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Regional disparities in road traffic injury rates involving elementary and junior high school children while commuting among Japan's 47 prefectures between 2004 and 2013

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ABSTRACT

Objectives: To investigate the extent and patterns of regional disparities of road traffic injury rates involving elementary and junior high school children while commuting among Japan's 47 prefectures.
Methods: We conducted a cross-sectional ecological study using the national police data for 2004–2013 on the number of children who were killed or seriously injured (KSI) in traffic collisions stratified by prefecture, grade, mode of transport, and purpose of trip (commuting or non-commuting). We calculated stratified KSI rates by dividing the number of KSI cases by the corresponding number of children and presented these rates for the 47 prefectures. Also, for pedestrian elementary school children and cyclist junior high school children, we regressed the KSI rates while commuting by prefecture on the non-commuting KSI rates and the proportion of people who live in the urban, densely inhabited districts.
Results: There were 6463 KSI cases while commuting. The ratios of the highest KSI rate to the lowest KSI rate among prefectures were 12, 30, and 58 for pedestrian elementary school children and pedestrian and cyclist junior high school children, respectively. The non-commuting KSI rates and the proportion of those living in densely inhabited districts were positively and inversely associated with the commuting KSI rates, respectively. The analysis of the residuals of the regression models did not identify prefectures with significantly higher or lower KSI rates while commuting than others.
Conclusions: There were large inter-prefecture disparities in the KSI rates while commuting, and the disparity was especially large among cyclist junior high school children.

1. Introduction

In Japan, road traffic injuries (RTI) is one of the leading causes of mortality and morbidity among children. In these years, approximately 60–100 children between the ages of 5–14 years died from RTI every year (Ministry of Health, Labour and Welfare, Japan, 2018), and 28,000–47,000 children in this age group sustained non-fatal RTI (National Police Agency, Japan, 2017). A substantial proportion of RTI among children occurred while commuting: Among pedestrian elementary school children who sustained RTI in 2013–2017, the leading purposes of the trip were commuting (35.3%), playing (15.6%), and visiting a friend (11.3%); and among cyclist junior and senior high school children, they were commuting (62.7%), visiting a friend (7.2%), and going shopping (6.1%) (National Police Agency, Japan, 2018a; 2018b).

Road safety for children while commuting to and from school is high on the political agenda in Japan. After several tragic fatal car crashes that involved commuting school children several years ago (The Japan Times, 2012), Japan's national and local governments in collaboration with schools and parents have been accelerating measures to promote road safety for school children (Ministry of Land, Infrastructure and Transport, Japan, 2018). Since local governments and police departments play a leading role in promoting road safety in each prefecture, it is essential to understand the frequency of RTI at the local level to inform them.

However, as is reviewed in the next chapter, the existing literature

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does not provide a full picture of the frequency of RTI in each prefecture or identify prefectures that require enhanced road safety measures for children while commuting; prefectures whose effective measures could be informative to others is also unknown. Therefore, the objectives of this study were to investigate the extent and patterns of inter-prefecture disparities of RTI rates involving elementary and junior high school children while commuting.

2. Literature review

To identify scientific papers that examined regional disparity of RTI among children while commuting on foot or by bicycle, we searched PubMed with search terms listed in Appendix A on December 3, 2018 and obtained 337 results. After screening the titles and abstracts, we identified four relevant papers. For the literature on RTI published in Japan, we searched journal articles and the grey literature with Internet search engines.

The four papers examined regional disparity of RTI among pedestrian or cyclist children in Japan (Inada et al., 2017), the U.K. (Jones et al., 2005), and the U.S. (Centers for Disease Control and Prevention, 2013; DiMaggio et al., 2016) Our previous study indicated that there is a substantial disparity of RTI among children while commuting between urban and rural areas: 63% of RTI occurred in suburban and rural areas, which have only 33% of the total population of Japan (Inada et al., 2017). DiMaggio et al. (2016) reported longitudinal rates of child pedestrian and bicyclist RTI during school travel hours on weekdays for 18 U.S. states, and there was a substantial regional disparity among the states (DiMaggio et al., 2016). The other two papers did not specifically examine RTI while commuting. In the U.S., the association between child pedestrian mortality rate per unit population and urbanization level of area was small (Centers for Disease Control and Prevention, 2013). Jones et al. (2005) reported that child pedestrian injury rates were associated with area deprivation status of census tracts in two cities in the U.K. (Jones et al., 2005)

In addition to the four scientific papers, we identified two grey literature studies. The Japan Sport Council reported the number of RTI cases while commuting in each prefecture among school children using police data for 2012 (Japan Sport Council, 2014). It also reported ten prefectures with the highest numbers of RTI cases while commuting per 100,000 school children and indicated that there is an inter-prefecture disparity (Japan Sport Council, 2014). As for the inter-prefecture disparity in road traffic mortality rates among all road users in Japan, it has decreased substantially in absolute values over the past half-century: The difference in mortality rates between the prefectures with the highest and lowest mortality rates per 100,000 population was 20.8 (28.0 in Tochigi and 7.2 in Tokyo) in 1970, 11.7 (15.8 in Ibaraki and Mie and 4.1 in Tokyo) in 1990, 5.7 (7.3 in Tochigi and Mie and 1.6 in Tokyo) in 2010, and 5.3 (6.5 in Fukui and Tokushima and 1.2 in Tokyo) in 2016 (Institute for Traffic Accident Research and Data Analysis, 2018).

3. Methods

3.1. Data sources

This is a cross-sectional ecological study. We obtained national police data on the number of children who sustained RTI in Japan between 2004 and 2013 from the Institute for Traffic Accident Research and Data Analysis, Japan. We limited the data to elementary and junior high school children who were killed within 24 h of the crash or seriously injured (KSI) and estimated to require medical treatment for 30 days or more after the crash. The aggregate data were stratified by 47 prefectures, grade of the child (elementary or junior high school), mode of transport of the child (pedestrian or cyclist), and purpose of trip of the child (commuting or non-commuting). Elementary school children are in grades 1–6 and aged 6–12 years, and junior high school children are in grades 7–9 and aged 12–15 years. The police officer who investigated the crash determined the purpose of trip of the child; we assume the measurement error is reasonably small because the child should be able to provide the police officer with the information unless the child is killed or unconscious. The police officer can also judge it from the child's belongings such as school textbooks. We excluded KSI cases of cyclist elementary school children from our data because they represented only 2% of all KSI cases among school children while commuting (Inada et al., 2017).

We obtained the number of children stratified by year, prefecture, and grade from the national school survey (Ministry of Education, Culture, Sports, Science and Technology, Japan, 2018). Since most elementary schools ($>$ 98.9%) and junior high schools ($>$ 92.2%) were public schools (Ministry of Education, Culture, Sports, Science and Technology, Japan, 2014), whose students live in the same prefecture where the school is located, we consider that most RTI while commuting also occurred in the same prefecture. Using the population estimates by the national statistics bureau, we calculated the proportion of people who live in the urban, densely inhabited districts (DID), which are defined as having $\geq$5000 population with population density $\geq$4000/km^2 (Statistics Bureau, Ministry of Internal Affairs and Communications, Japan, 2018). The Japanese Government started using the definition in 1960 to understand characteristics of urban districts in each municipality and prefecture (Ministry of Internal Affairs and Communications, Japan, 2018).

3.2. Statistical analyses

We pooled the 10-year RTI data stratified by prefecture, grade, mode of transport, and purpose of trip of the child and calculated KSI rates with the number of KSI cases as the numerator and the sum of the corresponding number of children in each year, prefecture, and grade as the denominator. Hereafter, the KSI rate of children whose purpose of trip was commuting is referred to as the commuting KSI rate, and the rate whose purpose of trip was non-commuting is referred to as the non-commuting KSI rate.

To display data, we listed the KSI rates by prefecture and mode of transport for elementary and junior high school children and calculated the ratios of the highest to the lowest KSI rates by dividing the KSI rate of the highest ranked prefecture by that of the lowest ranked prefecture. Further, to examine whether the KSI rates are different among the prefectures by chance alone, we created scatter plots of the KSI rates of pedestrian elementary school children, pedestrian and cyclist junior high school children, pedestrian junior high school children, and cyclist junior high school children by prefecture with the log of person-years of children as their horizontal axes. We also plotted the 95% prediction intervals along the horizontal axis, assuming the numbers of KSI cases follow Poisson distributions.

To identify prefectures that perform significantly better or worse than other prefectures in specifically preventing school children's RTI while commuting, we built two multiple linear regression models: one for pedestrian elementary school children and the other for cyclist junior high school children. The models regressed the commuting KSI rates by prefecture on the non-commuting KSI rates of corresponding children and the proportion of people who live in the DID in the prefecture:

$$(\text{commuting KSI rate}) = \beta_0 + \beta_1 \times (\text{noncommuting KSI rate}) + \beta_2 \times (\%\,\text{of people in DID}) + \varepsilon$$

Since KSI cases whose purpose of the trip was non-commuting include children's daily living activities such as playing, visiting a friend, and going shopping, we consider that the non-commuting KSI rate reflects the overall road safety situation for children in the prefecture including children's behavior such as choice of mode of transport (walking or cycling), frequency of road traffic crashes, and the prefecture's road safety policies and actions. As for the proportion of people who live in the DID, it is associated with the average distance of school commuting routes (Sadahiro, 2007) and the availability of public transport. Therefore, the residuals of the regression models would facilitate identifying prefectures that perform significantly better or worse in specifically preventing children's RTI while commuting than others. To examine whether the linearity and homoscedasticity assumptions hold, we plotted the independent variables and the fitted value against the dependent variable. When the residuals were heteroscedastic, we transformed the dependent variables as appropriate and employed an iterative weighted least squares method, (McCullagh and Nelder, 1983) in which we modeled the inverse variance weights as a function of the fitted values of the multiple linear regression model using the generalized linear model with a gamma distribution, estimated the regression coefficients of the multiple linear regression model using the weights, and repeated the processes until the change in the regression coefficients becomes sufficiently small ($< 0.1\%$). All the statistical analyses were conducted with R version 3.4.4.

3.3. Ethical considerations

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

4. Results

During the study period, there were 6463 KSI cases in total among elementary and junior high school children while commuting in Japan: 3299 and 804 cases among pedestrian elementary and junior high school children, respectively, and 2360 cases among cyclist junior high school children.

Fig. 1 lists prefectures and the KSI rates for elementary and junior high school children. Prefectures with the highest KSI rates tend to be outside the country's three most populous metropolitan areas (Tokyo, Tokyo Prefecture; Osaka, Osaka Prefecture; and Nagoya, Aichi Prefecture), and prefectures with the lowest KSI rates tend to be in or near the three metropolitan areas. The ratios of the highest KSI rate to the lowest KSI rate, which is calculated as the commuting KSI rate of Kumamoto and Kochi divided by that of Tokyo for elementary and junior high school children, respectively were 12 for elementary school children and 44 for junior high school children (30 for pedestrians and 58 for cyclists).

Fig. 2 shows scatter plots of the KSI rates by prefecture against the log of person-years of children. Over half of the prefectures were outside the 95% prediction intervals, which means there was a larger disparity of the KSI rates among prefectures than expected by chance alone. The disparity was larger among junior high school children (Fig. 2B) than elementary school children (Fig. 2A). The scatter plots stratified by mode of transport among junior high school children (Fig. 3) shows that the large inter-prefecture disparity among junior high school children (Fig. 2B) is mostly due to that among cyclists (Fig. 3B).

Fig. 4 displays scatter plots of the independent variables and the fitted value against the dependent variable of the regression analyses. The linearity assumption seems to hold, and the plots of the fitted value and the dependent variable showed a slight degree of heteroscedasticity. Table 1 shows the result of the regression analyses. Both

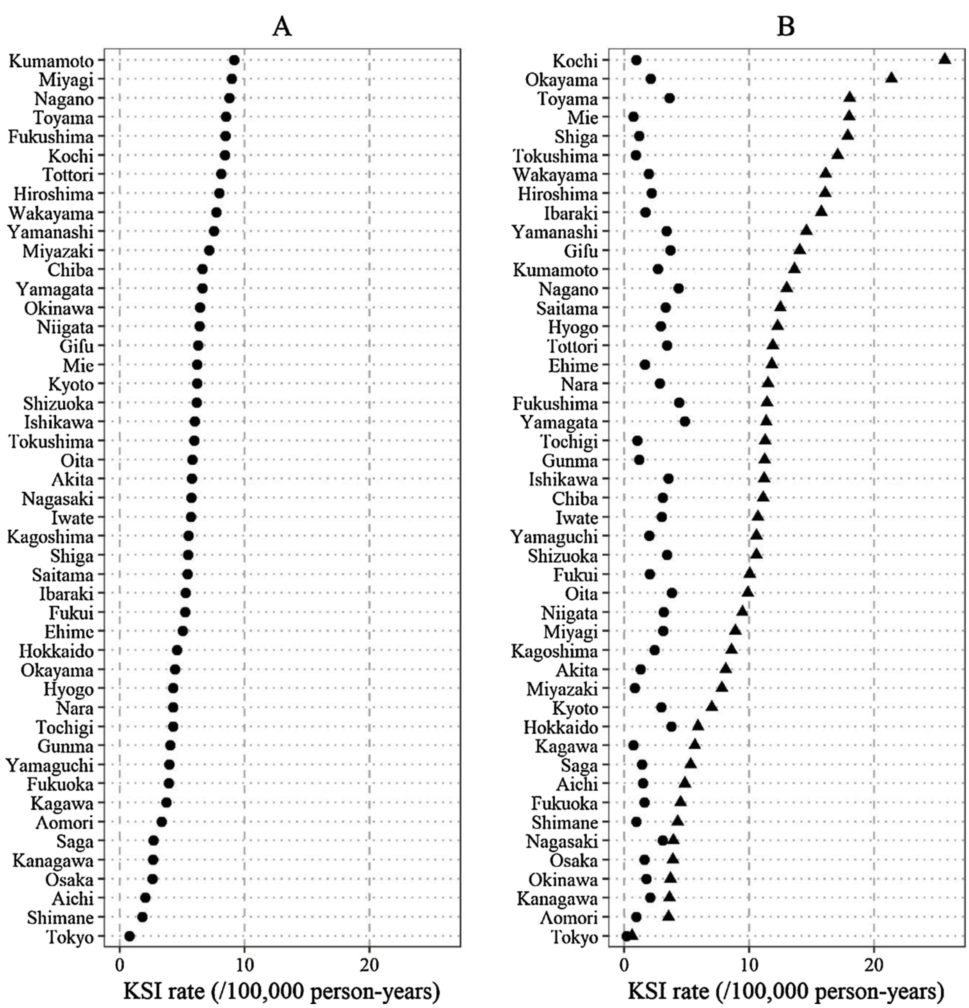

Fig. 1. A–B List of the KSI rates* while commuting among (A) elementary school children and (B) junior high school children in Japan's 47 prefectures between 2004 and 2013.
KSI: killed or seriously injured.
The solid circles represent the KSI rates among pedestrians and the solid triangles represent the KSI rates among pedestrians and cyclists combined.
* The numerator of the rate is the number of children who were killed within 24 h of the crash or seriously injured and were estimated to require medical treatment for 30 days or more after the crash by the physician, and the denominator of the rate is the sum of the corresponding number of children in each year, prefecture, and grade.

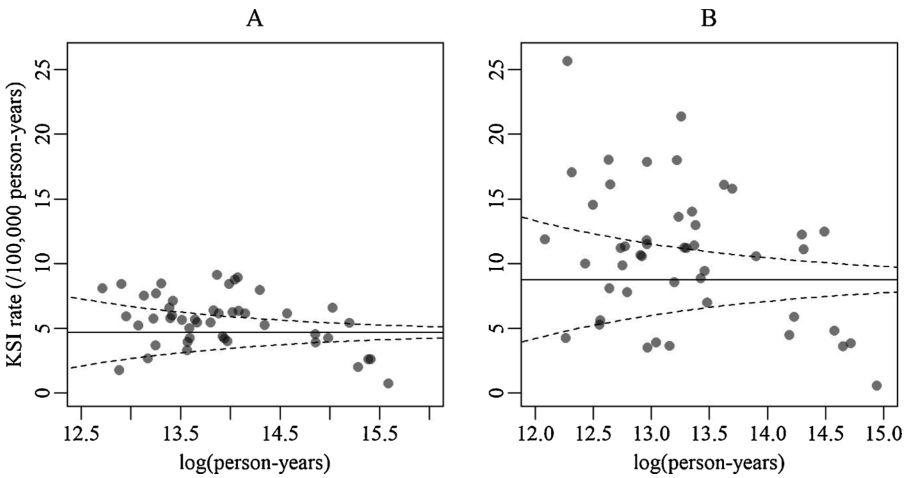

Fig. 2. A–B Scatter plots of the KSI rates* while commuting and population size among (A) pedestrian elementary school children and (B) pedestrian and cyclist junior high school children in Japan's 47 prefectures between 2004 and 2013.
KSI: killed or seriously injured.
The solid lines are national averages, and the dashed lines are 95% prediction intervals along the population size, assuming the numbers of KSI cases follow Poisson distributions.
* The numerator of the rate is the number of children who were killed within 24 h of the crash or seriously injured and were estimated to require medical treatment for 30 days or more after the crash by the physician, and the denominator of the rate is the sum of the corresponding number of children in each year, prefecture, and grade.

predictors, the non-commuting KSI rates and the proportion of people who live in the DID, were associated with the commuting KSI rates, and they explained over 50% of the variance of the dependent variable. All the prefectures had the standardized residuals within two standard deviations, ranging from -1.27 to 1.79 among pedestrian elementary school children and from -1.44 to 0.88 among cyclist junior high school children (results not shown).

5. Discussion

The current study revealed large inter-prefecture disparities in the commuting KSI rates of elementary and junior high school children in Japan; the disparity was larger amongst cyclists than pedestrians. Over 50% of the variance of the KSI rates by prefecture was explained by the two variables: the non-commuting KSI rates of corresponding children and the proportion of people who live in the DID. Since all the prefectures had the residuals within two standard deviations after controlling for the non-commuting KSI rate, which is a proxy indicator ofthe overall road safety situation for children in each prefecture and the prefecture's road safety policies and actions, we consider that no prefecture performed significantly better or worse than other prefectures in specifically preventing school children's RTI while commuting.

We consider that the large inter-prefecture disparity in the cyclist KSI rates among junior high school children was mainly caused by the difference in the proportion of children who commute by bicycle. The larger inter-prefecture disparity among cyclists (Fig. 3B) than pedestrians (Fig. 3A) supports this argument. In addition, all the residuals of the regression model were within two standard deviations after adjusting for the non-commuting KSI rate, which reflects the children's choice of mode of transport. Further, Kochi, Mie, and Tokushima were some of the prefectures with the lowest KSI rates among pedestrian junior high school children and the highest KSI rates among cyclist junior high school children (Fig. 1B). This finding is probably because the majority of junior high school children in the prefectures commuted by bicycle; it is unlikely that the prefectures had the best road safety situation for pedestrians and the worst for cyclists. In Tokyo, where school children enjoy the lowest commuting KSI rate among the 47 prefectures (Fig. 1), many junior high schools actually ban commuting by bicycle. Another reason for the large inter-prefecture disparity in the cyclist commuting KSI rate would be the difference in the overall road safety situation for children in each prefecture, which is reflected in the non-commuting KSI rate. The disparity in the non-commuting KSI rate was also larger among cyclists than pedestrians as shown in Figs. 4A and 4D. Furthermore, although there is no legal penalty for cyclists for not using a helmet, some junior high schools obligate their students to wear a helmet when commuting by bicycle with their school rules. Given such school rules' effectiveness in preventing head injuries (Ichikawa and Nakahara, 2007), a potential inter-prefectural disparity in the proportion of junior high schools that have such school rules would also partially explain the inter-prefectural disparity of the commuting KSI rate.

How can we mitigate the inter-prefectural disparities of the commuting KSI rate among school children? It is estimated that over 90% of junior high school children live within 3 km of their school (Sadahiro, 2007), which is well within walking distance. Since the commuting KSI

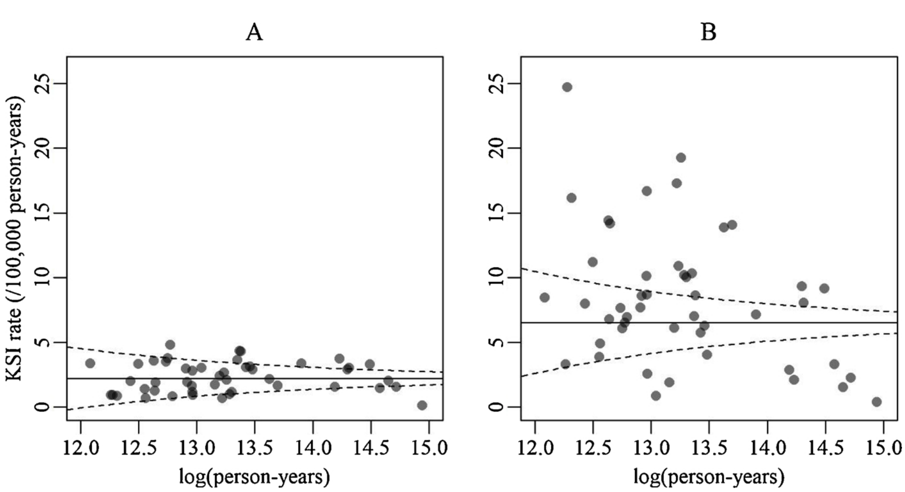

Fig. 3. A–B Scatter plots of the KSI rates* of junior high school children while commuting and population size among (A) pedestrians and (B) cyclists in Japan's 47 prefectures between 2004 and 2013.
KSI: killed or seriously injured.
The solid lines are national averages, and the dashed lines are 95% prediction intervals along the population size, assuming the numbers of KSI cases follow Poisson distributions.
* The numerator of the rate is the number of children who were killed within 24 h of the crash or seriously injured and were estimated to require medical treatment for 30 days or more after the crash by the physician, and the denominator of the rate is the sum of the corresponding number of children in each year, prefecture, and grade.

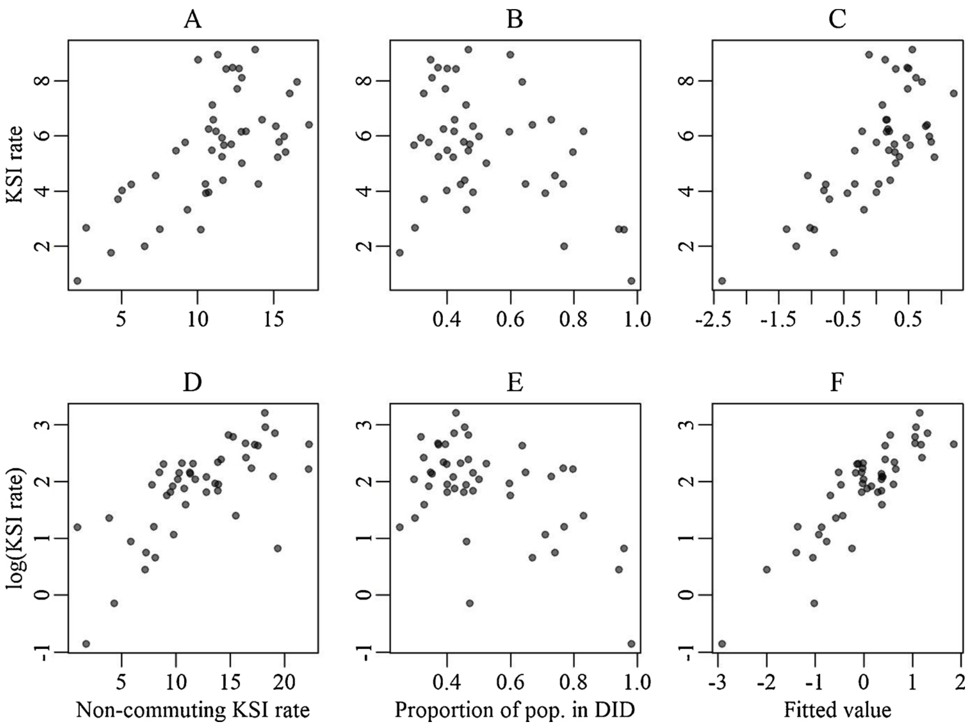

Fig. 4. A–F Scatter plots of the independent variables (non-commuting KSI rates* and the proportion of population in the densely inhabited districts†), fitted values of the regression models‡, and the dependent variable (commuting KSI rate) among (A–C) pedestrian elementary school children and (D–F) cyclist junior high school children in Japan's 47 prefectures between 2004 and 2013.
DID: densely inhabited districts; KSI: killed or seriously injured.
* The numerator of the rate is the number of children who were killed within 24 h of the crash or seriously injured and were estimated to require medical treatment for 30 days or more after the crash by the physician, and the denominator of the rate is the sum of the corresponding number of children in each year, prefecture, and grade.
† The DID is defined as having ≥5000 population with population density ≥4000/km^2 (Ministry of Health, Labour and Welfare, Japan, 2018).
‡ The model is (commuting KSI rate) = $\beta_0 + \beta_1 \times$ (non-commuting KSI rate) + $\beta_2 \times$ (% of people in DID) + ε. The fitted values were estimated using an iterative weighted least squares methods (McCullagh and Nelder, 1983). See the main text for details.

rate of cyclists is ten times higher that of pedestrians (Inada et al., 2017), safer, alternative modes of transport than cycling such as walking, bus, train, and subway should be encouraged for junior high school children. The results of the regression analyses also suggest that improving the overall safety situation for children and reducing the distance of commuting routes might be effective in reducing RTI while commuting among elementary and junior high school children. A promising measure to improve the overall safety road safety is area-wide traffic calming (Bunn et al., 2010; Grundy et al., 2009; Li and Graham, 2016). The Zone 30 policy that started in Japan in 2011 employs such a scheme, and a pre-post comparison showed an 18.6% reduction of crashes that involved a cyclist or pedestrian (National Police Agency, Japan, 2018a; 2018b). Last but not least, obligating cyclist helmet use while commuting might also mitigate the inter-prefectural disparity of the commuting KSI rate (Ichikawa and Nakahara, 2007).

Our findings also have international implications. In an effort to increase physical activity among children, active commuting to school has garnered much attention in these years, as is evidenced by three recent publications of systematic reviews related to interventions to promote active commuting to school (Larouche et al., 2018; Pang et al., 2017; Villa-González et al., 2018). However, the present study, our previous study (Inada et al., 2017), and studies conducted in the U.S. (Transportation Research Board of the National Academies, 2002), New Zealand (Schofield et al., 2008), and Canada (Gropp et al., 2013; Lavoie et al., 2014) consistently showed an increased risk of RTI by active commuting, especially among cyclists (Inada et al., 2017; Lavoie et al., 2014; Schofield et al., 2008). Securing safe routes to school, therefore, should be a prerequisite to encourage active commuting. This might help fill disparities of the incidence of RTI while commuting among school children.

The strengths of the current study include that it is a robust descriptive epidemiological study that used the 10-year national complete data. In Japan, under-reporting of pedestrian and cyclist RTI is small (Nakahara and Wakai, 2001) presumably because RTI victims must report to the police to receive the compulsory automobile liability insurance benefit. Another strength of the current study is that the two multiple linear regression models showed good fits with adjusted R^2 over 0.50.

It is possible that some of the disparities in the KSI rate is due to the difference in the practice of classifying non-fatal injuries. Although the definition of serious injury, being estimated to require medical treatment for 30 days or more after the crash, is uniform across the country, physicians in different prefectures may tend to over- or under-estimate the duration of medical treatment than physicians in other prefectures. However, the possible difference in practice does not explain the larger disparity among cyclists than pedestrians, and it is unlikely that it alone explains the significant inter-prefecture disparities in the KSI rates.

Table 1
Association between the predictors and the KSI rates[a] while commuting among pedestrian elementary school children and cyclist junior high school children in Japan between 2004 and 2013.

Predictors	Pedestrian elementary school children Point estimate[‡] [95% CI]	Cyclist junior high school children[†] Point estimate[‡] [95% CI]
Non-commuting KSI rates	0.60 [0.48, 0.72]	0.74 [0.61, 0.88]
Proportion of population in DID[§]	−0.36 [-0.48, -0.25]	−0.56 [-0.69, -0.43]
Unweighted adjusted R^2	0.53	0.76

CI: confidence interval; DID: densely inhabited districts; KSI: killed or seriously injured.
[a] The numerator of the rate was the number of children who were killed within 24 h of the crash or seriously injured and were estimated to require medical treatment for 30 days or more after the crash by the physician, and the denominator of the rate was the sum of the corresponding number of children in each year, prefecture, and grade.
[†] The KSI rate of cyclists was log-transformed to account for heteroscedasticity.
[‡] The model is (commuting KSI rate) = $\beta_0 + \beta_1 \times$ (non-commuting KSI rate) + $\beta_2 \times$ (% of people in DID) + ε. The regression coefficients were standardized and estimated with an iterative weighted least squares method.
[§] The DID is defined as areas having ≥5000 population with population density ≥4000/km^2 (Ministry of Internal Affairs and Communications, 2018).

6. Conclusion

We found large inter-prefecture disparities in RTI rates involving elementary and junior high school children while commuting in Japan; the rate was higher in prefectures with lower proportions of residents who live in urban districts. The disparity was especially large among cyclist junior high school children. Further research is warranted to elucidate the causes of inter-prefecture disparities of RTI rates among Japanese school children while commuting and to reduce the rates and their disparities.

Contributors

HI, JT, and MI conceived the study. JT obtained the data. HI analyzed the data and drafted the manuscript. JT, MI, and SN made comments that led to substantial revisions of the manuscript, and all the authors approved its final version.

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Declarations of interest

None.

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Appendix A

(" accidents, traffic"[MeSH Terms] OR death[MeSH Terms] OR "wounds and injuries"[MeSH Terms]) AND (adolescent[MeSH Terms] OR adolescence[All Fields] OR adolescent*[All Fields] OR child[MeSH Terms] OR child[All Fields] OR children[All Fields] OR childhood[All Fields] OR junior[All Fields] OR kid[All Fields] OR kids[All Fields] OR pediatrics[MeSH Terms] OR paediatric*[All Fields] OR pediatric*[All Fields] OR pupil[MeSH Terms] OR pupil*[All Fields] OR schools[MeSH Terms] OR school*[All Fields] OR students[MeSH Terms] OR student*[All Fields] OR young[All Fields] OR younger[All Fields] OR youngest[All Fields]) AND (cities[MeSH Terms] OR geography[MeSH Terms] OR "geographic locations"[MeSH Terms] OR area*[All Fields] OR city[All Fields] OR cities[All Fields] OR county[All Fields] OR counties[All Fields] OR district*[All Fields] OR division*[All Fields] OR geograph*[All Fields] OR location*[All Fields] OR municipal*[All Fields] OR prefectur*[All Fields] OR provinc*[All Fields] OR region*[All Fields] OR state*[All Fields]) AND (attend*[All Fields] OR commut*[All Fields] OR travel*[All Fields]) AND (bicycling[MeSH Terms] OR bicycl*[All Fields] OR cycling[All Fields] OR cyclist*[All Fields] OR pedestrians[MeSH Terms] OR pedestrian*[All Fields] OR walking[MeSH Terms] OR walk*[All Fields]) AND (English[Language] OR Japanese[Language]).

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