Title

Increased traffic injuries among older unprotected road users following the introduction of an age-based cognitive test to the driver's license renewal procedure in Japan

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Abstract

Background

To deal with the increasing number of motor vehicle collisions (MVCs) among older drivers, a cognitive test has been introduced to a license renewal procedure for drivers aged ≥75 years since June 2009. This might have prompted the reduction or cessation of driving by older drivers. We therefore examined whether older drivers' chance of experiencing MVCs as unprotected road users has increased after the test was introduced.

Methods

Using police-reported national data on MVCs from January 2005 through December 2016, we calculated the monthly injury rates (including deaths, severe injuries, and minor injuries) among unprotected road users (bicyclists and pedestrians) by sex and age group (70–74, 75–79, 80–84, and ≥85 years). The ratios of the injury rates of unprotected road users in the three oldest age groups (who were subjected to the test) to those aged 70–74 years (not subjected to the test) were also calculated. Then, we conducted an interrupted time-series analysis based on the injury rate ratios to control for extraneous factors affecting MVCs over the study period.

Results

There was a significant increase in traffic injuries of unprotected road users at the time the test was introduced among females aged 75–84 years, and at a later time among males aged ≥80 years and females aged ≥85 years.

Conclusion

Licensing policies for older drivers should be rigorously evaluated, taking into account the safety of older unprotected road users, and should be balanced against it.

Keywords

Traffic policy; older adults; vulnerable road users; interrupted time series; Japan

1. Introduction

With aging in driver populations, particularly in industrialized countries, stringent driver licensing policies have been adopted for older drivers to deal with the increasing number of motor vehicle collisions (MVCs).[1–3] In Denmark; Japan; Ontario, Canada; and Taiwan, from 2006, 2009, 2014, and 2017, respectively, cognitive test was introduced to older drivers' license renewal procedures. This cognitive test was intended to reduce older drivers' MVCs by dissuading those cognitively impaired from driving. However, the effectiveness of such a licensing practice in reducing MVCs has remained unclear.[1,4,5] Rather, there have been concerns about the deterrent effect of a demanding licensing procedure on premature driving cessation[1,6] and adverse health consequences associated with driving cessation.[7]

One of the possible adverse consequences of driving cessation is an increased injury risk because such older adults become unprotected road users due to the modal shift from driving to walking and cycling. A study in the United Kingdom reported that the risk of fatal injuries per trip for pedestrians was higher than that for drivers and passengers among adults aged ≥70,[8] suggesting increased risk of fatal injuries per trip after driving cessation. In fact, a pre-post study in Denmark observed an increase in fatal injuries among older unprotected road users after the introduction of a cognitive test to older drivers that is possibly due to their modal shift from driving to non-driving.[9]

The magnitude of the possible adverse consequences, however, could differ between Japan and Denmark or any other Western countries; given the proportion of fatal road injuries shared by pedestrians and bicyclists in Japan (over 50%), which is much higher than that in the Western countries (about 20–30%).[10] This implies differences in the road environment and exposure to traffic of unprotected road users between the countries, which might influence the consequences. Thus, it is necessary to investigate the degree to which introducing a cognitive test to older drivers' licensing renewal procedure influenced injury risk of the consequent older unprotected road users in Japan. Furthermore, a more rigorous method of evaluation should be employed to confirm findings of previous studies. This is because, some studies, such as the evaluation study conducted in Denmark was simply a pre-post comparison study.[9] Causality is hard to claim from the finding of such a study.

Licensing policies for older drivers should be balanced against the safety of the consequent older unprotected road users to secure the overall traffic safety of older adults. Therefore, in the present study, we compared traffic deaths and injuries by type of road users among older adults, to identify the most vulnerable road users and to examine the relevance of the current traffic safety policies. Then, we conducted an interrupted time-series analysis, a more rigorous method than a pre-post comparison, to evaluate the impact of introducing the cognitive test to older drivers' license renewal procedure on traffic deaths and injuries in older unprotected road users. An interrupted time-series analysis is one of quasi-experimental study designs, and this design has been used for the evaluation of traffic safety interventions such as cycle helmet legislation and traffic speed zones.[11]

2. Methods

2.1 Study settings

In Japan, a cognitive test at license renewal of drivers aged ≥75 years began nationwide in June 2009. For these drivers, the interval of license renewal is 3 years and the age and month of license renewal differs between drivers. However, all those subjected to the test had taken it at least once by June 2012. The purpose of the test was to identify older drivers that are suspected of having dementia and to discourage such from driving. Those suspected of having dementia during the test who subsequently committed a traffic violation were obliged to see a physician and had their license revoked if they were diagnosed with dementia. In 2017, this regulation was revised, and those suspected of having dementia during the test have to see a physician before license renewal.[10] Therefore, older people who reduced or stopped driving or had their license revoked might make more trips as unprotected road users such as bicyclists and pedestrians than before. The detail of the cognitive test and license renewal procedures was described previously, and the introduction of the cognitive test had no intended safety benefits of reducing MVCs by older drivers.[5]

2.2 Study design

This is an interrupted time-series study, which is based on police-reported MVC national data from 2005 to 2016, consisting of pre-introduction of a cognitive test (53 months, from January 2005 to May 2009), during-introduction (36 months, from June 2009 to May 2012), and post-introduction periods (55 months, from June 2012 to December 2016).

2.3 Data

We obtained monthly police-reported MVC national data on the number of deaths, severe injuries, and minor injuries by type of road users (motor vehicle drivers, their passengers, bicyclists, and pedestrians), and by their sex and age between 2005 and 2016. The data were made available by the Institute for Traffic Accident Research and Data Analysis, which compiles the traffic statistics of the National Police Agency. Death was defined as death within 24 hours of the MVC, severe injury was defined as injuries that were estimated to require medical care for 30 days or longer after the MVC by the physician, and minor injury was defined as injuries that were estimated to require care for less than 30 days. The monthly number of population stratified by sex and age was derived from population estimates by the Ministry of Internal Affairs and Communications for the same period.[12]

2.4 Variables

Based on the data, we calculated the rates (per person-year) and the proportions of deaths, severe injuries, and minor injuries (as mutually exclusive categories) of both sexes by age group (70–74, 75–79, 80–84, and ≥85 years) and type of road users for the entire study period, in order to identify by what mode of transportation older adults were most likely to be victimized. The numerator of the rate was the sum of the monthly number of deaths, severe injuries or minor injuries of both sexes by age group and type of road users, and the denominator of the rate was the sum of monthly estimated population of corresponding sex and age group divided by 12 (the number of months per year) to make its unit person-year. The denominator of the proportion was the total number of deaths, severe injuries, and minor injuries, respectively, of both sexes in all ages, which also include those younger than 70 years.

Next, we calculated the monthly rates of injuries (including deaths, severe injuries, and minor injuries, hereinafter referred to as injury rates) per person-year among unprotected road users (bicyclists and pedestrians) who were aged ≥70 years by sex and age group (70–74, 75–79, 80–84, and ≥85 years). The numerator of the injury rate was the monthly number of injuries (including deaths, severe injuries, and minor injuries) of unprotected road users by sex and age group, and the denominator was the monthly population estimates of corresponding sex and age group divided by 12. We used five-year age groups, instead of three-year age groups based on the interval of license renewal (every 3 years), because the age and month of license renewal differs between drivers according to their birthday and age of last renewal (i.e., it is not that all and only drivers aged 75, 78, 81,… years renew their license and take the cognitive test, but that all drivers aged ≥75 years whose license is expiring take the test when they renew their license).

Then, we calculated the ratios of injury rates (referred to as injury rate ratios) of unprotected road users aged 75–79, 80–84, and ≥85 years to those aged 70–74 years, as the outcome variable to be used in an interrupted time-series analysis. Here, it should be reminded that those aged ≥75 years are subjected to the cognitive test at their license renewal whereas their adjacent age group of 70–74 years are not. The injury rate ratio accounts for the effect of extraneous factors, such as the road environment and traffic volume, other than the cognitive test, influencing the experience of MVCs in unprotected road users.[4,5,13,14] The assumption behind the injury rate ratios is that, the injury rate ratios would remain constant even if the extraneous factors changed over the study period given their influence on the injury rate would be irrespective of the age groups. For example, during the study period, a policy of limiting vehicle speed up to 30 km/hour in designated residential areas (called "Zone 30") was introduced in September 2011, but this policy benefited all age groups of unprotected road users, and the magnitude of benefits was similar between age groups 65–74 years and ≥75 years[15]; therefore, the policy would not have affected the injury rate ratios (the injury rate of one age group to that of another) very much. However, the injury rate ratios would change if the cognitive test had any influence on the injury rate because the test was only for those aged ≥75 years. This is how the injury rare ratio works to control for the potential confounders.

2.5 Analysis

To examine whether the injury rate of unprotected road users aged ≥75 years changed after the introduction of the cognitive test for drivers in that age category, we conducted an interrupted time-series analysis by regressing the injury rate ratios stratified by sex and age group on the number of months from January 2005 (predictor: *month*), June 2009 (predictor: *slope_change_at_54*), and June 2012 (predictor: *slope_change_at_90*). The predictors allowed an elbow at the 54th and 90th month for the predicted injury rate ratios when these drivers started (June 2009, 54th month) and completed (June 2012, 90th month) the test. We also conducted the same analysis on older aged motor vehicle passengers (non-driver vehicle occupants) of both sexes because drivers might have become passengers as well. The strength of the interrupted time-series analysis is to control for potential confounders that slowly change over time when modelling the underlying long-term trend.[11] So, the trend change, if any, is the net effect of the intervention or event of interest. Moreover, we ensured the validity of this analysis by using the injury rate ratio as the outcome variable to control for history bias that is caused by concurrent interventions such as Zone 30, as explained above.

In the analysis, when the residuals of the regression models were autocorrelated, we fitted a seasonal autoregressive integrated moving average (ARIMA) model to the residuals.[16] All the statistical analyses were conducted with R version 3.4.4, and we used the seasonal autoregressive integrated moving average (sarima) function of the applied statistical time series analysis (astsa) package to fit the seasonal ARIMA models to the residuals.

3. Results

Table 1 shows the numbers, rates, and proportions of deaths, severe injuries, and minor injuries by age group (70–74, 75–79, 80–84, and ≥85 years) and type of road users for the entire study period. In all age groups, the death rate was the highest among pedestrians. In older age groups

(80–84, and ≥85 years), the severe injury rate was also the highest among pedestrians, but in younger age groups (70–74, and 75–79 years), it was the highest among motor vehicle drivers. The minor injury rate was the highest among motor vehicle drivers except in the oldest age group (≥85 years). Regarding the proportions of deaths, 41% of overall traffic deaths occurred among people aged 70 years or older, and it is of note that older pedestrians and bicyclists shared a total of 28% of overall traffic deaths.

Table 1 Number, rate per 100,000 person-years, and proportion of deaths, severe injuries, and minor injuries by age group and type of road users* over a 12-year period (from 2005 to 2016) in Japan

	Deaths			Severe injuries			Minor injuries		
	n	Rate	%†	N	Rate	%†	n	Rate	%†
70–74 years									
Motor vehicle drivers	1,869	2.17	3.18	17,842	20.71	3.01	155,320	180.26	1.63
Motor vehicle passengers	411	0.48	0.70	4,579	5.31	0.77	62,157	72.14	0.65
Bicyclists	1,086	1.26	1.85	12,941	15.02	2.18	71,924	83.47	0.75
Pedestrians	2,601	3.02	4.42	11,917	13.83	2.01	39,025	45.29	0.41
75–79 years									
Motor vehicle drivers	1,900	2.67	3.23	14,142	19.87	2.39	85,138	119.65	0.89
Motor vehicle passengers	494	0.69	0.84	4,399	6.18	0.74	44,873	63.06	0.47
Bicyclists	1,257	1.77	2.14	11,485	16.14	1.94	52,710	74.08	0.55
Pedestrians	3,196	4.49	5.43	12,933	18.18	2.18	34,862	48.99	0.37
80–84 years									
Motor vehicle drivers	1,407	2.70	2.39	8,011	15.40	1.35	34,665	66.64	0.36
Motor vehicle passengers	466	0.90	0.79	3,112	5.98	0.52	26,648	51.23	0.28
Bicyclists	1,051	2.02	1.79	7,447	14.32	1.26	28,355	54.51	0.30
Pedestrians	3,424	6.58	5.82	10,452	20.09	1.76	24,145	46.42	0.25
85 years+									
Motor vehicle drivers	718	1.51	1.22	3,012	6.32	0.51	9,937	20.85	0.10
Motor vehicle passengers	440	0.92	0.75	2,088	4.38	0.35	16,191	33.97	0.17
Bicyclists	704	1.48	1.20	3,781	7.93	0.64	12,410	26.04	0.13
Pedestrians	2,968	6.23	5.05	7,212	15.13	1.22	14,637	30.71	0.15
All ages (including <70 years)	58,814	3.84	100	592,914	38.76	100	9,550,391	624.30	100

*Motor vehicle includes cars, motorcycles, and mopeds. †The denominator is the total number of deaths, severe injuries, and minor injuries, respectively (as mutually exclusive categories), of both sexes in all ages, which also include those younger than 70 years.

Figure 1 shows the injury rates (including deaths, severe injuries, and minor injuries) of unprotected road users (i.e., bicyclists and pedestrians) per 100,000 person-years by sex and for the four oldest age groups over the study period. The injury rates showed a longitudinal decrease without any apparent effects of the introduction of the cognitive test. Age had a differential effect on the injury rates by sex. Among males, the injury rates were similar across the four age groups; among females, increasing age was associated with substantially decreased injury rates and those aged 70–74 years seemed to have had a larger longitudinal decrease in injury rate than the other age groups.

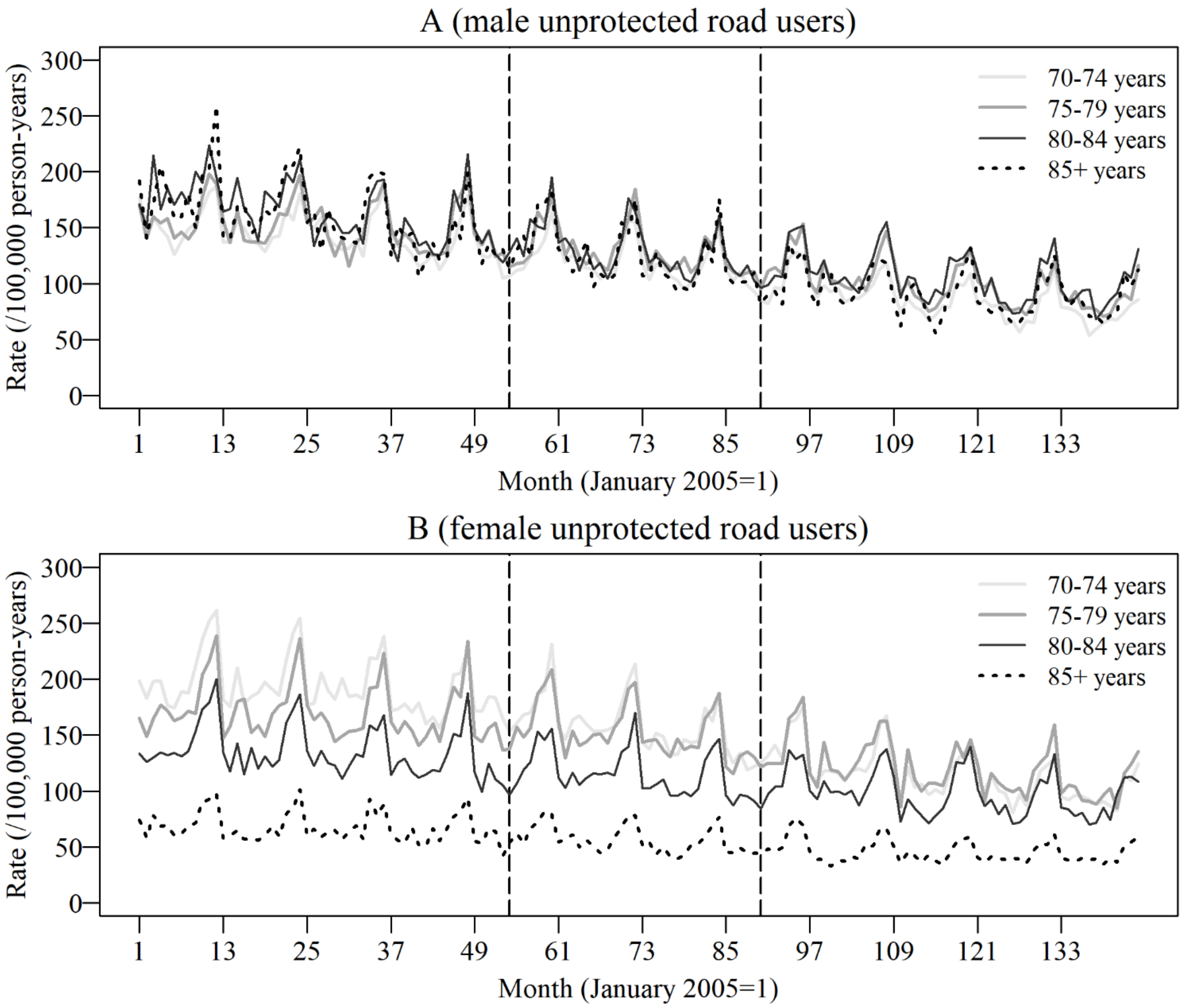

Figure 1 Injury rates* of older unprotected road users in Japan in 2005–2016

The vertical dashed lines are the 54th (June 2009) and 90th months (June 2012) when the new policy that mandated all drivers aged ≥75 years to take the cognitive test at license renewal was introduced, and when all drivers who were aged ≥75 years in June 2009 renewed or surrendered their license, respectively.

* The numerator of the injury rate was the monthly number of injuries (including deaths, severe injuries, and minor injuries) of unprotected road users (bicyclists and pedestrians) by sex and age group, and the denominator was the corresponding population size divided by 12.

Figure 2 shows the injury rate ratios of unprotected road users by sex in the three oldest age groups. Among males, there are no apparent effects of the introduction of the cognitive test; however, the injury rate ratios in females aged 75–79 and 80–84 years seemed to have increased slightly after the introduction.

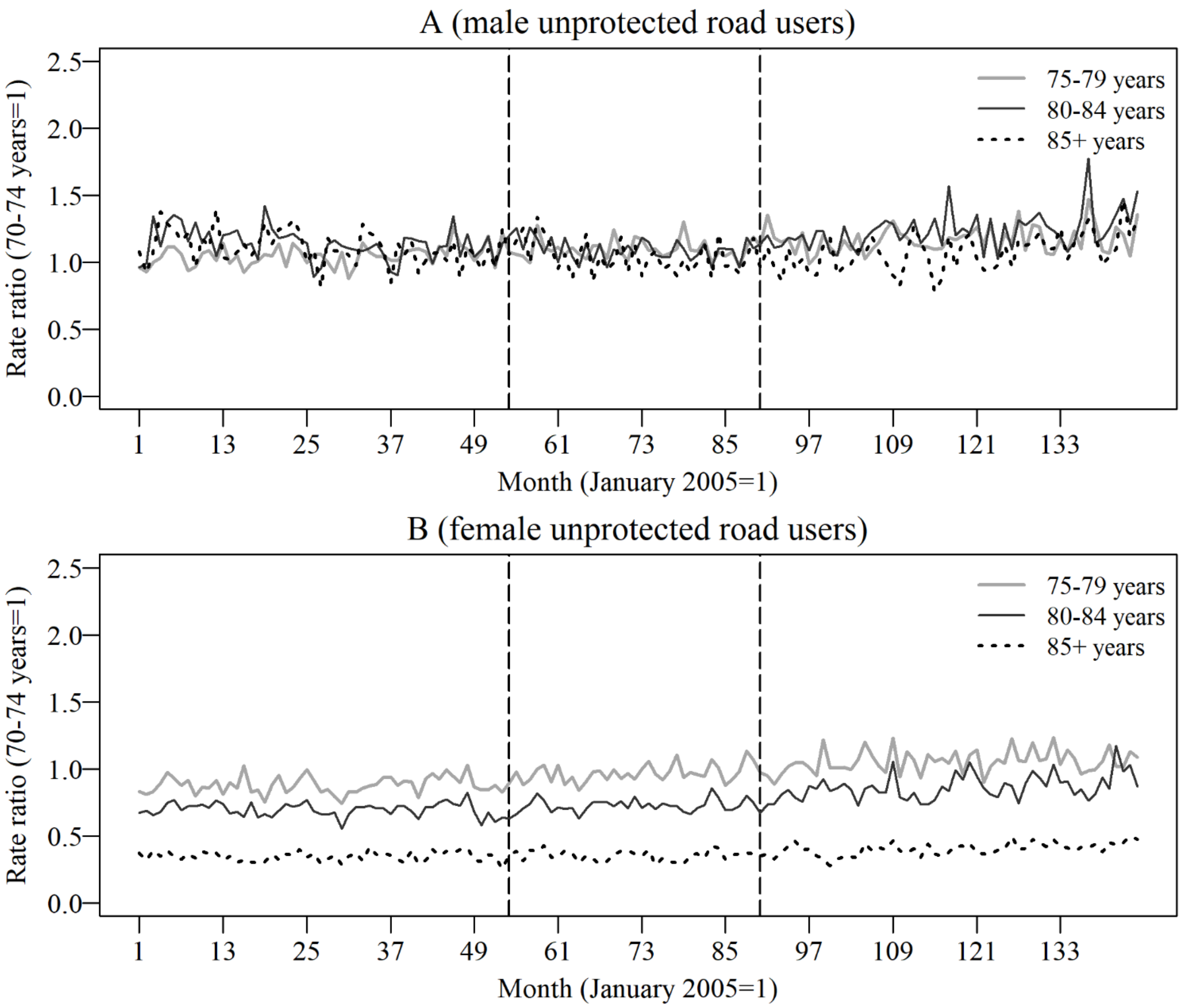

Figure 2 Injury rate ratios* of older unprotected road users in Japan in 2005–2016

The vertical dashed lines are the 54th (June 2009) and the 90th months (June 2012) when the new policy that mandated all drivers aged ≥75 years to take the cognitive test at license renewal was introduced and when all drivers who were ≥75 years in June 2009 renewed or surrendered their license, respectively.

* The numerator of the injury rate is the monthly number of injuries (including deaths, severe injuries, and minor injuries) of unprotected users (bicyclist or pedestrian) by sex and age group, while the denominator is the corresponding population size. The numerator of the injury rate ratio was the monthly injury rate by sex and age group (75–79, 80–84, and ≥85 years), and the denominator was that of those aged 70–74 years in the corresponding month.

Table 2 shows the results of the interrupted time-series analysis of the injury rate ratios in male and female unprotected road users in the three oldest age groups. During the three years since the introduction of the cognitive test (*slope_change_at_54*), the injury rate ratio in females aged 75–79 and 80–84 years showed an additional increase of 2.1×10^{-3} and 2.6×10^{-3} per month, respectively, to the trend represented by the regression coefficient for the variable *month.* These are equivalent to increases of 0.075 and 0.093 in the injury rate ratios between June 2009 and May 2012 (36 months). Women aged ≥85 years experienced a significant increase of 1.4×10^{-3} after the 90th month (represented by the *slope_change_at_*90 terms). On the other hand, none of the three age groups in males showed a significant change immediately after the introduction. However, those aged 80–84 and ≥85 years had a significant increase of 4.1×10^{-3} and 6.0×10^{-3}, respectively, after three years of the introduction (represented by the *slope_change_at_*90 terms). These changes are equivalent to an increase of 0.22 and 0.33, respectively, in the injury rate ratios between June 2012 and December 2016 (55 months).

The analysis of the injury rate ratios of older motor vehicle passengers revealed a statistically significant monthly decrease of -1.9×10^{-3} (95% confidence interval: -3.8×10^{-3}, -4.4×10^{-5}) among people aged 75–79 years after the introduction of the cognitive test (data not shown in the table).

Table 2 Results of the interrupted time-series analysis* of potential changes in the injury rate ratios† of older unprotected road users following the introduction of the cognitive test for drivers aged ≥75 years to the driver's license renewal procedure in Japan

		Age group		
		75–79 years	80–84 years	≥85 years
Sex	Variables	Point estimate [95%CI]	Point estimate [95%CI]	Point estimate [95%CI]
Male	(intercept)	1.01 [0.96, 1.05]	1.19 [1.13, 1.25]	1.17 [1.12, 1.21]
	month	1.6×10^{-3} [3.6×10^{-4}, 2.8×10^{-3}]	-1.8×10^{-3} [-3.4×10^{-3}, -1.8×10^{-4}]	-1.8×10^{-3} [-3.1×10^{-3}, -4.8×10^{-4}]
	slope change at 54‡	-7.5×10^{-4} [-3.2×10^{-3}, 1.7×10^{-3}]	2.1×10^{-3} [-1.1×10^{-3}, 5.2×10^{-3}]	-8.0×10^{-4} [-3.3×10^{-3}, 1.7×10^{-3}]
	slope change at 90‡	7.7×10^{-4} [-1.6×10^{-3}, 3.1×10^{-3}]	4.1×10^{-3} [1.0×10^{-3}, 7.1×10^{-3}]	6.0×10^{-3} [3.5×10^{-3}, 8.4×10^{-3}]
Female	(intercept)	0.86 [0.82, 0.89]	0.71 [0.68, 0.73]	0.35 [0.33, 0.37]
	month	9.3×10^{-4} [-1.1×10^{-4}, 2.0×10^{-3}]	-3.1×10^{-4} [-1.0×10^{-3}, 3.9×10^{-4}]	2.5×10^{-5} [-5.0×10^{-4}, 5.5×10^{-4}]
	slope change at 54‡	2.1×10^{-3} [5.2×10^{-5}, 4.1×10^{-3}]	2.6×10^{-3} [1.3×10^{-3}, 3.9×10^{-3}]	2.0×10^{-4} [-7.9×10^{-4}, 1.2×10^{-3}]
	slope change at 90‡	-1.6×10^{-3} [-3.5×10^{-3}, 3.9×10^{-4}]	6.9×10^{-4} [-6.0×10^{-4}, 2.0×10^{-3}]	1.4×10^{-3} [4.1×10^{-4}, 2.3×10^{-3}]

CI: confidence interval

* The data spanned the first month (January 2005) to the 144th month (December 2016). The residuals were modelled using seasonal autoregressive integrated moving average structures.

† The numerator of the injury rate is the monthly number of injuries (including deaths, severe injuries, and minor injuries) of unprotected users (bicyclist or pedestrian) by sex and age group, while the denominator is the corresponding population size divided by 12. The numerator of the injury rate ratio is the monthly injury rate by sex and age group (75–79, 80–84, and ≥85 years), and the denominator is that of those aged 70–74 years in the corresponding month.

‡ The values of the spline terms were set at zero until the 53rd and 89th months and thereafter, month minus 53 and 89, respectively. The new policy that mandated all drivers aged ≥75 years to take the cognitive test at license renewal was introduced in the 54th month (June 2009), and all drivers who were aged ≥75 years in June 2009 renewed or surrendered their license by the 90th month (June 2012).

4. Discussion

We found a significant increase in traffic deaths and injuries among unprotected road users aged ≥75 years in Japan after the cognitive test was introduced to drivers aged ≥75 years. The increase at the time of test introduction was observed among females aged 75–84 years; the increase occurred at a later time among males aged ≥80 years and females aged ≥85 years. Since our analyses controlled for extraneous factors influencing the experience of MVCs in unprotected road users, increased deaths and injuries among older unprotected road users were most likely attributable to their increased exposures to road traffic as unprotected road users. This probably resulted from the modal shift from driving to non-driving status, once the test was introduced. Our study, which used a more rigorous method of evaluation, confirmed the previous Danish report, which revealed increased fatal injuries among older unprotected road users after the introduction of an age-based cognitive test.[9]

Sex differences in the trend of increased deaths and injuries among older unprotected road users could be due to sex differences in their perception of driving. In a recent survey among drivers aged ≥60 years, women were more likely to have a fear of driving than men, because of their subjective poor driving skills, and it was found that women anticipated retiring from driving at an earlier age than men did.[17] Therefore, female drivers might be more responsive to the demanding license renewal procedure than male drivers, by giving up on driving, earlier.

Deaths and injuries of motor vehicle passengers aged 75–79 years decreased after the introduction of the cognitive test. In contrast, our previous study found that the cognitive test did not change MVC rates among drivers aged ≥75 years.[5] Because older drivers tend to ride with older passengers,[18] we expected similar changes in both drivers and passengers. This contrast implies differential trends in exposure to road traffic. Older drivers who were suspected of having impaired cognitive function during the cognitive test may continue to drive a car, while their spouses and friends rode less frequently with them after learning about the test results.

Probably, older drivers' family members, who are also likely to have learnt about the test results, may reduce having to ride when the older driver is driving; or they may even discourage the older drivers' friends from riding when the older driver is driving, for fear of vehicle collisions and injuries. Convincing an older driver with dementia to stop driving can be a challenge for the family members[19] and the family members experience various kinds of stress including safety concerns posed by their neighbours in the community.[20] This experience could motivate the family members to pay extra attention to the safety of non-family members.

Our study raised two issues regarding Japan's traffic safety policies that are aimed at reducing traffic injuries among older adults. First, while attempting to encourage older drivers with possible cognitive function impairments to desist from driving, there is need to pay more attention to the safety of older unprotected road users. Our findings suggest that the introduction of the cognitive test might have promoted older drivers' modal shift to walking and cycling, resulting in increased deaths and injuries among older unprotected road users. Second, a large proportion of traffic deaths involved older unprotected road users in Japan. During the study period, 28% of overall traffic deaths were observed among unprotected road users age 70 years or older.

The strength of the present study was that the analyses were based on national longitudinal data and rigorous evaluation methods. However, the major limitation was the weak inference on causal mechanisms and the lack of exposure information. With our data, we could only speculate that modal shifts from driving to non-driving occurred among older adults after the introduction of the cognitive test. We are unsure whether the distance and patterns of trip as unprotected road users among older adults might have changed after the introduction. However, we still observed increased deaths and injuries among older unprotected road users after the introduction. Traffic safety policies need to deal with such undesirable consequences.

Another limitation was that the effect of extraneous factors influencing injury risk of unprotected road users might have not been fully controlled for with the injury rate ratios. As explained earlier, the traffic calming Zone 30 policy was introduced during the study period. If this was more beneficial for older unprotected road users, the injury rate ratios of unprotected road users aged 75–79, 80–84, and ≥85 years to those aged 70–74 years might have decreased with age after the introduction of the policy. In this case, we underestimated the increase in traffic injuries among older unprotected road users. However, the policy had a similar magnitude of safety benefits for pedestrians and cyclists aged 65–74 years and ≥75 years,[15] which suggests the potential bias due to this limitation is likely small.

In conclusion, traffic deaths and injuries among older unprotected road users increased after the cognitive test at driver's license renewal was introduced for older drivers. This means that the cognitive test increased traffic deaths and injuries among older people because it lacked intended safety benefits for older drivers.[5] Licensing policies for older drivers should be rigorously evaluated, taking into account the safety of older unprotected road users, and such policies should be balanced against the findings of such evaluations.

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