EDITOR'S CHOICE

Reducing regional inequality in mortality from road traffic injuries through enforcement of the mandatory motorcycle helmet law in Taiwan

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ABSTRACT

Background This study was conducted to examine whether passage of the mandatory motorcycle helmet law in 1997 reduced the regional inequality in mortality from road traffic injuries (RTIs) across 22 cities/counties in Taiwan.

Methods We calculated the absolute (between-group variance, BGV) and relative (rate ratio between the city/county with the highest and lowest rate, RR) terms of inequality for the overall and motorcycle-related RTI mortality rates, the rate of helmet use and three other explanatory factors associated with RTI mortality at the city/county level from 1997 through 2008.

Results The BGV of the overall and motorcycle-related RTI mortality rates across the 22 cities/counties showed persistently decreasing trends from 1997 to 2008; however, the RR of RTI mortality first increased and then levelled off from 2002. The decreasing trend in inequality was most prominent in males aged 0–24 years. The BGV and RR of the rate of motorcycle helmet use decreased after passage of the law but increased from 2002 onwards.

Conclusion In Taiwan, passage of the mandatory motorcycle helmet law reduced the regional inequality in RTI mortality; however, a resurgence in regional inequality in the helmet use rate years after passage of the helmet law was noted. It is therefore necessary to monitor the helmet use rate after passage of such a law to ensure the effect of a reduction in regional inequality in RTI mortality.

INTRODUCTION

Tackling inequality in health is an important part of the public policy agenda in many countries[1 2]; however, many interventions that could improve overall health might also increase inequality.[3] The inverse equity hypothesis, proposed by Victora *et al*, is the most popular hypothesis used to explain this phenomenon.[4] According to the hypothesis, new interventions will initially reach those of a higher socioeconomic position and only later filter down to those of poorer status. Inequalities in coverage, morbidity and mortality therefore increase first, followed later by a reduction when those of lower socioeconomic status gain greater access to the intervention and the minimum achievable levels of morbidity and mortality have been achieved in those of higher status.

Similarly, Tugwell *et al*[5] indicated that community effectiveness is often substantially lower than efficacy owing to a staircase effect, which is the result of lower awareness, access or coverage; screening, diagnosis or targeting; compliance of providers and adherence of consumers. The poor probably experience a greater reduction in efficacy at all four steps and therefore a greater staircase effect than those of higher socioeconomic status, which results in a widening of the gap between the poorest and the richest.[5] Furthermore, White *et al* suggested that compulsory enforced legislation interventions are less likely to result in an increase in social inequality in health than those of a voluntary behavioural change nature.[3]

Enforced legislations have been proposed to be very effective interventions in reducing mortality from road traffic injuries (RTIs).[6 7] Motorcycles and other two-wheeled vehicles are the most commonly used means of transportation in many Asian countries, in which the numbers of deaths and head injuries sustained are also high.[8] Using Taiwan as an example, by the end of 2009, the population was around 23 million, with 21.4 million registered motor vehicles, 14.6 million (68%) of which were motorcycles,[9] and on average, two motorcycles are owned per household in Taiwan. It was estimated that two-thirds of reported traffic crashes in 2002 involved motorcycles, and motorcycle-related deaths accounted for 55% of all traffic deaths.[10]

Motorcycle helmet laws[11] and the enforcement of these laws[12 13] have been proven to effectively reduce motorcycle head injuries, hospitalisations and deaths. A mandatory motorcycle helmet use law was passed and enforced in Taiwan in June 1997, and evaluative studies have revealed a subsequent dramatic reduction in motorcycle head injuries and deaths.[14 15] Nonetheless, little is known about the effects of enforced legislation on inequality in RTI mortality. The aim of this study was therefore to examine whether there was a decrease in regional inequality in overall and motorcycle-related RTI mortality after the introduction of the motorcycle helmet law in Taiwan.

As ongoing monitoring of process indicators to gauge the progress of implementation by socioeconomic status is an important step in the equity effectiveness loop proposed by Tugwell *et al*, we further assessed the inequality in the rate of helmet use among motorcyclists across cities/counties of differing socioeconomic development after the introduction of the motorcycle helmet law in Taiwan.

METHODS

RTI mortality

We calculated the overall and motorcycle-related RTI mortality rates in this study. Data regarding

the overall RTI mortality of 22 cities/counties in Taiwan from 1997 through 2008 were provided by the Statistics Office, Department of Health of Taiwan. Deaths from RTI were identified using the *International Classification of Diseases, Ninth Revision*, codes E810–E825.

The vital registration system was established during the Japanese colonial period in the early 1900s. Every citizen in Taiwan has a unique ID number, and every district has her own Census Administration Office in charge of vital registration affairs. The coverage of mortality data in each city/county is almost complete in Taiwan, and the concordance rate of the number of deaths according to the Department of Health and that according to the Division of Census in the Ministry of Interior was 98.7% in Taiwan.[16]

However, the quality of reporting of road user information related to RTI sufferers is not very satisfactory in Taiwan.[17] Many Taiwanese certifiers record only RTI without specifying whether the decedent was a motorcyclist or a driver of a car. Luckily, road user information is recorded in detail in the road traffic injury file of the Department of Police,[18] and we therefore asked the Department of Health and the Department of Police to link the mortality file with the road traffic injury file by ID number. As the completeness of the recording of the ID numbers of persons suffering RTI in the road traffic injury file was not very satisfactory until 2001, we thus were only able to analyse reliable linked data from 2001 onwards. Motorcycle-related death was defined as death within 30 days of the road traffic injury in which the road use item was recorded as being a motorcycle. As only four-fifths of RTI deaths in the mortality file of the Department of Health could be linked to the road traffic injury file of the Department of Police, we thus used the proportion of motorcycle-related deaths in the linked data of each city/county to estimate the motorcycle-related RTI mortality rate in each city/county for the years 2001 through 2008.

Helmet use rate

There is no surveillance of motorcycle helmet use in Taiwan, but there exists an item in the road traffic injury file recording whether the motorcyclist was wearing a helmet. We therefore used the road traffic injury file of the Department of Police of Taiwan to estimate the rates of helmet use in each city/county from 1997 through 2008.[18] In other words, we used the helmet use behaviour of persons involved in RTI events as a proxy of the helmet use behaviour of the general population.

Inequality measures

There are many kinds of inequality measures, and these can be classified into those for non-ordered variables, such as regions, ethnicities or races, etc, and those for ordered variables, such as educational achievements, income levels and occupation rankings, etc.[19 20] Another important classification of inequality measures is whether the measure is in absolute terms (eg, rate difference) or in relative terms (eg, rate ratio (RR)).[21 22] As region is a non-ordered variable, we therefore selected between-group variance (BGV) as the absolute term of inequality measure in this study. BGV is the inequality measure most relevant to health policy decision-making because it incorporates the population size of each city/county. It is defined as: [19 20]

$$BGV = \sum_{i=1}^{n} P_i \left(y_i - \bar{y}\right)^2$$

where P_i is the population size of the i^{th} city/county,

Table 1 Selected contextual socioeconomic indicators in each city/county and percentage change between 1997 and 2008 in Taiwan

	Population density (population/km^2)			Percentage of work force in primary industry			Annual household disposable income (US$)		
	1997	2008	Change	1997	2008	Change	1997	2008	Change
Whole of Taiwan	592	637	8	10.6	5.2	−51	24 309	26 105	7
North	1231	1384	12	2.9	1.0	−66	27 774	30 064	8
Taipei City	9687	9650	0	0.5	0.3	−33	34 036	36 316	7
Hsinchu City	3269	3892	19	2.6	0.5	−81	26 235	33 923	29
Keelung City	2778	2930	5	1.3	0.6	−53	23 679	23 334	−1
Taipei County	1610	1868	16	2.0	0.6	−70	24 833	27 773	12
Taoyuan County	1248	1604	29	4.4	1.4	−68	25 935	27 430	6
Hsinchu County	286	353	23	8.0	2.8	−65	26 367	30 399	15
Yilan County	218	215	−1	10.1	6.9	−32	22 437	24 227	8
Middle	515	548	6	17.4	8.6	−51	20 144	22 515	12
Taichung City	5221	6524	25	2.2	0.6	−73	26 736	26 184	−2
Miaoli County	308	308	0	12.5	5.2	−58	23 616	21 553	−9
Taichung County	685	759	11	9.8	4.3	−56	21 381	23 353	9
Changhua County	1199	1222	2	18.5	10.2	−45	21 535	21 730	1
Nantou County	133	129	−3	26.1	19.3	−26	21 239	20 255	−5
Yunlin County	584	561	−4	30.9	21.0	−32	18 971	18 399	−3
South	624	644	3	14.8	7.7	−48	21 226	23 265	10
Kaohsiung City	9284	9933	7	2.1	0.9	−58	26 093	27 481	5
Chiayi City	4354	4561	5	3.9	0.9	−77	23 615	21 183	−10
Tainan City	4024	4375	9	3.5	1.4	−60	23 426	26 294	12
Chiayi County	298	289	−3	32.1	20.5	−36	18 207	18 718	3
Tainan County	537	548		18.7	10.1	−46	18 961	20 847	10
Kaohsiung County	428	445	4	10.8	6.9	−36	21 408	22 289	4
Pingtung County	329	319	−3	24.4	17.0	−30	21 609	20 032	−7
East	75	70	−7	18.9	15.1	−20	21 296	18 620	−13
Hualien County	78	74	−5	12.1	9.0	−25	21 802	19 858	−9
Taitung County	72	66	−8	27.7	22.6	−18	16 311	16 757	3

y_i is the mortality or helmet use rate of the i^{th} city/county and $\bar{y}$ is the average mortality or helmet use rate of Taiwan as a whole.

We also computed the RR of the rate of the city/county with the highest and the lowest rate and the rate of the East (least-developed) and North (most-developed) regions as the relative term of inequality measure.

Contextual and other explanatory factors

We selected three contextual factors to illustrate the large variations in socioeconomic development across cities/counties in Taiwan: population density (population per square kilometre), percentage of the work force in primary industry (farming, fishing, mining, etc) and annual median disposable household income (US$).[23] The percentage changes in the three indicators between 1997 and 2008 in each city/county were computed.

To explore the effects of changes in other explanatory factors that might be associated with RTI mortality, we analysed three indicators: the number of registered motorcycles per 1000 population as a proxy of road traffic exposure, the number of police-recorded RTI per 10 000 population as proxy of the occurrence of RTI and the number of general beds per 10 000 population as a proxy of access to hospital.[23]

Analysis

For overall RTI mortality, we first calculated the age-adjusted death rate for each city/county using the population structure of Taiwan for the year 2000 as the standard. The age groups used to calculate the age-adjusted rates were 0–14, 15–24, 25–44, 45–64 and 65+ years. We then computed the sex- and age-specific RTI death rates for each city/county. To avoid small numbers of deaths in some sex–age groups in some cities/counties, we combined 3 years together, that is, 1997–1999, 2000–2002, 2003–2005 and 2006–2008.

For motorcycle-related RTI mortality, the Department of Police did not approve of providing the sex- and age-specific numbers of linked cases owing to the liability of identifying specific persons in regions with small populations. We were therefore only able to calculate the crude death rate for each city/county.

For inequality measures, we calculated the BGV and RR of the overall and motorcycle-related RTI mortality rates, helmet use rate and three other explanatory factors across 22 cities/counties for each study year to indicate the changes in inequality after the introduction of the mandatory motorcycle helmet law.

RESULTS

Huge variations in the socioeconomic contextual indicators across the 22 cities/counties were noted (table 1). Taipei City had the highest population density and household disposable income and the lowest percentage of the work force in primary industry in 1997 and 2008. On the contrary, Taitung County was the least-developed region in Taiwan in 1997 and 2008. Most cities/counties, except those in the East region, showed an increase in population density and household disposable income from 1997 to 2008.

Table 2 Mortality from overall road traffic injuries in each city/county and absolute inequality (between-group variance, BGV), relative inequality (rate ratio between the highest and lowest regions or between the east and north regions) and percentage change between 1997 and 2008 in Taiwan

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Change
Whole of Taiwan	31	28	25	24	21	19	19	20	20	19	16	15	−52
North	22	19	18	17	14	13	14	15	14	14	11	10	−54
Taipei City	13	10	8	8	7	6	7	7	7	7	6	5	−61
Hsinchu City	26	27	23	24	20	22	15	15	18	18	14	13	−49
Keelung City	17	17	18	15	14	11	13	15	12	14	10	9	−48
Taipei County	19	16	13	14	11	10	11	12	12	12	10	9	−53
Taoyuan County	33	27	30	28	22	21	22	24	21	22	18	14	−57
Hsinchu County	48	45	43	38	35	28	29	28	28	25	23	24	−50
Yilan County	41	38	40	32	32	28	26	28	25	27	22	22	−48
Middle	36	34	31	29	24	22	21	23	24	24	20	19	−48
Taichung City	13	14	12	10	10	9	11	12	15	12	14	9	−30
Miaoli County	47	42	40	40	34	27	29	27	28	32	23	20	−58
Taichung County	34	28	20	21	14	14	16	19	21	22	19	17	−52
Changhua County	40	38	37	33	28	23	22	23	26	24	22	20	−51
Nantou County	47	44	41	35	31	29	25	30	24	26	20	24	−49
Yunlin County	43	44	51	47	39	41	31	34	38	34	29	29	−33
South	35	32	30	29	27	23	24	25	24	22	19	18	−50
Kaohsiung City	29	21	16	18	17	15	16	16	15	15	11	10	−65
Chiayi City	25	22	22	21	24	20	15	21	18	12	12	9	−64
Tainan City	21	21	19	22	19	16	15	16	19	15	15	15	−28
Chiayi County	45	46	39	34	35	32	31	29	29	27	26	21	−53
Tainan County	40	39	39	37	31	26	28	30	26	27	22	20	−49
Kaohsiung County	40	35	35	34	29	25	27	29	26	23	21	19	−53
Pingtung County	42	41	41	35	40	34	33	34	34	33	30	29	−31
East	70	56	42	47	49	41	40	44	43	40	31	27	−61
Hualien County	61	61	46	45	50	39	40	42	44	37	25	24	−61
Taitung County	81	48	38	51	48	43	41	46	42	43	38	32	−61
Inequality													
BGV	179	157	170	135	129	97	77	82	78	71	52	49	
Highest/lowest	6.25	5.93	6.49	6.32	7.09	7.41	6.02	6.21	6.04	5.85	6.58	6.20	
East/North	3.13	2.92	2.41	2.74	3.44	3.15	2.98	3.00	3.08	2.84	2.66	2.62	

For each city/county, we identified a drastic reduction in the overall RTI mortality rate immediately after passage of the helmet law in 1997 (table 2). It is interesting to note that the two most prosperous metropolitans (Taipei City and Kaohsiung City) and the two least-developed counties in the East region (Hualien County and Taitung County) showed the largest decreasing trends in the overall RTI mortality rate. Nevertheless, some cities/counties (such as Taipei County, Taichung City, Taichung County and Yunlin County) did not exhibit a prominent reduction in the motorcycle-related RTI mortality rate (table 3).

In terms of the absolute inequality measure, the BGV of the overall and motorcycle-related RTI mortality rates across the 22 cities/counties exhibited persistently decreasing trends from 1997 to 2008 (tables 2 and 3 and figure 1). However, with regards to the relative inequality measure, the RR of the overall and motorcycle-related RTI mortality rates between the city/county with the highest and the lowest rate kept on increasing after passage of the helmet law, reaching a maximum in 2002, and then levelled off (tables 2 and 3 and figure 1). The decreasing trend in inequality was most prominent in males aged 0–24 years (table 4).

Table 5 reveals the estimated rate of motorcycle helmet use for each city/county in Taiwan from 1997 through 2008. The helmet use rate increased drastically from 1997 through 2002 and then levelled off, the rate for Taiwan as a whole being 93% in 2002 and decreasing to 88% in 2008. Hsingchu City, Taipei County, Miaoli County and Yunlin County had a helmet use rate lower than 80% in 2008, and Hsingchu City, Taipei County and Yunlin County showed the largest decrease in the helmet use rate from 2002 to 2008. The absolute and relative terms of inequality in the helmet use rate decreased from 1997 to 2002 and then increased onwards.

Regarding other explanatory factors associated with mortality from RTI, we found that most cities/counties had a one-third increase in registered motorcycles per 1000 population, a one-third decrease in reported RTI per 10 000 population and no prominent change in general beds per 10 000 population from 1997 to 2008 (table 6). The absolute term of inequality (BGV) increased for owning a motorcycle, decreased for the occurrence of reported RTI and did not change for access to hospitals from 1997 to 2008.

DISCUSSION

The findings of this study indicate a drastic decrease in the absolute term of inequality in overall and motorcycle-related RTI mortality after passage of the motorcycle helmet law, which persisted throughout the study period. However, the relative term of inequality in RTI mortality first increased and then levelled off, as predicted by the inverse equity hypothesis proposed by Victora *et al*.[4] With regard to the motorcycle helmet use rate, the absolute and relative terms of inequality exhibited a decreasing trend after passage of the helmet law, but an increase in inequality in the rate of helmet use was noted 5 years after passage of the law.

Table 3 Mortality from motorcycle-related road traffic injuries in each city/county and absolute inequality (between-group variance, BGV), relative inequality (rate ratio between the highest and lowest regions or between the east and north regions) and percentage change between 2001 and 2008 in Taiwan

	2001	2002	2003	2004	2005	2006	2007	2008	Change
Whole of Taiwan	12	11	11	12	12	12	11	10	−14
North	7	7	7	8	8	8	7	6	−11
Taipei City	4	3	3	4	4	4	3	3	−16
Hsinchu City	13	12	8	9	10	11	11	9	−30
Keelung City	7	6	7	8	6	7	6	5	−27
Taipei County	5	6	5	6	7	7	6	6	7
Taoyuan County	10	11	11	12	11	12	10	8	−17
Hsinchu County	17	15	14	15	16	14	15	14	−16
Yilan County	20	16	17	13	17	19	12	16	−21
Middle	13	14	12	15	16	15	13	13	−7
Taichung City	5	4	6	8	9	8	9	6	20
Miaoli County	20	15	16	13	16	19	12	13	−35
Taichung County	7	8	9	12	12	13	11	11	55
Changhua County	15	14	13	14	17	16	14	13	−13
Nantou County	17	17	14	16	13	15	12	16	−8
Yunlin County	20	28	19	23	22	24	22	20	3
South	15	13	15	15	15	16	14	12	−18
Kaohsiung City	10	10	12	10	10	11	7	7	−32
Chiayi City	12	12	8	14	10	7	8	4	−68
Tainan City	11	8	9	10	13	9	11	11	−5
Chiayi County	21	18	18	17	16	17	19	15	−29
Tainan County	16	16	17	18	16	16	15	14	−11
Kaohsiung County	18	15	18	20	19	18	17	14	−21
Pingtung County	25	21	22	22	24	27	22	21	−13
East	25	24	24	26	24	28	21	18	−25
Hualien County	24	24	23	24	23	23	17	17	−29
Taitung County	25	25	26	28	26	34	26	20	−22
Inequality									
BGV	42	41	33	34	33	40	30	26	
Highest/lowest	6.81	9.83	7.37	7.25	6.99	7.69	7.83	6.97	
East/North	3.41	3.40	3.43	3.33	3.09	3.37	2.97	2.86	

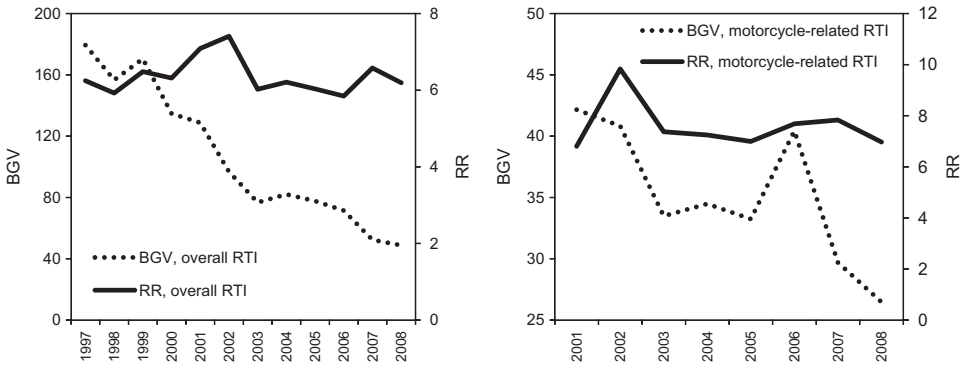

Figure 1 Changes in absolute inequality (between-group variance, BGV) and relative inequality (rate ratio between the highest and lowest regions, RR) in mortality from road traffic injuries (RTIs) from 1997 through 2008 in Taiwan (left: overall RTIs; right: motorcycle-related RTIs).

Strengths and limitations

One strength of this study was the high percentage of motorcycle use as the main method of transportation in Taiwan, which provided a good opportunity to examine the possible effects of passage of the motorcycle helmet law on reducing the regional inequality in mortality from RTI. A second strength was the examination of the rate of motorcycle helmet use in each city/county, which is the intermediate factor between passage of the motorcycle helmet law and RTI mortality. The information this study provided could enable a better understanding of the mechanisms and pathways resulting in changes in regional inequality in RTI mortality.

However, several limitations should be noted in interpreting the findings of this study. First, the motorcycle-related RTI mortality in each city/county was estimated according to linked data between the mortality file of the Department of Health and the road traffic injury file of the Department of Police, and the percentage of road traffic injury reports in which an ID number was reported might differ in different cities/counties, resulting in differing linkage rates across the various cities/counties. Furthermore, some RTI deaths recorded in the mortality file might not be reported to police officers and may therefore not be recorded in the road traffic injury file.

The second limitation was the selection of three indicators as proxies of explanatory factors associated with RTI mortality, which might not be ideal measures of the real exposure to motorcycles, incidence of RTI and access to hospitals. In addition, the changes in regional inequality in RTI mortality might be due to differential development of the road traffic infrastructure, such as the establishment of mass transit systems in Taipei City and Kaohsiung City. We also found that some cities/counties have already reached the ceiling effect of helmet use rate (more than 95%), but still exhibit a decrease in the RTI rate: that is to say, many other explanatory factors are working to reduce RTI mortality.

The third limitation was that the motorcycle helmet use rate in each city/county might be underestimated because the estimation was based on the helmet use rate among motorcyclists suffering RTI reported to the police. As many RTIs involve violation of traffic laws, it is reasonable to hypothesise that people who violated some traffic laws might be less compliant with the motorcycle helmet law.

Table 4 Absolute inequality (between-group variance, BGV) and percentage change between 1997–1999 and 2006–2008 and relative inequality (rate ratio between the highest and lowest regions, RR) in mortality from overall road traffic injuries by sex and age in Taiwan

	BGV					RR				
	1997–1999	2000–2002	2003–2005	2006–2008	Change	1997–1999	2000–2002	2003–2005	2006–2008	Change
Males and females										
0–14 yr	10	5	3	3	−72	11.9	7.8	7.4	8.9	−26
15–24 yr	223	165	91	57	−74	4.6	4.4	3.9	3.3	−28
25–44 yr	139	91	66	52	−63	6.6	9.2	7.8	8.6	30
45–64 yr	373	254	175	115	−69	6.2	8.4	8.3	8.4	36
65+ yr	646	724	467	372	−42	3.3	4.7	4.7	5.3	60
All ages	161	117	77	56	−65	5.4	6.8	6.0	6.2	15
Males										
0–14 yr	14	7	4	5	−62	13.6	9.5	5.7	9.5	−30
15–24 yr	587	451	226	137	−77	5.0	4.8	3.9	2.9	−41
25–44 yr	295	196	142	122	−59	5.3	8.0	7.4	7.7	46
45–64 yr	736	490	332	221	−70	7.2	8.6	8.3	8.6	21
65+ yr	1746	1711	1045	917	−47	3.8	5.4	5.1	6.5	74
All ages	355	258	160	125	−65	5.5	6.9	6.0	6.1	12
Females										
0–14 yr	9	4	4	2	78	7.8	5.4	13.8	7.0	−11
15–24 yr	31	22	19	14	56	3.3	3.3	3.5	4.5	34
25–44 yr	24	17	13	7	69	9.7	9.3	4.4	8.4	−13
45–64 yr	129	88	61	39	70	3.7	7.1	7.5	7.3	97
65+ yr	114	188	147	103	9	2.4	2.6	3.4	3.2	34
All ages	35	26	20	12	65	4.2	5.3	4.8	5.5	31

Table 5 Estimated helmet use rate among motorcyclists in each city/county and absolute inequality (between-group variance, BGV), relative inequality (rate ratio between the highest and lowest regions or between the east and north regions) and percentage change between 2002 and 2008 in Taiwan

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Change
Whole of Taiwan	45	72	77	82	89	93	91	91	90	89	89	88	−11
North	56	87	81	89	94	96	96	95	94	91	89	86	−18
Taipei City	64	93	95	98	99	99	99	98	97	98	97	97	−3
Hsinchu City	24	41	52	60	79	88	90	88	90	87	84	70	−75
Keelung City	37	67	85	89	91	95	88	89	92	94	97	93	−5
Taipei County	38	67	79	85	93	97	98	98	95	87	81	75	−58
Taoyuan County	41	65	75	84	92	94	93	92	93	91	93	95	1
Hsinchu County	27	34	57	64	77	84	87	86	85	84	83	87	10
Yilan County	29	59	65	75	81	91	90	91	92	93	94	96	15
Middle	31	55	69	73	85	90	91	90	90	90	90	87	−9
Taichung City	35	56	72	79	92	97	98	98	98	98	98	98	5
Miaoli County	18	69	52	65	77	84	80	72	77	76	78	79	−27
Taichung County	33	55	63	74	92	96	95	94	95	92	96	93	−10
Changhua County	19	29	57	70	84	92	93	95	94	93	91	86	−32
Nantou County	16	43	48	52	72	87	90	81	76	81	87	84	−15
Yunlin County	22	22	33	62	65	74	68	65	61	61	57	56	−82
South	42	71	81	81	87	92	88	87	87	87	88	89	−7
Kaohsiung City	44	70	72	83	89	92	89	89	93	96	97	97	11
Chiayi City	17	80	93	97	98	98	99	100	99	99	97	90	−46
Tainan City	42	76	85	88	94	97	93	92	94	93	94	95	−4
Chiayi County	41	36	46	73	76	88	82	80	83	81	80	82	−14
Tainan County	25	41	66	67	81	90	88	87	85	86	88	90	−2
Kaohsiung County	28	41	40	59	79	89	85	84	81	76	77	80	−33
Pingtung County	31	53	41	53	76	88	86	83	81	80	81	80	−27
East	31	59	74	82	88	89	91	90	90	89	91	94	16
Hualien County	27	64	84	87	92	93	98	94	93	91	93	96	9
Taitung County	45	51	58	72	86	85	86	86	85	87	90	91	13
Inequality													
BGV	169	221	149	168	78	31	48	58	66	69	78	95	
Highest/lowest	4.10	4.21	2.84	1.87	1.52	1.34	1.46	1.54	1.64	1.64	1.71	1.76	
East/North	0.56	0.68	0.91	0.93	0.94	0.92	0.95	0.95	0.95	0.98	1.03	1.08	

Enforcement and compliance of motorcycle helmet use

Despite the possibility of underestimation of the helmet use rate, we still found quite different patterns of change in the motorcycle helmet use rate in different cities/counties. Some cities/counties (Taipei City, Keelung City, Taoyuan County, Yilan County, Taichung County, Kaohsiung City and Tainan City) had persistently high helmet use rates from 2001 through 2008; however, other cities/counties (Hsingchu City, Taipei County, Miaoli County and Yunlin County) had a helmet use rate lower than 80% in 2008, and Hsingchu City, Taipei County and Yunlin County exhibited a gradual decrease in the helmet use rate since 2002.

Previous studies have also revealed regional differences in the increase in the helmet use rate after passing of the legislation and the decrease in the helmet use rate several years after the legislation was passed.[24 25] Legislation mandating the use of bicycle helmets by all children younger than 18 years was introduced in the city of East York, Ontario, in October 1995, and an evaluation in 1996 suggested that the effect of the legislation was most powerful among children who resided in low-income areas, the helmet use rate being 33% in 1995 and increasing to 61% in 1996.[24] Sadly, the helmet use rate in middle- and low-income areas returned to the prelegislation level (50% and 33%, respectively) in 2001, 6 years after introduction of the legislation.[25]

The decline in the helmet use rate several years after passage of the helmet law might be partially due to a decrease in rigorous enforcement of the law by the police and partially due to cyclists' compliance. In most cases, enforcement of traffic laws involves the compliance of individuals in terms of a certain behaviour, such as avoiding speeding or drunk-driving, and the use of restraints in vehicles.[3] Compliance with these legally prescribed behaviours also varies by socioeconomic status: for example, rear-passenger seatbelt use has been compulsory in the UK since 1991; however, an observational study indicated that only 74% of rear passengers wear seatbelts, and a 2.2-fold increase in the wearing of seatbelts was observed between the lowest and highest socioeconomic position (SEP) groups.[26]

The strength of enforcement of the motorcycle helmet law by the police might differ in different cities/counties across Taiwan. Policing behaviour is not as highly structured by law as most people would expect. In reality, the task of individual police officers is to negotiate various uncertainties to achieve a resolution that is optimal for the officer, his/her agency, the citizen(s) involved and the public at large.[27] Study has also revealed that the collective police culture has an impact on police discretion and varies between large urban and small rural agencies.[28] Further studies are needed to explore the regional inequality in policing factors across cities/counties in Taiwan.

Policy implications

As indicated by Margret Whitehead, not all inequalities in health can be described as inequities.[29] The term inequity refers to inequalities in health that are unnecessary and avoidable. Whitehead classifies only four out of seven determinants of health inequalities as unnecessary and avoidable. Inequalities in

Table 6 Selected explanatory factors associated with mortality from road traffic injuries in each city/county and percentage change between 1997 and 2008 in Taiwan

	Registered motorcycles per 1000 population			Road traffic injuries per 10 000 population			General beds per 100 000 population		
	1997	2008	Change	1997	2008	Change	1997	2008	Change
Whole of Taiwan	464	623	34	1.3	0.9	−31	30	32	7
North	413	519	26	1.1	0.6	−45	34	32	−6
Taipei City	335	412	23	0.8	0.3	−63	51	53	3
Hsinchu City	526	636	21	1.4	0.7	−50	30	30	2
Keelung City	352	482	37	1.1	0.4	−64	39	35	−10
Taipei County	426	580	36	0.6	0.4	−33	14	15	11
Taoyuan County	426	543	28	1.2	0.7	−42	39	35	−9
Hsinchu County	435	527	21	2.3	1.5	−35	21	17	−18
Yilan County	498	626	26	2.1	1.7	−19	43	41	−6
Middle	483	642	33	1.4	1.1	−21	26	30	15
Taichung City	460	595	29	1.3	0.6	−54	44	51	15
Miaoli County	472	615	30	2.4	1.2	−50	25	29	15
Taichung County	474	637	34	0.8	1.0	25	20	27	36
Changhua County	503	677	35	1.2	1.1	−8	22	28	27
Nantou County	476	646	36	2.9	1.6	−45	26	23	−14
Yunlin County	484	663	37	1.3	1.6	23	18	24	37
South	532	757	42	1.9	1.1	−42	32	35	9
Kaohsiung City	558	790	42	1.5	0.5	−67	44	42	−5
Chiayi City	576	726	26	1.6	0.5	−69	53	65	24
Tainan City	547	753	38	4.0	0.5	−88	41	32	−22
Chiayi County	491	654	33	2.0	1.9	−5	12	25	109
Tainan County	502	718	43	0.9	1.5	67	22	24	12
Kaohsiung County	542	804	48	1.5	1.3	−13	26	28	7
Pingtung County	529	774	46	0.9	1.7	89	29	31	5
East	519	719	39	3.7	2.0	−46	39	38	−3
Hualien County	512	1025	100	3.8	1.9	−50	46	44	−5
Taitung County	521	511	−2	3.6	2.3	−36	32	32	0
Inequality									
BGV	4454	15 055		0.70	0.28		175	152	
Highest/lowest	1.72	2.49		6.67	7.67		4.40	4.21	
East/North	1.26	1.39		3.36	3.33		1.15	1.19	

health due to health-damaging behaviours in which the choice of lifestyle is severely restricted are unnecessary and avoidable. Not wearing a motorcycle helmet is a health-damaging behaviour in which the choice is shaped by social context (strength of enforcement by the police and a law-abiding culture). It is unfair and unjust that the police in different cities/counties enforce the motorcycle helmet law to different degrees, resulting in huge differences in the helmet use rate and ultimately causing large differences in the RTI mortality rate.

To avoid unnecessary RTI deaths and to ensure a high compliance with the helmet use law in every city/county in Taiwan, it is necessary to establish a helmet use surveillance system to identify whether some cities/counties have experienced a decline in the helmet use rate several years after passage of the helmet law. The Department of Police could use this information to urge Police Bureaus in some cities/counties to improve the helmet use rate.

In conclusion, in Taiwan, passage of the motorcycle helmet law reduced the inequality in RTI mortality between regions of differing socioeconomic development. Nevertheless, analysis of helmet use also indicated an increase in inequality in the rate of helmet use across regions 5 years after passage of the law. It is therefore necessary to monitor the helmet use rate after passage of a motorcycle helmet law to ensure the effect of a reduction in regional inequality in RTI mortality.

'All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) (initials of relevant authors) have support from (name of company) for the submitted work; (2) (initials of relevant authors) have (no or specified) relationships with (name of

What is already known on this subject

- It has been proven that passage of mandatory motorcycle helmet laws effectively reduces motorcycle head injuries, hospitalisations and deaths.
- However, little is known regarding the effect of motorcycle helmet laws on reducing regional inequality in mortality from road traffic injuries (RTIs).

What this study adds

- In Taiwan, passage of the motorcycle helmet law reduced the regional inequality in the overall and motorcycle-related RTI mortality.
- However, a resurgence in regional inequality in the helmet use rate 5 years after passage of the helmet law was noted.

Policy implications

- It is necessary to monitor the helmet use rate after passage of a motorcycle helmet law to ensure the effect of a reduction in regional inequality in RTI mortality.

companies) that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners or children have (specified) financial relationships that may be relevant to the submitted work and (4) (initials of relevant authors) have no (or specified) non-financial interests that may be relevant to the submitted work.'

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Physician arrested for speeding

A Japanese physician has been arrested after a joy ride in a $220 000 Ferrari driving at 124 km/h in 40 km/h zone. The 50-year-old doctor faces up to six months in jail and a fine of about $1200. After posting the escapade on YouTube, local police caught up with him. When arrested, the doctor boasted "I wanted to make a Ferrari promotional video".