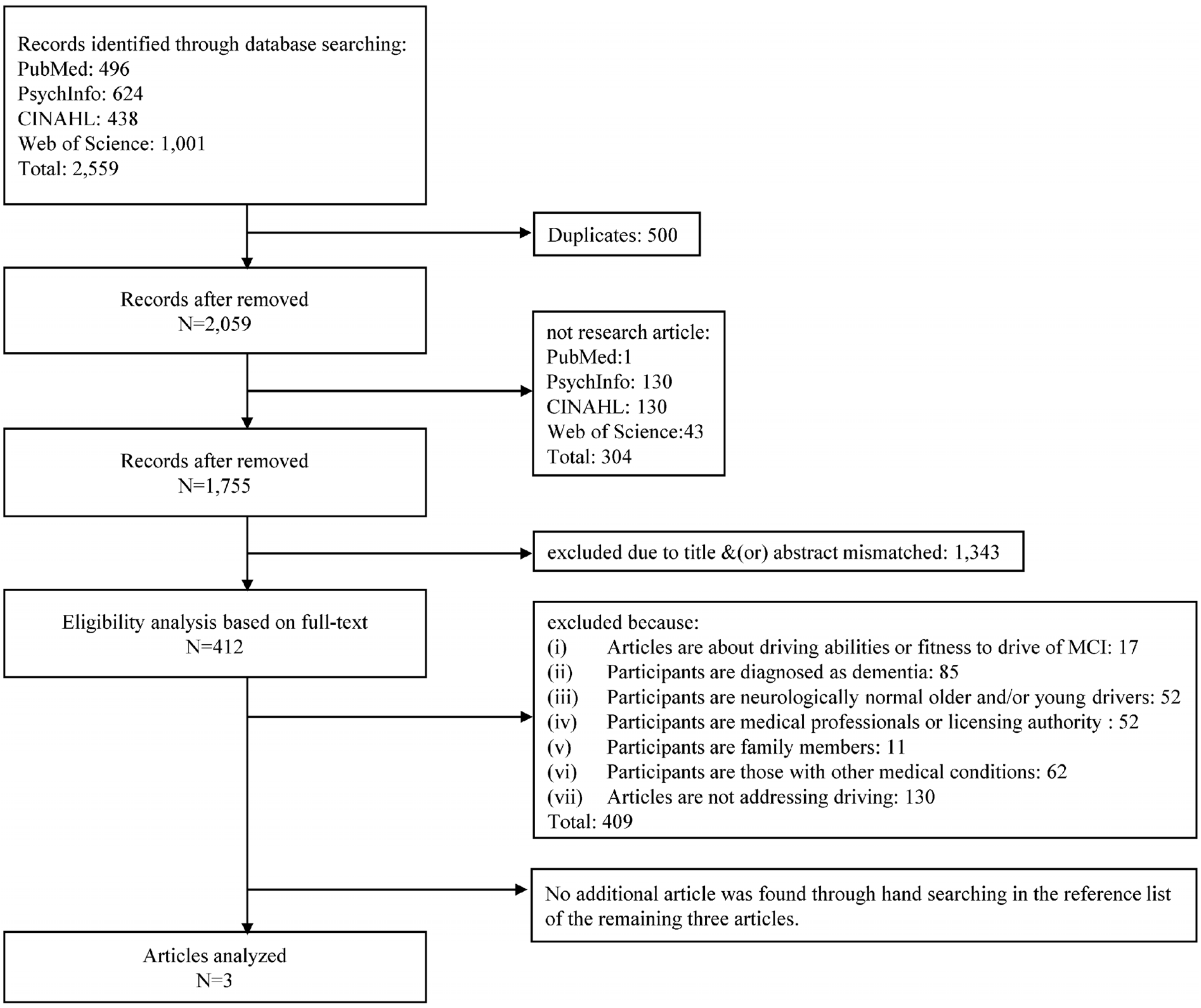

Figure 1. Illustration of review process.

3. Results

A total of 2,559 articles were identified from the database search, of which 500 duplicates and 304 non-research articles were removed. We further excluded 1,343 articles because they did not meet the inclusion criteria. Three authors performed full-text eligibility analysis on the remaining 412 articles, of which 409 did not meet the inclusion criteria, the reasons for which are depicted in Figure 1. Finally, three articles met the inclusion criteria. The reference lists of the three eligible articles were hand searched, however, no studies on driving training for individuals with MCI were found.

Teasdale et al.[20] conducted a non-randomized pre-post comparative study without a control group, recruited 15 patients with normal vision and functional autonomy, who were diagnosed with amnestic MCI (eight single-domain; seven multiple-domain) by physicians at their memory clinic by the Albert criteria.[21] They also evaluated patients' cognitive status in terms of general cognitive function (by means of the Montreal Cognitive Assessment), episodic memory (by means of the Rappel libre/Rappel Indice), visuo-spatial function (by the Rey-Osterrieth Complex Figure Test), information processing speed (the Coding subtest in the Wechsler Adult Intelligence Scale III), fluency (the Pyramids and Palm Tree Test), and executive function (the Stroop task), confirming that all patients showed memory dysfunction, with some having additional cognitive decline most frequently in fluency and executive function. The etiology of MCI was not described. The patients were given training with auditory feedback by the DS, which included five simulator sessions on five different days within three weeks and one session after six months. The results showed that the error frequency of speeding, weaving, failure to verify a blind spot, and visual search, in addition to vehicle control at intersections with a stop sign gradually decreased over the initial five sessions. However, the level of improvement was not maintained at the six-month recall session. Shimada et al.[22] conducted a randomized controlled study, recruiting 2,096 community-dwelling adults aged 65 years and above with normal visual acuity at the base line; finally, 160 individuals with MCI diagnosed by physicians based on the Petersen criteria[10] were analyzed. The study also evaluated participants' cognitive status in terms of general cognitive function (MMSE), memory, attention, executive function, and processing speed (the National Center for Geriatrics and Gerontology Functional Assessment Tool, NCGG-FAT). They did not describe the etiology of MCI and excluded those who had a history of dementia or Parkinson's disease. Seventy-one individuals with MCI were assigned to the intervention group and the remainder were assigned to a control group. There was no significant difference in demographic characteristics including cognitive status between the groups. The intervention group was given a classroom lessen, in which they underwent vision training, DS-training, and on-road training once a week for three months. The control group was given a classroom lesson with safety driving education only once during the study period. They found that the intervention group showed improvement in the safe driving skill score and a decline in safety disconfirmations and dangerous driving in on-road driving. Ishii et al.[23] conducted a follow-up study of the study by Shimada et al.,[22] examining the long-term positive effects of driving training in 104 individuals with MCI (intervention group: 58; control group: 46). They found that compared with the control group, the intervention group maintained on-road driving performance at the one-year follow-up without any feedback.

Addressing the research question of whether individuals with MCI can benefit from driving training, it could be summarized that both DS training alone and multiple driving training including vision training, DS training, and on-road training can bring short-term positive effects, on the other hand, long-term positive effect can be found only when multiple driving training was given. However, these results should be interpreted with caution as the sample size was small, and subtypes, cognitive tests used, outcome measures, data schedules, complications, and the basic functions such as visual acuity, auditory function, physical function varied among studies. Furthermore, considering the research question on whether different subtypes and etiology of MCI respond differently to driving training, this review was unable to draw a conclusion due to the lack of analysis based on subtype and description of etiology. Table 1 summarizes the contents of the three articles.

4. Discussion

The review found that individuals with MCI can benefit from driving training, exhibiting short-term positive effects on their DS performance with the DS training alone and long-term effects on their on-road performance using multiple training. This suggests that individuals with MCI have a potential to improve their driving ability. The common manifestation of MCI is cognitive impairment irrespective of subtype and etiology, therefore, the cognitive functions required to driving, such as executive function, attention, visuospatial function, and processing speed,[23] should be targeted during the training. The association between cognitive function and corresponding unsafe driving performance is a contentious topic, with some insisting the existence of an association,[24] while others do not.[25] Nevertheless, it was hard to extract the specific cognitive functions underlying specific unsafe driving performance from the reviewed three articles due to absence of relevant analysis. Further, several intervention approaches exist in the literature, including DS training, on-road training, cognitive training, safety education,[16,26] and applied across a variety of populations.[27–29] Although multiple driving training is expected to bring a larger improvement compared to a single driving training,[30] an optimal combination of approaches[31] and a tailored training approach[32] addressing affected cognitive functions has not yet been studied in individuals with MCI. In addition, physical exercise,[33] participation in social activities,[34] and education on lifestyle habits[35,36] could improve cognitive functions leading to an indirect improvement of driving ability. Future studies are expected to bridge these gaps with overcoming following barrier. The most concerning barrier is the heterogeneity of MCI. The clinical manifestation of MCI is affected by etiology,[37,38] subtype,[5,9] and even psychiatric symptom such as depression.[7,39] Among the reviewed studies, Teasdale et al.[20] confirmed the subtypes of subjects and absence of depression, but Shimada et al.[22] and Ishii et al.[23] did not; none of them described etiology, which means that the subjects with MCI in these studies are not the same. To increase the credibility of results, future studies need to describe the criteria and subtype of MCI in addition to the cognitive tests used, other medical conditions, and etiology.

5. Limitations

The first limitation of this review is that few studies on the effectiveness of driving training for individuals with MCI has been conducted. Therefore, the effectiveness of driving training extracted through the charting process have low generalizability, and should be interpreted with caution. Although speculative, one possible explanation could be that given the nature of MCI, the potential participants are functionally independent in daily life and living in the community, leading to a lesser chance of being detected/recruited.

Table 1
The summary of included articles.

Authors, year	Participants & sample size	Subtype of MCI	Etiology of MCI	Study design	Diagnosis of MCI	Cognitive domain tested	Intervention	Outcome	Data schedules	Main results
Teasdale et al., 2016[20]	Amnestic MCI total 15 - Single domain 8 - Multiple domain 7	Amnestic single domain Amnestic multiple domain	Not described	Non-randomized pre/post intervention without control	Albert (2011) criteria 1. Concern regarding a change in cognition 2. Impairment in one or more cognitive domains 3. Preservation of independence in functional abilities 4. Not demented	General cognitive function Episodic memory Visuo-perception/ construction Information processing speed Semantic fluency Executive functions	Intervention - DS - Automated auditory feedback (+)	Number of errors	Day 1, day 2, day 3, day 4, day 5 (within 21 days interval) Day 6 (6 months after)	Initial five sessions, gradual decrease in the number of errors was observed. However, the level was not maintained at the 6-month recall session.
Shimada et al., 2019[22]	MCI or MMSE-score of 24 total 160 - Intervention 71 - Control 89	Not verified	Not described	Japanese national cohort RCT study	Petersen (2004) criteria 1. Cognitive complaint 2. Not normal for age 3. Not demented 4. Cognitive decline 5. Essentially normal functional activities	General cognitive function Memory Attention Processing speed Executive function	Intervention - Class lesson (60 min/week); vision training, DS-training - On-road training (50 min/week) Control - One class room education	On-road driving performance Subscore of on-road test Dynamic vision Cognitive function	Base line Post-intervention (3 months after)	Driving skill program significantly improved safe driving performance.
Ishii et. al., 2021[23]	MCI or MMSE-score of 24 total 160 - Intervention 71 - Control 89	Not verified	Not described	Japanese national cohort study	Petersen (2004) criteria 1. Cognitive complaint 2. Not normal for age 3. Not demented 4. Cognitive decline 5. Essentially normal functional activities	General cognitive function Memory Attention Processing speed Executive function	Intervention - Class lesson (60 min/week); vision training, DS-training - On-road training (50 min/week) Control - One class room education	On-road driving performance Subscore of on-road test Dynamic vision Cognitive function	Base line Post-intervention 1 year follow-up (3 months after)	Driving skill program maintained driving performance at 1-year follow-up.

To address this, a well-designed population-based cohort study should be conducted.

Second, we may possibly miss studies with potential cases with MCI. Some studies on older drivers may include individuals with MCI. Similarly, research on pre-Alzheimer's disease, Parkinson's disease, stroke patients might include individuals with MCI. This limitation may have affected the number of eligible articles and biased the results of this review.

The third limitation is about the outcome measure of the effectiveness of the training. Whether participants are safe drivers should be measured by the number of traffic accidents involved. The three studies did not report accidents in real traffic conditions, thus, whether individuals with MCI who took driving training were safe drivers remains a matter of speculation. Future research should address this issue.

6. Conclusions

The present scoping review revealed that individuals with MCI can benefit from driving training, with short-term positive effects on their DS performance via the single DS training and long-term positive effects on their on-road performance through the use of multiple driving training. This indicates that individuals with MCI have a potential to improve their driving ability. The review also identified certain issues, such as the small sample size and the variations in subtypes, cognitive tests used, outcome measures, data schedules, complications, and the basic functions assessed such as visual acuity, auditory function, physical function among studies. It is suggested that future studies should describe at least subtypes including cognitive tests used.

Declaration of interest statement

The authors declare no conflict of interest associated with this manuscript.

Funding

This work was supported by the Japan Society for the Promotion of Science, Grant-in-Aid for Scientific Research (C) under Grant 18K10685.

Acknowledgements

We would like to thank Editage (www.editage.com) for English language editing.

References

1. Hirai H, Ichikawa M, Kondo N, et al. The risk of functional limitations after driving cessation among older Japanese adults: The JAGES cohort study. *J Epidemiol.* 2019;30:332–337.
2. Oxley J, Whelan M. It cannot be all about safety: the benefits of prolonged mobility. *Traffic Inj Prev.* 2008;9:367–378.
3. Frittelli C, Borghetti D, Iudice G, et al. Effects of Alzheimer's disease and mild cognitive impairment on driving ability: a controlled clinical study by simulated driving test. *Int J Geriat Psychiatry.* 2009;24:232–238.
4. Kawano N, Iwamoto K, Ebe K, et al. Effects of mild cognitive impairment on driving performance in older drivers. *J Am Geriatr Soc.* 2012;60:1379–1381.
5. Hird MA, Vesely KA, Fischer CE, et al. Investigating simulated driving errors in amnestic single- and multiple-domain mild cognitive impairment. *J Alzheimers Dis.* 2017;56:447–452.
6. Delvin A, McGillivray J, Charlton J, et al. Investigating driving behaviour of older drivers with mild cognitive impairment using a portable driving simulator. *Accid Anal Prev.* 2012;49:300–307.
7. Beratis IN, Andronas N, Kontaxopoulou D, et al. Driving in mild cognitive impairment: the role of depressive symptom. *Traffic Inj Prev.* 2017;18:470–476.
8. Winblad B, Palmer K, Kivipelto M, et al. Mild cognitive impairment – beyond controversies, towards a consensus: report of the International Working Group on Mild Cognitive Impairment. *J Intern Med.* 2004;256:240–246.
9. Eramudugolla R, Huque MH, Wood J, et al. On-road behavior in older drivers with mild cognitive impairment. *J Am Med Dir Assoc.* 2021;22:399–405.e1.
10. Petersen RC. Mild cognitive impairment as a diagnostic entity. *J Intern Med.* 2004;256:183–194.
11. Vardaki S, Dickerson AE, Beratis I, et al. Driving difficulties as reported by older drivers with mild cognitive impairment and without neurological impairment. *Traffic Inj Prev.* 2019;20:630–635.
12. Anstey KJ, Eramuduggolla R, Chopra S, et al. Assessment of driving safety in older adults with mild cognitive impairment. *J Alzheimers Dis.* 2017;57:1197–1205.
13. Okonkwo OC, Griffith HR, Vance DE, et al. Awareness of functional difficulties in mild cognitive impairment: A multidomain assessment approach. *J Am Geriatr Soc.* 2009;57:978–984.
14. Wadley VG, Okonkwo O, Crowe M, et al. Mild cognitive impairment and everyday function: an investigation of driving performance. *J Geriatr Psychiatry Neurol.* 2009;22:87–94.
15. Staplin L, Lococo K, Gish KW, et al. *Mild cognitive impairment and driving performance (Report No. DOT HS 812 577)*. Washington, USA: National Highway Traffic Safety Administration. 2019.
16. Castellucci HI, Bravo G, Arezes PM, et al. Are interventions effective at improving driving in older drivers?: A systematic review. *BMC Geriatr.* 2020;20:125.
17. Classen S, Monahan M, Auten B, et al. Evidence-based review of interventions for medically at-risk older drivers. *Am J Occup Ther.* 2014;68:e107–e114.
18. George S, Crotty M, Gelinas I, et al. Rehabilitation for improving automobile driving after stroke. *Cochrane Database Syst Rev.* 2014;2014:CD008357.
19. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med.* 2018;169:467–473.
20. Teasdale N, Simoneau M, Hudon L, et al. Older adults with mild cognitive impairments show less driving errors after a multiple sessions simulator training program but do not exhibit long term retention. *Front Hum Neurosci.* 2016;10.653.
21. Albert MS, DeKosky ST, Dickson D, et al. The diagnosis of mild cognitive impairment due to Alzheimer's disease: recommendations from the National Institute on Aging-Alzheimer's Association workgroups on diagnostic guidelines for Alzheimer's disease. *Alzheimers Dement.* 2011;7:270–279.
22. Shimada H, Hotta R, Makizako H, et al. Effects of driving skill training on safe driving in older adults with mild cognitive impairment. *Gerontology.* 2019;65:90–97.
23. Ishii H, Doi T, Tsutsumimoto K, et al. Long-term effects of driving skill training on safe driving in older adults with mild cognitive impairment. *J Am Geriatr Soc.* 2021;69:506–511.
24. Kosmidis M, Economou A, Liozidou A, et al. Neurocognitive correlates of driving behavior. *Arch Clin Neuropsychol.* 2014;29:569–570.
25. Vaughan L, Hogan PE, Rapp SR, et al. Driving with mild cognitive impairment or dementia: cognitive test performance and proxy report of daily life function in older women. *J Am Geriatr Soc.* 2015;63:1774–1782.
26. Unsworth CA, Baker A. Driver rehabilitation: A systematic review of the types and effectiveness of interventions used by occupational therapists to improve on-road fitness-to-drive. *Accid Anal Prev.* 2014;71:106–114.
27. Ott BR, Heindel WC, Papandonatos GD, et al. A longitudinal study of drivers with Alzheimer disease. *Neurology.* 2008;70:1171–1178.
28. Mazer B, Gélinas I, Duquette J, et al. A randomized clinical trial to determine effectiveness of driving simulator retraining on the driving performance of clients with neurological impairment. *Br J Occup Ther.* 2015;78:369–376.
29. Cox DJ, Davis M, Singh H, et al. Driving rehabilitation for military personnel recovering from traumatic brain injury using virtual reality driving simulation: a feasibility study. *Mil Med.* 2010;175:411–416.

30. Sawula E, Polgar J, Poter MM, et al. The combined effects of on-road and simulator training with feedback on older drivers' on-road performance: evidence from a randomized controlled trial. *Traffic Inj Prev.* 2018;19: 241–249.
31. Sangrar R, Mun J, Cammarata M, et al. Older driver training programs: A systematic review of evidence aimed at improving behind-the-wheel performance. *J Safety Res.* 2019;71:295–313.
32. Anstey KJ, Eramudugolla R, Kiely KM, et al. Effect of tailored on-road lessons on driving safety in older adults: A randomised controlled trial. *Accid Anal Prev.* 2018;115:1–10.
33. Young J, Angevaren M, Rusted J, et al. Aerobic exercise to improve cognitive function in older people without known cognitive impairment. *Cochrane Database Syst Rev.* 2015;(4):CD005381.
34. Kim M, Park JM. Factors affecting cognitive function according to gender in community-dwelling elderly individuals. *Epidemiol Health.* 2017;39: e2017054.
35. Canevelli M, Grande G, Lacorte E, et al. Spontaneous reversion of mild cognitive impairment to normal cognition: a systematic review of literature and meta-analysis. *J Am Med Dir Assoc.* 2016;17:943–948.
36. Xu W, Tan CC, Zou JJ, et al. Sleep problems and risk of all-cause cognitive decline or dementia: an updated systematic review and meta-analysis. *J Neurol Neurosurg Psychiatry.* 2020;91:236–244.
37. Gorelick PB, Scuteri A, Black SE, et al. Vascular contributions to cognitive impairment and dementia: a statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke.* 2011;42;2672–2713.
38. Litvan I, Goldman JG, Tröster AI, et al. Diagnostic criteria for mild cognitive impairment in Parkinson's disease: movement disorder sociey task force guidelines. *Mov Disord.* 2012;27:349–356.
39. Petersen RC, Doody R, Kurz A, et al. Current concepts in mild cognitive impairment. *Arch Neurol.* 2001;58:1985–1992.