Area-Wide Traffic-Calming Zone 30 Policy of Japan and Incidence of Road Traffic Injuries Among Cyclists and Pedestrians

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Objectives. To quantify the impact of the "Zone 30" policy introduced in September 2011 on the incidence of cyclist and pedestrian injuries in Japan.

Methods. This was an interrupted time-series study. We used the data of cyclist and pedestrian injuries recorded by the Japanese police between 2005 and 2016. We evaluated the monthly number of deaths and serious injuries per person-time on narrow roads (width < 5.5 m, subjected to the policy) compared with that on wide roads (≥ 5.5 m) to control for secular trends. We regressed the injury rate ratio on 2 predictors: the numbers of months after January 2005 and after September 2011. Using the regression results, we estimated the number of deaths and serious injuries prevented.

Results. There were 266 939 deaths and serious injuries. By 2016, the cumulative changes in the rate ratio spanned from –0.26 to –0.046, depending on sex and age, and an estimated number of 1704 (95% confidence interval = 1293, 2198) injuries were prevented.

Conclusions. The policy had a large preventive impact on cyclist and pedestrian deaths and serious injuries at the national level. (*Am J Public Health.* 2020;110: 237–243. doi:10.2105/AJPH.2019.305404)

Globally, road injuries are a leading cause of mortality and morbidity, killing approximately 1.3 million people and injuring tens of millions annually.[1,2] Cyclists and pedestrians represent a quarter of all road fatalities, and the proportion varies substantially among countries.[1] The benefits of safeguarding cyclists and pedestrians are not limited to reduced road injuries; active travel is conducive to health,[3–6] and previous studies reported that neighborhood walkability was associated with increased physical activity,[7] lower body mass index,[8,9] better profiles for metabolic risk factors,[10] and lower diabetes incidence.[9] Moreover, promoting active travel reduces fossil fuel consumption and ultimately protects public health by improving ambient air quality and moderating climate change.[11]

Evidence shows that area-wide traffic-calming interventions reduce road injuries involving cyclists and pedestrians. These interventions include a maximum speed limit of 30 kilometers per hour or lower, installing traffic-calming devices such as road bumps and chicanes, temporary or permanent road closings, enhancing visibility of road signs, and increasing law enforcement in the area.[12] A systematic review found a modest reduction of road injuries in the area with a pooled rate ratio of 0.85[12]; more recent studies that investigated the effectiveness of 20-miles-per-hour zones in London, England, found 41.9% and 24% reductions of those killed and seriously injured, respectively, within these zones.[13,14] Twenty-miles-per-hour zones were also effective in preventing road injuries in New York, NY.[15] However, the effectiveness of such interventions could be undermined if conducted inappropriately; for example, in Seoul, South Korea, the ineffectiveness of its Silver Zone policy was likely because of a mismatch between the high-casualty and intervention areas.[16]

In Japan in 2010, cyclists and pedestrians represented 51% of all fatal cases, and the proportion was higher than that in other densely populated high-income countries such as the United Kingdom (28%), Germany (23%), and France (16%).[17] In addition, previous area-wide traffic-calming policies in Japan had limited effects in preventing road injuries involving cyclists and pedestrians presumably because they sometimes lacked effective measures such as the low maximum speed limit or failed to spread widely as a result of demanding requirements and a low level of support by local residents.[18–21]

Against this backdrop, Japan started a new area-wide traffic-calming policy, "Zone 30," in residential areas throughout the country in September 2011.[18,20] Leveraging lessons learned from previous road safety policies since the 1970s,[22] the Zone 30 policy enhanced community engagement through its multisectoral approach that involves local residents, local governments, police, and the Ministry of Land, Infrastructure, Transport and Tourism.[19,20] It also relaxed regulations on requirements for the zone by abolishing

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This article was accepted September 18, 2019.
doi: 10.2105/AJPH.2019.305404

minimum area requirements and requiring only a 30-kilometers-per-hour speed limit in the zone, which can be implemented with a relatively small budget (see Methods for details). These amendments facilitated the zone's nationwide spread, and 3105 zones were designated between September 2011 and March 2017.[18] There is good evidence that area-wide traffic-calming is effective in preventing road injuries for cyclists and pedestrians[12–15]; however, no study has reported the impact of enhancing community engagement and limiting the requirements for the designation of areas to a maximum speed limit in an area-wide traffic-calming policy for cyclist and pedestrian safety at the national level, and the Zone 30 policy provides a unique opportunity to do so.

Therefore, the objective of the present study was to quantify cyclist and pedestrian injuries prevented by the policy. Specifically, we attempted to answer the following 2 research questions: To what degree did the cyclist and pedestrian injury rate per person-time on local roads decrease compared with that on arterial roads after the introduction of the policy at the national level? And how many cyclist and pedestrian injuries were totally prevented by the policy between September 2011 and December 2016?

METHODS

This was an interrupted time-series study. Using monthly longitudinal data on the incidence of road injuries in Japan between 2005 and 2016, we examined whether the introduction of the Zone 30 policy in September 2011 (or the 81st month of the study period) prevented road injuries on local narrow roads compared with arterial wide roads.

Study Setting

Japan introduced its first area-wide traffic-calming intervention of School Zone in 1972, followed by Neighborhood Zone in 1974, Silver Zone in 1988, Community Zone in 1996, and Safe Walking Area in 2003.[19] However, the effectiveness of these measures in reducing road injuries between 2000 and 2010 was limited; only an 8.0% reduction in road injuries on narrow roads (road width < 5.5 m) was observed, which was significantly lower than the 29.2% reduction on wide roads (≥ 5.5 m). This was presumably because these interventions sometimes lacked essential components of effective area-wide traffic-calming interventions, such as lower maximum vehicle speed limits and clearly visible road signs to inform drivers about the zone.[18,19] In addition, some interventions were not applicable to small areas or were not supported by local residents, or the budget was not sufficient for the implementation.[18,20,21] For example, Community Zone required a minimum area of 0.25 square kilometers to be designated, and this limited the number of zones designated in the whole country to up to 40 per year.[18]

The Zone 30 policy enhanced community engagement through its multisectoral approach that involves local residents, local governments, police, and the Ministry of Land, Infrastructure, Transport and Tourism.[19] Stronger community engagement led to local residents' increased support for designating zones in their neighborhood and the zone's nationwide spread. To further facilitate dissemination, the policy required only a maximum vehicle speed limit of 30 kilometers per hour in the zone without a minimum area requirement. In addition to the speed limit, some of the following optional measures were included: establishment of clearly visible road signs upon entrance to the zone to inform drivers, notification alerts in car navigation services upon entering the zone, installation of traffic-calming devices and improved pedestrian paths, erasing the centerline of the road, and measures that facilitate efficient traffic flow around the zone to discourage motor vehicle drivers from entering the zone.[18,20] Table 1 shows the proportion of zones with each optional measure. The zones were designated on the basis of local residents' requests, traffic volume, crash frequency, and the presence of elementary and junior high schools and public and tourist facilities.[23] As of March 2017, 3105 zones were established, thus exceeding the original target of 3000 zones.[18]

Data Sources and Variables

We obtained national police data on the monthly number of road injuries in Japan between January 2005 and December 2016 from the Institute for Traffic Accident Research and Data Analysis and monthly estimated population data for the same period from the National Statistics Bureau.[24] The police data were collected according to a standardized definition of measurements.[25] Categorization of the obtained data was based on the definitions used in the police data: time (year and month); width of road where the crash occurred (< 5.5 m and ≥ 5.5 m); sex, age (0–14, 15–24, 25–64, 65–74, and ≥ 75 years), and mode of transport (cyclists and pedestrians) of the victims; and severity of injury (death, serious injury, and minor injury). Death from the crash was defined as a death that occurred within 24 hours from the crash, and an injury was defined as "serious" if it was estimated to require medical care for 30 days or longer by the physician, or else it was defined as "minor."[25]

Outcome Variable for Evaluation

We evaluated occurrence of fatal and serious injuries, unless otherwise noted, because a previous study showed that the incidence of fatal and incapacitating injuries decreased more than that of nonincapacitating and minor injuries among pedestrians when the speed limit was reduced from 40 to 50 kilometers per hour to 30 kilometers per hour.[26] We calculated the monthly incidence rate of deaths and serious injuries (hereafter referred to as "injury rate"): the numerator was the number of fatal and serious injuries, and the denominator was the corresponding population size divided by 12 multiplied by 100 000 (injuries per 100 000 person-years). Then, we calculated injury rate ratios by dividing the rate on the narrow roads by the corresponding rate on the wide roads. We assumed that the Zone 30 policy affected the injury rate on the narrow roads exclusively if it had an effect because only these narrow roads with a single lane, including those with 2 lanes at the time of the zone designation but that were planned to be downsized to 1 lane, were covered under the policy as "local neighborhood roads."[19,20] The use of ratios enabled us to examine the effect of the policy while controlling for secular trends that were not affected by the policy,[27–30] including those of the incidence of cyclist and pedestrian injuries on wide roads and of standards of prehospital and medical care for road injuries. Using the rates on wide roads as the

TABLE 1—Number and Proportion of Zones With Each Optional Measure for the Zone 30 Policy Among 3105 Zones: Japan, March 2017

Measures	No. (%)
Installing road signs or markings at the entrance	2679 (86.3)
Road sign "Zone 30" on pole	583 (18.8)
Road marking "Zone 30"	2606 (83.9)
Road markings other than "Zone 30"	214 (6.9)
Coloring the entrance	401 (12.9)
Erasing the centerline and widening sidewalk	650 (20.9)
Traffic control	320 (10.3)
Prohibiting the entrance of large vehicles	77 (2.5)
Installing a stop sign	174 (5.6)
Installing a crosswalk	157 (5.1)
Installing traffic-calming devices	129 (4.2)
Road hump	37 (1.2)
Narrowing	69 (2.2)
Chicane	32 (1.0)

Note. A maximum speed limit of 30 kilometers per hour is mandatory. More than 1 optional measure can be implemented in 1 zone.
Source. National Police Agency, Japan.[18]

denominator of the ratio would be justified because adverse spillover effects were not observed around the 20-miles-per-hour zones in London and New York.[13,15]

Descriptive Statistics

We pooled the 12-year data and described the number of injuries stratified by width of road, sex, and age. We displayed the trends of the monthly injury rates stratified by width of road, sex, and age and the injury rate ratios stratified by sex and age.

Interrupted Time-Series Analysis

We evaluated the effectiveness of the policy by regressing the longitudinal injury rate ratio stratified by sex and age on the number of months after January 2005 (predictor: *month*) and after September 2011 (predictor: *slope_change_after_81st_month*):

$$(1)\quad (rate\ ratio)_t = b_0 + b_1 \times month + b_2 \times (slope\_change\_after\_81st\_month) + \varepsilon_t$$

where b_1 represents the average monthly change in the predicted rate ratios before September 2011, and the predictor *slope_change_after_81st_month* allowed the predicted rate ratios to have a knot at the 81st month. We hypothesized that b_2 was a negative number (i.e., the slope of the rate ratios went downward at September 2011) if the policy was effective. To facilitate interpretation of the results, we converted the monthly rate ratio change to a cumulative change by December 2016 (54th month from September 2011) by multiplying the point estimate and the confidence interval (CI) of b_2 by 54. Because the number of zones increased gradually after the introduction of the policy, we considered no discontinuous gap in the rate ratio in September 2011 and therefore did not include a dichotomous predictor that indicated before or after policy introduction in the model. When the residuals (ε_t) had an autocorrelated structure, we fitted a seasonal autoregessive integrated moving average model.[31]

Estimation of the Impact

We estimated the number of injuries for cyclists and pedestrians on narrow roads prevented by the policy between September 2011 and December 2016 for each subgroup (stratified by sex and age) with

$$(2)\quad \sum_{m=81}^{144} \{n_{i,m}/[1 + b_{2i} \times (m - 80)] - n_{i,m}\},$$

where m is the number of month after January 2005 ($m = 1$), which is identical with the predictor *month* in the interrupted time series analyses; i (= 1, 2,. . ., 10) is the subgroup; b_{2i} (with mean μ_i and standard error σ_i) is the estimated monthly change in the rate ratio after September 2011 for subgroup i; and $n_{i,m}$ is the observed number of injuries for subgroup i in the mth month.

To acquire the total number of injuries prevented between September 2011 and December 2016, we summed the estimated numbers across the subgroups; to acquire the CI, we conducted a Monte Carlo simulation of 1000 draws from

$$(3)\quad b_{2i} \sim N(\mu_i, \sigma_i)$$

for each subgroup, plugged them into

$$(4)\quad \sum_{m=81}^{144} \{n_{i,m}/[1 + b_{2i} \times (m - 80)] - n_{i,m}\}$$

to obtain 1000 sets of the estimated number of injuries prevented across the subgroups, summed them across the subgroups using each set to obtain 1000 estimated number of injuries prevented, and reported the 2.5th and 97.5th percentiles. In this simulation, we assumed independence of the extent of deviation of drawn b_{2i} across the subgroups (i.e., how many σ_i randomly sampled b_{2i} deviates from μ_i in each draw for each subgroup).

Sensitivity Analyses

We repeated the interrupted time-series analysis with data of all injury severity and those with serious injuries. We also repeated the analysis using data restricted to deaths, pedestrians, and cyclists and stratified by sex but not by age, because the number of injuries was too low for some subgroups. We also estimated the total number of injuries prevented, irrespective of severity. We conducted all statistical analyses with R version 3.4.4 (R Foundation, Vienna, Austria), and we used the sarima function of the astsa package to fit the seasonal autoregressive integrated moving average models.[31,32]

RESULTS

During the study period of 2005 to 2016, there were 28 333 deaths and 238 606 serious injuries (totaling 266 939) involving cyclists and pedestrians in Japan. Table 2 shows the number and rate of injuries stratified by width of road where the crash occurred, sex, age, and mode of transport. Among all injuries, the proportion of cases on narrow roads was 28%. The proportion of injuries on narrow roads was higher for the youngest age group compared with all other age groups (Table 2).

The monthly injury rates by width of road, sex, and age showed a decreasing trend for all subgroups, except for men aged 25 to 64 years on narrow roads, and the decreasing trend in some subgroups on narrow roads appeared to have accelerated after the introduction of the Zone 30 policy (Figure A, available as a supplement to the online version of this article at http://www.ajph.org).

The monthly ratio of injury rates on narrow roads to wide roads showed an increasing trend before the policy was introduced followed by a decreasing trend after the introduction among boys aged 0 to 14 years (Figure B, available as a supplement to the online version of this article at http://www.ajph.org). Other subgroups did not show a clearly visible trend.

Interrupted Time-Series Analysis

This was the main analysis of our study. Table 3 shows the results of the interrupted time-series analyses of the injury rate ratios among cyclists and pedestrians of the 10 subgroups. The Zone 30 policy decreased the rate ratios in all 10 subgroups, reflected by negative point estimates for the coefficient of *slope_change_after_81st_month*, and their 95% CIs did not include the null value (i.e., 0 in 6 subgroups). The largest absolute effect of –4.1 multiplied by 10^{-3} per month was observed in boys aged 0 to 14 years, followed by –2.9 multiplied by 10^{-3} per month in men aged 15 to 24 years; these effects are equivalent to cumulative relative changes of –0.26 (95% CI = –0.38, –0.15) and –0.19 (95% CI = –0.28, –0.090), respectively, in the rate ratio between September 2011 and December 2016 (data not shown). Cumulative relative changes of the other subgroups ranged from –0.11 to –0.046.

Estimation of the Impact

Table 4 shows the estimated number of injuries prevented by the policy between September 2011 and December 2016. In total, 1704 injuries were prevented, more than two fifths of whom were boys aged 0 to 14 years or women aged 75 years or older.

TABLE 2—Number and Rate per 100 000 Person-Years, and Proportion of Deaths and Serious Injuries Among Cyclists and Pedestrians: Japan, 2005–2016

	Narrow Road (< 5.5 m)		Wide Road (≥ 5.5 m)		
Age, Years	No. (%)[a]	Rate[b]	No. (%)[a]	Rate[b]	% on Narrow Road[c]
Total	75 039 (100)	4.9	191 900 (100)	12.5	28
Females					
Cyclists					
0–14	1 678 (2.2)	1.7	2 275 (1.2)	2.3	42
15–24	2 768 (3.7)	3.7	5 586 (2.9)	7.4	33
25–64	8 203 (10.9)	2.0	16 813 (8.8)	4.1	33
65–74	6 188 (8.2)	6.3	10 889 (5.7)	11.0	36
≥ 75	4 780 (6.4)	4.5	7 830 (4.1)	7.4	38
Pedestrians					
0–14	1 839 (2.5)	1.9	3 425 (1.8)	3.5	35
15–24	372 (0.5)	0.5	1 919 (1.0)	2.5	16
25–64	3 383 (4.5)	0.8	13 651 (7.1)	3.4	20
65–74	3 359 (4.5)	3.4	12 278 (6.4)	12.5	21
≥ 75	6 153 (8.2)	5.8	22 014 (11.5)	20.8	22
Subtotal	38 723 (51.6)	4.9	96 680 (50.4)	12.3	29
Males					
Cyclists					
0–14	4 804 (6.4)	4.6	5 934 (3.1)	5.7	45
15–24	3 789 (5.0)	4.8	7 535 (3.9)	9.5	33
25–64	7 232 (9.6)	1.8	17 240 (9.0)	4.2	30
65–74	2 995 (4.0)	3.4	6 781 (3.5)	7.7	31
≥ 75	3 986 (5.3)	6.1	9 129 (4.8)	14.0	30
Pedestrians					
0–14	4 222 (5.6)	4.1	6 958 (3.6)	6.7	38
15–24	511 (0.7)	0.6	2 228 (1.2)	2.8	19
25–64	4 377 (5.8)	1.1	20 757 (10.8)	5.1	17
65–74	2 108 (2.8)	2.4	8 932 (4.7)	10.1	19
≥ 75	2 292 (3.1)	3.5	9 726 (5.1)	15.0	19
Subtotal	36 316 (48.4)	4.9	95 220 (49.6)	12.8	28

[a]The numerator of the proportion is the number of killed or seriously injured cases in each subgroup, and the denominator is the total number of killed or seriously injured cases stratified only by width of road.
[b]The numerator of the rate is the number of killed or seriously injured cyclists and pedestrians stratified by width of road, sex, and age during the study period of 12 y, and the denominator is the corresponding population size, which is the sum of monthly estimated populations stratified by sex and age divided by 12 × 100 000.
[c]The numerator of the proportion is the number of killed or seriously injured cases on narrow roads in each subgroup, and the denominator is the total number of killed or seriously injured cases in the subgroup.

Sensitivity Analyses

The results of the interrupted time-series analyses of the data of all injury severity and of those that were restricted to serious injuries, pedestrians, or cyclists were similar to those of the main analysis, except that those restricted to serious injuries produced 2 more subgroups (women aged 65–74 years and men aged 25–64 years) whose 95% CIs for the coefficient of *slope_change_after_81st_month* did not include 0 (Table A, available as a supplement to the online version of this article at http://www.ajph.org). However, the analyses that were restricted to deaths produced nonsignificant small monthly changes in the rate ratio after the policy was introduced (b_2 was -5.4×10^{-4} [95% CI = -1.3×10^{-3}, 1.8×10^{-4}] for females and 4.2×10^{-4} [95% CI = -4.5×10^{-4}, 1.3×10^{-3}] for males).

TABLE 3—Results of Interrupted Time-Series Analyses of Potential Changes in Injury Rate Ratios Among Cyclists and Pedestrians With the Introduction of Zone 30: Japan, 2005–2016

	Variables, Point Estimate (95% CI)		
	Intercept	Month, b_1	Slope Change After 81st Month, b_2
Females			
Age, y			
0–14	0.63 (0.56, 0.70)	2.7×10^{-4} (-1.0×10^{-3}, 1.6×10^{-3})	-1.7×10^{-3} (-4.3×10^{-3}, 8.9×10^{-4})
15–24	0.38 (0.34, 0.43)	7.7×10^{-4} (-1.6×10^{-4}, 1.7×10^{-3})	-8.1×10^{-4} (-2.7×10^{-3}, 1.1×10^{-3})
25–64	0.36 (0.33, 0.39)	6.4×10^{-4} (1.7×10^{-5}, 1.3×10^{-3})	-1.6×10^{-3} (-2.8×10^{-3}, -3.5×10^{-4})
65–74	0.40 (0.36, 0.44)	5.5×10^{-4} (-1.7×10^{-4}, 1.3×10^{-3})	-1.3×10^{-3} (-2.7×10^{-3}, 1.6×10^{-4})
≥75	0.33 (0.31, 0.35)	9.7×10^{-4} (5.4×10^{-4}, 1.4×10^{-3})	-1.6×10^{-3} (-2.4×10^{-3}, -8.0×10^{-4})
Males			
Age, y			
0–14	0.63 (0.59, 0.68)	1.9×10^{-3} (9.8×10^{-4}, 2.8×10^{-3})	-4.1×10^{-3} (-5.9×10^{-3}, -2.3×10^{-3})
15–24	0.40 (0.36, 0.44)	1.2×10^{-3} (4.5×10^{-4}, 1.9×10^{-3})	-2.9×10^{-3} (-4.4×10^{-3}, -1.4×10^{-3})
25–64	0.27 (0.24, 0.30)	6.7×10^{-4} ($1.1 \times 10^{-4,}$ 1.2×10^{-3})	-7.3×10^{-4} (-1.8×10^{-3}, 3.4×10^{-4})
65–74	0.30 (0.27, 0.33)	7.1×10^{-4} (1.3×10^{-4}, 1.3×10^{-3})	-1.5×10^{-3} (-2.6×10^{-3}, -2.9×10^{-4})
≥75	0.29 (0.27, 0.32)	9.5×10^{-4} (4.4×10^{-4}, 1.5×10^{-3})	-1.4×10^{-3} (-2.4×10^{-3}, -3.8×10^{-4})

Note. CI = confidence interval. The data span from the first month (January 2005) to the 144th month (December 2016). Residuals were modeled by using seasonal autoregressive integrated moving average structures. The numerator of the rate is the number of killed or seriously injured cases stratified by width of road, sex, and age, and the denominator is the corresponding population size divided by 12 × 100 000. The numerator of the rate ratio is the killed or seriously injured rate from crashes that occurred on narrow roads in each month, sex, and age group, and the denominator is the corresponding rate from crashes on wide roads. The value of the spline term was set at zero until the 80th month and thereafter month minus 80. The term allows the predicted rate ratios to have a knot at the 81st month. The Zone 30 policy was introduced in the 81st month (September 2011).

The total number of injuries of all severity prevented by the policy between September 2011 and December 2016 was estimated to be 21 639 (95% CI = 17 305, 26 870).

DISCUSSION

After the introduction of the Zone 30 policy in September 2011, the pedestrian and cyclist injury rates decreased on narrow roads compared with wide roads at the national level. The decrease was especially large for boys aged 0 to 14 years, and their cumulative relative change by December 2016 was as large as –26%. Between September 2011 and December 2016, the policy prevented 1704 deaths and serious injuries.

Comparison With Previous Studies

There are a few previous studies that reported the effectiveness of the Zone 30 policy. A pre–post comparison of the number of crashes in the zones revealed an 18.6% reduction in the number of crashes that involved a cyclist or pedestrian between the previous and following years of the intervention[23]; a difference-in-difference analysis conducted in Saitama, one of the 47 prefectures in Japan, revealed a reduction in the number of crashes in the zones when they were accompanied by improved intersections.[33] The present study's estimated effectiveness of the policy (estimates of b_2 in Table 3: ranging from -7.3×10^{-4} to -4.1×10^{-3}) was smaller than the 18.6% reduction reported in the previous study, which would be approximately equivalent to a change of –0.186 divided by 24 equals –7.8 multiplied by 10^{-3} per month.[23] This is because the previous study examined the reduction of road injuries only in the designated zones, and it did not control for decreasing secular trends, whereas we estimated the average effectiveness on all narrow roads, which include both designated zones and nondesignated areas and also because we controlled for secular trends by using ratios.[27–30] If we adjust for the proportion (e.g., in terms of road length or road injuries) of narrow roads in the designated zones among all narrow roads, the estimated effectiveness would become larger; however, no such data are available. This limitation, however, does not undermine the validity of our findings because our study objective was to quantify the impact of the policy at the national level, which does not require estimating the change only in the designated zones.

Meaning of the Study

Our study provides strong evidence that a multisectoral, area-wide traffic-calming policy with local residents' participation and support and relatively relaxed regulations can have a large impact on the incidence of cyclist and pedestrian injuries at the national level by enabling rapid expansion of area-wide traffic-calming projects nationwide. In Japan, before the policy change, strict regulations and oppositions from the residents used to impede the implementation and expansion of such projects. Our study results suggest that promoting a community-based flexible preventive framework beyond traditional regulatory approaches could be a good solution to achieve a safer traffic environment in residential areas in many countries.

Strengths and Weaknesses

A key strength of the present study is that it evaluated the effectiveness of multisectoral area-wide traffic-calming interventions by using complete 12-year data from a country with more than 120 million people. We attributed the previously mentioned changes in the rate ratios and the number of injuries prevented to the Zone 30 policy because we adjusted for the longitudinal trend of the rate ratios before the introduction of the policy by including a linear time variable and because we also accounted for secular changes in the cyclist and pedestrian injury rates in the interrupted time-series analyses.[27–30]

The consistent results across the 10 subgroups stratified by sex and age show the robustness of our findings. The quantification of the number of injuries prevented by the policy stratified by sex and age would facilitate dissemination of our findings to decision-makers and other stakeholders because of their ease of interpretation. We consider that boys aged 0 to 14 years were overrepresented

TABLE 4—Estimated Number of Deaths and Serious Injuries Among Cyclists and Pedestrians Prevented by the Zone 30 Policy: Japan, September 2011 to December 2016

	No. Killed or Seriously Injured Cases Prevented, Point Estimate[a] (95% CI)[b]
Total	1704 (1293, 2198)
Females	
Age, y	
0–14	66 (−30, 188)
15–24	31 (−38, 113)
25–64	215 (44, 406)
65–74	152 (−17, 346)
≥ 75	263 (125, 411)
Males	
Age, y	
0–14	457 (234, 728)
15–24	174 (78, 286)
25–64	112 (−50, 290)
65–74	100 (19, 190)
≥ 75	135 (36, 243)

Note. CI = confidence interval.

[a]We obtained the point estimates for each subgroup with $\sum_{m=81}^{144}\{n_{i,m}/[1+b_{2i}\times(m-80)]-n_{i,m}\}$, where m is the number of months after January 2005 (m = 1), i (= 1, 2,..., 10) is the subgroup, b_{2i} (with mean μ_i and standard error σ_i) is the estimated monthly change in the rate ratio after September 2011 for subgroup i, and $n_{i,m}$ is the observed number of killed or seriously injured cases for subgroup i in the mth month. We obtained the total number of killed or seriously injured cases prevented by summing the estimated numbers across subgroup.

[b]We obtained the 95% CI for each subgroup by plugging in the upper and lower limits of b_{2i} to $\sum_{m=81}^{144}\{n_{i,m}/[1+b_{2i}\times(m-80)]-n_{i,m}\}$. We obtained the 95% CI for the total number through a Monte Carlo simulation of 1000 draws from $b_{2i}\sim N(\mu_i,\sigma_i)$ for each subgroup, assuming independence of randomness among the subgroups. See the "Estimation of the Impact" subsection in the Methods for details.

in the number of injuries prevented mainly because of the large reduction in the injury rate ratio. Women aged 75 years or older were also overrepresented mainly because of a rapid increase in the population of this subgroup compared with the other subgroups, which experienced a smaller increase or even a decrease during the study period.

On the other hand, one of the weaknesses of the present study is that there may have been concurrent events that have also affected the outcome of interest specifically, which is often unavoidable in longitudinal observational studies; however, we are not aware of such events. In addition, the rate ratios started decreasing immediately after the time of the introduction of the policy, especially for boys aged 0 to 14 years, which would enhance our interpretation that the observed decrease is because of the policy. Another weakness is that we were not able to adjust for the distance traveled by cyclists and pedestrians or the frequency of passages. If these data were available, the estimated effect of the policy on injury rates would become larger than the estimates of the present study because the policy may have improved perceived traffic safety in the neighborhood and increased active travel.[34,35]

The small and insignificant changes in the rate ratios of deaths were unexpected because it is well-established that the preventive effect of reducing the speed limit is larger for fatal injuries than for minor injuries.[26] It is necessary to examine whether measures taken in each zone are effective in preventing deaths and whether the intervened areas match high-fatality areas.[16]

To better inform decision-makers, in addition to the policy's effect shown in this study, an analysis of the cost-effectiveness of the policy would be useful. Another direction of future research is to examine whether optional measures in the zones in addition to the speed limit modified the effectiveness.

Conclusions

The area-wide traffic-calming Zone 30 policy introduced in September 2011 decreased the cyclist and pedestrian injuries on local narrow roads compared with arterial wide roads in Japan. The successful multisectoral policy with local residents' participation and relatively relaxed regulations had a large preventive impact on the rate and number of deaths and serious injuries among cyclists and pedestrians. AJPH

CONTRIBUTORS

M. Ichikawa conceptualized the study and obtained the data. H. Inada and M. Ichikawa designed the study. H. Inada analyzed the data and drafted the article. J. Tomio, S. Nakahara, and M. Ichikawa made comments that led to substantial revisions of the article, and all authors approved the final version. H. Inada, being the corresponding author, attests that all listed authors meet authorship criteria and that no other individuals meeting authorship criteria have been omitted. H. Inada accepts full responsibility for the work and the conduct of the study, had access to the data, and controlled the decision to publish.

ACKNOWLEDGMENTS

This study was supported by the Japan Society for the Promotion of Science (KAKENHI grant 18K10081).

CONFLICTS OF INTEREST

The authors declare no conflicts of interest other than the previously mentioned research grant.

HUMAN PARTICIPANT PROTECTION

This study did not require institutional review board approval because it is an observational study that used only aggregate public domain data.

REFERENCES

1. World Health Organization. Global status report on road safety 2018. 2018. Available at: https://www.who.int/violence_injury_prevention/road_safety_status/2018/en. Accessed December 28, 2018.

2. GBD 2017 Causes of Death Collaborators. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1736–1788.

3. Kelly P, Kahlmeier S, Götschi T, et al. Systematic review and meta-analysis of reduction in all-cause mortality from walking and cycling and shape of dose response relationship. *Int J Behav Nutr Phys Act*. 2014;11(1):132.

4. Martin A, Panter J, Suhrcke M, Ogilvie D. Impact of changes in mode of travel to work on changes in body mass index: evidence from the British Household Panel Survey. *J Epidemiol Community Health*. 2015;69(8):753–761.

5. Flint E, Webb E, Cummins S. Change in commute mode and body-mass index: prospective, longitudinal evidence from UK Biobank. *Lancet Public Health*. 2016;1(2):e46–e55.

6. Mytton OT, Panter J, Ogilvie D. Longitudinal associations of active commuting with body mass index. *Prev Med*. 2016;90:1–7.

7. Sallis JF, Cerin E, Conway TL, et al. Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. *Lancet*. 2016;387(10034):2207–2217.

8. Wasfi RA, Dasgupta K, Orpana H, Ross NA. Neighborhood walkability and body mass index trajectories: longitudinal study of Canadians. *Am J Public Health*. 2016;106(5):934–940.

9. Creatore MI, Glazier RH, Moineddin R, et al. Association of neighborhood walkability with change in overweight, obesity, and diabetes. *JAMA*. 2016;315(20):2211–2220.

10. Loo CKJ, Greiver M, Aliarzadeh B, Lewis D. Association between neighbourhood walkability and metabolic risk factors influenced by physical activity: a cross-sectional study of adults in Toronto, Canada. *BMJ Open*. 2017;7(4):e013889.

11. Woodcock J, Edwards P, Tonne C, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: urban land transport. *Lancet*. 2009;374(9705):1930–1943.

12. Bunn F, Collier T, Frost C, et al. Area-wide traffic calming for preventing traffic related injuries. *Cochrane Database Syst Rev*. 2003;(1):CD003110.

13. Grundy C, Steinbach R, Edwards P, et al. Effect of 20 mph traffic speed zones on road injuries in London, 1986–2006: controlled interrupted time series analysis. *BMJ*. 2009;339:b4469.

14. Li H, Graham D. Quantifying the causal effects of 20 mph zones on road casualties in London via doubly robust estimation. *Accid Anal Prev*. 2016;93:65–74.

15. Jiao B, Kim S, Hagen J, Muennig PA. Cost-effectiveness of neighbourhood slow zones in New York City. *Inj Prev*. 2019;25(2):98–103.

16. Choi Y, Yoon H, Jung E. Do Silver Zones reduce auto-related elderly pedestrian collisions? Based on a case in Seoul, South Korea. *Accid Anal Prev*. 2018;119:104–113.

17. World Health Organization. Global status report on road safety 2013. 2013. Available at: https://www.who.int/violence_injury_prevention/road_safety_status/2013/en. Accessed March 11, 2019.

18. National Police Agency, Japan. Progress in the promotion of Zone 30 [in Japanese]. 2017. Available at: https://www.npa.go.jp/bureau/traffic/seibi2/kisei/zone30/pdf/shosai.pdf. Accessed September 3, 2018.

19. National Police Agency, Japan. Research report on the promotion of area-wide road traffic safety measures in neighborhood roads [in Japanese]. 2011. Available at: https://www.npa.go.jp/bureau/traffic/seibi2/kisei/zone30/pdf/houkokusyo.pdf. Accessed October 24, 2018.

20. National Police Agency, Japan. Circular notice: promotion of Zone 30 [in Japanese]. 2011. Available at: https://www.npa.go.jp/pdc/notification/koutuu/kisei/kisei20110920.pdf. Accessed November 20, 2019.

21. Sumitomo K. Toward the formulation of next-term social infrastructure key improvement plan relating to traffic safety facilities maintained, improved and installed by police [in Japanese]. *IATSS Rev*. 2008;33(1):78–82.

22. Nakahara S, Ichikawa M, Kimura A. Population strategies and high-risk-individual strategies for road safety in Japan. *Health Policy*. 2011;100(2-3):247–255.

23. National Police Agency, Japan. Summary of Zone 30 [in Japanese]. 2019. Available at: https://www.npa.go.jp/bureau/traffic/seibi2/kisei/zone30/pdf/zone30.pdf. Accessed August 12, 2019.

24. Statistics Bureau, Ministry of Internal Affairs and Communications, Japan. Population estimates [in Japanese]. Available at: http://www.stat.go.jp/data/jinsui/index.html. Accessed July 22, 2018.

25. Institute for Traffic Accident Research and Data Analysis. Handbook of terms in the statistics of road traffic crashes [in Japanese]. 2017. Available at: https://www.itarda.or.jp/service/term.php. Accessed February 20, 2019.

26. National Highway Traffic Safety Administration. Literature review on vehicle travel speeds and pedestrian injuries. 1999. Available at: https://one.nhtsa.gov/people/injury/research/pub/hs809012.html. Accessed November 20, 2019.

27. Hingson R, Heeren T, Winter M. Effects of Maine's 0.05% legal blood alcohol level for drivers with DWI convictions. *Public Health Rep*. 113(5):440–446.

28. Voas RB, Tippetts AS, Fell J. The relationship of alcohol safety laws to drinking drivers in fatal crashes. *Accid Anal Prev*. 2000;32(4):483–492.

29. Nakahara S, Ichikawa M. Effects of high-profile collisions on drink-driving penalties and alcohol-related crashes in Japan. *Inj Prev*. 2011;17(3):182–188.

30. Ichikawa M, Nakahara S, Inada H. Impact of mandating a driving lesson for older drivers at license renewal in Japan. *Accid Anal Prev*. 2015;75:55–60.

31. Shumway RH, Stoffer DS. *Time Series Analysis and Its Applications*. 4th ed. Cham, Switzerland: Springer; 2017.

32. Stoffer D. astsa: Applied Statistical Time Series Analysis. 2017. Available at: https://cran.r-project.org/package=astsa. Accessed January 10, 2019.

33. Yamagishi M. An analysis of the effectiveness of the Zone 30 designation on traffic crash [in Japanese]. 2015. Available at: http://www3.grips.ac.jp/~up/pdf/paper2014/MJU14618yamagishi_abst.pdf. Accessed August 12, 2019.

34. Simons D, De Bourdeaudhuij I, Clarys P, et al. Psychosocial and environmental correlates of active and passive transport behaviors in college educated and non-college educated working young adults. *PLoS One*. 2017;12(3):e0174263.

35. Tappe KA, Glanz K, Sallis JF, Zhou C, Saelens BE. Children's physical activity and parents' perception of the neighborhood environment: neighborhood impact on kids study. *Int J Behav Nutr Phys Act*. 2013;10(1):39.