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Motorcyclist accident involvement by age, gender, and risky behaviors in Taipei, Taiwan

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Abstract

This study aimed to investigate the relationship between age, gender, and risky behaviors of motorcyclists and their involvement in accidents. The results of a self-reported survey on motorcyclist behavior in the Taipei metropolitan area were analyzed. A two-step cluster analysis was used to classify motorcyclist behavior to different levels of risk within each of three risky behavior types. This was used to examine the regression relationship with accident risk. The results indicated that young and male riders were more likely to disobey traffic regulations, and that young riders also had a higher tendency towards negligence of potential risk and motorcycle safety checks. These "error" and "violation" behaviors increased the likelihood of an accident. However, in addition to these risks, there are additional factors that put young riders, particularly young female riders with the least riding experience, at increased risk of having an accident. These additional factors may be poor driving skills and less experience, all of which may result from the slack motorcycle licensing system. There should be increased emphasis on the necessity of providing appropriate training and a lower risk environment for novice riders.

Keywords: Risky behaviors; Accident involvement; Motorcyclists; Two-step cluster analysis; Logistic regression

1. Introduction

The associations between drivers' age, gender, and driving behavior, and involvement in accidents are important factors in developing traffic safety strategies. Motorcycle riders have an increased likelihood of being involved in an accident compared with other motor vehicle drivers (Mannering & Grodsky, 1995; Plasència, Borrell, & Antó, 1995). However, most studies exploring the relationships between risk factors and involvement in accidents have focused on the drivers of motor vehicles with four or more wheels, and relatively few studies have focused on motorcyclists, particularly on the risks of minor injuries and property damage only (PDO) accidents (Lin, Chang, Pai, & Keyl, 2003). Therefore, to gain a better understanding of

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motorcycle riding behaviors, it is valuable to extend our focus to the risk factors that contribute to motorcyclist minor accidents.

Young and male motorcycle riders have a stronger propensity for risky behaviors, and these behaviors have been shown to be associated with increased risks of accidents (Lin et al., 2003; Rutter & Quine, 1996). Young riders and male riders also perceived themselves to be at a greater risk of accidents (Mannering & Grodsky, 1995). Rutter and Quine (1996) identified particular patterns of youth behaviors, such as a willingness to break the law and to violate the rules of safe riding, which had a much greater role in accident involvement than inexperience.

However, riding experience does seem more important for motorcyclists than for drivers of vehicles with more than two wheels, possibly because motorcycle riding requires particular control and balance skills. In several countries, the use of graduated licensing systems have highlighted that novice motorcycle riders should first gain experience in a lower risk environment to reduce their disproportionate accident rate (Haworth & Mulvihill, 2005). Since almost all motorcycle riders (engine capacity lower than 250 cc) in Taiwan are self-taught with a lack of appropriate driving education or training, riders may accumulate their experience via trial-and-error process and tend to overlook the importance of safe riding concepts.

To reduce the incidence of accidents, it is important to uncover how age and gender affect risky behaviors, and how age and gender combine with risky behaviors to influence accident involvement. Consequently, the first objective of this study was to investigate whether young and male riders had a greater propensity for risky behaviors, and whether they had a greater likelihood of being involved in non-fatal accidents. In addition, whether there is any domination of these risky behaviors on accident involvement in different age and gender cohorts were also explored.

2. The motorcycle licensing system in Taiwan

The motorcycle licensing system in Taiwan classes motorcycles according to engine capacity: mopeds (engine capacity less than 50 cc), light motorcycles (50–250 cc), and heavy motorcycles (greater than 250 cc).[1] Without additional speed or power limitations for vehicles, engine capacity is the only classification standard (Taiwan MOTC, 2002a).

Motorcycles with engine capacities more than 150 cc were prohibited from registration in 1980 due to the oil crisis in the early 1980s. The licensing system was amended in July 2002 because the government promised the import of motorcycles greater than 150 cc after Taiwan joined the World Trade Organization (WTO). Prior to the amendment of the regulations, the licensing system set 50 cc as the marker to distinguish mopeds and heavier motorcycles.

Since heavy motorcycles have only recently been included into the licensing system, the number of heavy motorcycles is still small (less than 1% of the total number of registered motorcycles). However, mopeds and light motorcycles (especially those with engine capacities less than 150 cc) are popular in Taiwan because of their easy operation and low cost for short trips, even though they are prohibited from the expressways and freeways. At the end of 2003, the total number of motorcycles comprised 67% of all motor vehicles (1.8 motorcycles per household), and more than 99% of these were mopeds and light motorcycles (MOTC, 2004).

The minimum licensing age for mopeds and light motorcycles is 18 years, whereas for heavy motorcycles, the minimum age is 20 years. Except for medical examinations, no prior experience or compulsory training is required for mopeds and light motorcycles before the license tests. An individual can obtain a moped license simply by passing the theoretical test, or obtain a light motorcycle license by passing the theoretical and practical tests. In contrast, heavy motorcycle licenses require an individual to have held a light motorcycle license for at least 1 year, and to have completed 32 h of compulsory training at a driving school before completing the theoretical and the practical tests.

[1] The direct translations for the three classes of motorcycles from Taiwan's Road Traffic Regulations are light motorcycles, heavy motorcycles, and extra heavy motorcycles. However, these titles appear not to conform with international convention if we take into consideration the range of engine capacity. For convenience of international comparison, it seems more appropriate to use "mopeds", "light motorcycles", and "heavy motorcycles" as the three classes.

Without compulsory education and training requirements for mopeds and light motorcycles, almost all riders gain experience and skills by a process of self-learning. The casual management of these two types of motorcycle license has raised concerns over their safety.

3. Methods

3.1. Subjects and measures

In 2001, the MOTC Department of Statistics conducted a self-reported survey on motorcycle use, riding behavior and accident incidence over the previous year. Motorcycles registered in Greater Taipei were randomly selected from the vehicle registration system and 6134 questionnaires were sent to the owners of these motorcycles. The main user of each motorcycle was asked to answer the questions and 1451 questionnaires were returned – a respondent rate of 23.7%. Thirty-seven percent of respondents rode mopeds and 63% rode light motorcycles, only four of which had engine capacities of 150–250 cc. Even though the respondent rate was quite low, except for male riders aged 50 years or more, the sample distribution reflected the population distribution of licensed riders in Greater Taipei (Table 1).

The Taiwan police accident database mainly records accidents involving occupant injuries or fatalities, so unreported PDO or minor injury crashes have not been recorded by any of the official reporting systems. It is believed that a large proportion of PDO and minor injury crashes in Taiwan have not been reported because the accident reporting policy only includes more severe injury or fatal crashes. In contrast to automobile drivers, motorcyclists seem more likely to be involved in these unreported crashes, possibly owing to the lack of stability associated with motorcycle riding. To have a more complete understanding of motorcyclist involvement in accidents, the self-reported accident records were used in this study, which mainly included PDO and injury crashes, and obviously excluded fatalities due to the self-reported nature.

Data on mileage, motorcycle type, risky behavior and several useful demographic factors were obtained from the questionnaires. Mileage was measured by the average distance traveled each day in kilometers, and respondents were divided into riders of mopeds and of light motorcycles. Demographic data included gender, age, education level, and average monthly income. Based on their age, the motorcyclists were divided into four categories (<20, 20–29, 30–49, and ⩾50 years). The motorcyclists were classified into two categories according to education level (attended college or not). They were also divided into two groups according to average monthly incomes (greater or less than 30,000 New Taiwan (NT) dollars, which is approximately equal

Table 1
Comparisons between sample and population distributions

Gender	Age	Sample	Population[b]
Male	<20	34[a] (2.4%)	27,403 (1.1%)
	20–29	249 (17.5%)	378,663 (15.2%)
	30–49	452 (31.8%)	777,256 (31.2%)
	50+	196 (13.8%)	458,382 (18.4%)
	Subtotal	931 (65.5%)	1,641,704 (65.9%)
Female	<20	18 (1.3%)	12,456 (0.5%)
	20–29	155 (10.9%)	281,506 (11.3%)
	30–49	263 (18.5%)	458,382 (18.4%)
	50+	55 (3.9%)	97,157(3.9%)
	Subtotal	491 (34.5%)	849,501 (34.1%)
Total		1422 (100%)	2,491,205 (100%)

[a] In the "<20" category, only one male rider is under the age limit of 18 years and all female riders are aged 18–20 years.

[b] Population represents the number of moped and light motorcycle licenses among different age and gender riders in Greater Taipei at the end of 2000.

Table 2
Detailed questions used to measure the three types of risky behaviors

Behavior facet	Code number	Measuring items
Negligence of potential risk	R1	1. While riding or turning, what was your frequency of not using the mirror to notice other vehicles?
	R2	2. During early night or dawn, what was your frequency of not using the headlight?
	R3	3. While turning, what was your frequency of not using the turning signal?
	R4	4. While waiting at the stop line for a red light, what was your frequency of rush running at the start of the green light?
	R5	5. When blocked by a car in front of you, what was your frequency of overtaking it, followed by a sudden braking on purpose to let off your dissatisfaction?
	R6	6. When a heavy vehicle was near to you, what was your frequency of not keeping a sufficient distance from it?
	R7	7. In order to ride faster, what was your frequency of squeezing through an extremely narrow space between other vehicles?
Violation	V1	1. What was your frequency of riding while intoxicated?
	V2	2. What was your frequency of riding in the opposite direction?
	V3	3. What was your frequency of running through a red light?
	V4	4. While interrupted by slow moving or temporarily parked vehicles, what was your frequency of riding through a prohibited lane?
	V5	5. When encountering a two-phased left turning intersection[a] for motorcycles, what was your frequency of making a direct left turn?
	V6	6. What is your usual highest speed on urban roads?
	V7	7. What is your usual highest speed on rural roads?
Negligence of vehicle examination	N1	1. Before riding, what is your frequency of not examining the braking system?
	N2	2. Before riding, what is your frequency of not examining the tire condition?
	N3	3. Before riding, what is your frequency of not examining the function of the headlight, turning signal, and braking light?

[a] A two-phased left turning intersection, as defined by Taiwan's traffic regulations, requires the left turning motorcyclists to wait temporarily in front of the stop line of the transverse direction, and to depart when the green light of that direction turns on. It is usually installed on a running direction over two lanes.

to US$900). To assess risky behaviors, three types of behavior patterns were identified: negligence of potential risk, (law) violation, and negligence of motorcycle safety checks.

The questions used to determine the three types of risky behaviors are listed in Table 2. Except for the highest riding speed on urban and rural roads (V6 and V7 items), the frequency of each behavior was measured on an ordinal scale: possible responses were "never", "occasionally", and "frequently". "Speeding" is defined as a motorcyclist riding faster than the 50 kph speed limit on urban roads and the 60 kph limit on rural roads, according to the traffic regulations. We classified responses regarding speeding into one of three options: without speeding, speeding by no more than 20 kph, and speeding by more than 20 kph.

3.2. Measuring risky behaviors

Driving errors and violations have been used to determine accident liability (Underwood, Chapman, Wright, & Crundall, 1997). According to Parker, West, Stradling, and Manstead (1995), violations can be described as "deliberate deviations from safe driving practice", whereas errors can be described as "driving mistakes or omissions". The driver's intent can usually be used to distinguish driving errors and violations.

The term "negligence of the potential risk" can be used to describe motorcyclists' inattention to their potentially dangerous behaviors that might lead to a crash. This is a similar description to that of "errors" mentioned above. Motorcyclists are less visible than other automobiles, and engaging in risky behaviors such as approaching heavy vehicles, accelerating at high speed from a green light, and squeezing through narrow spaces between other vehicles, as well as driving without using the mirrors, the turning signal or the headlights can all increase this risk. Seven detailed questions were used to measure this in this study.

Another type of risky behavior is deliberate risk-taking, where people are usually aware that their behavior may be dangerous or illegal, but they still do it. This behavior can be classified as "violations", and includes behaviors such as riding while intoxicated, speeding, and driving through a red light. Seven questions were used to measure "violation" behaviors.

The third type of risky behavior measured was "negligence of motorcycle examination". Although little research has focused on this, we believe this kind of behavior may be worthy of studying. Motorcycle riding is associated with instability and poor visibility, so regularly and routinely examining the brakes, lights, and tires is crucial to the safety of motorcyclists. Three questions were used to assess this type of behavior.

3.3. Statistical methods

3.3.1. Two-step cluster analysis

Composite measurements of the individual responses to each behavior question may be useful to investigate the propensity of specific risky behaviors and to determine a regression relationship with accident involvement. However, since the individual ordinal scales do not follow the linearity and additive nature of measurements, direct assignment of weightings to the ordinal scales may produce methodological problems. Therefore, a two-step cluster analysis was separately applied to differentiate risky clusters within each of the three behavioral types.

The two-step cluster analysis described by Chiu, Fang, Chen, Wang, and Jeris (2001) involves two steps (pre-cluster and cluster steps) and is effective for very large datasets with both continuous and categorical variables. In the first pre-cluster step, observations are pre-clustered using log-likelihood distances, creating a cluster feature "tree". In calculating the log-likelihood, the continuous variables are assumed to be normally distributed, and the categorical variables are assumed to follow multinomial distributions. The resulting sub-clusters are further grouped in the second step by comparing their distances to a specified threshold. If the log-likelihood distance is larger than the threshold, the two clusters are merged. The distance $D(j,s)$ between two clusters j and s, is defined as the decrease in log-likelihood due to merging of the two clusters:

$$D(j,s) = \xi_j + \xi_s - \xi_{\langle j,s\rangle} \quad (1)$$

where

$$\xi_j = -N_j\left[\sum_{k=1}^{K^A}\frac{1}{2}\log(\hat{\sigma}_k^2 + \hat{\sigma}_{jk}^2) + \sum_{k=1}^{K^B}\hat{E}_{jk}\right] \quad \text{and} \quad \hat{E}_{jk} = -\sum_{l=1}^{L_k}\frac{N_{jkl}}{N_j}\log\frac{N_{jkl}}{N_j}$$

and where K^A is the total number of continuous variables used, K^B is the total number of categorical variables used, L_k is the number of levels for the kth categorical variable, N_j is the number of observations in cluster j, $\hat{\sigma}_k^2$ is the variance of the kth continuous variable in the original data set, $\hat{\sigma}_{jk}^2$ is the variance of the kth continuous variable in cluster j, N_{jkl} is the number of observations in cluster j whose kth categorical variable takes the lth level, and $\langle j,s\rangle$ represents the cluster formed by merging clusters j and s. Since all variables in this study are categorical variables, the above ξ_j could be reduced to $-N_j\left[\sum_{k=1}^{K^B}\hat{E}_{jk}\right]$.

According to Bacher, Wenzig, and Vogler (2004), the optimal number of clusters can be determined using a two-phase estimator. In the first phase, either a Bayesian or Akaike Information Criterion (BIC and AIC) is computed to obtain a good initial estimate of the maximum number of clusters. For J clusters, we have,

$$\mathrm{BIC}(J) = -2\sum_{j=1}^{J}\xi_j + m_J\log(N) \quad (2)$$

$$\mathrm{AIC}(J) = -2\sum_{j=1}^{J}\xi_j + 2m_J \quad (3)$$

where $m_J = J\left[2K^A + \sum_{k=1}^{K^B}(L_k - 1)\right]$ and N is the total number of observations. The maximum number (J-max) of clusters is set equal to the number of clusters where the ratio BIC(J-max)/BIC(1) is smaller than c_1 ($c_1 = 0.04$).[2]

The second phase uses the ratio change $R(J)$ in distance for J clusters, defined as

$$R(J) = D_{J-1}/D_J \tag{4}$$

where D_{J-1} is the distance if J clusters are merged to $J-1$ clusters. The distance D_J is defined similarly.[3] The ratio change is computed as,

$$R(J_1)/R(J_2) \tag{5}$$

for the two largest values, $R(J_1)$ and $R(J_2)$, of $R(J)$ ($J = 1, 2, \ldots, J$-max; J-max obtained from the first step). If the ratio change is larger than the threshold value c_2 ($c_2 = 1.15$)[2], the number of clusters is set equal to J_1, otherwise the number of clusters is set equal to the solution with max (J_1, J_2).

3.3.2. Logistic regression model

The binary dependent variable postulated in the logistic regression model could indicate whether any accident occurred for a motorcycle rider in one year. The form of the logistic regression equation is (McCullagh & Nelder, 1989):

$$\ln P(X)/(1 - P(X)) = \alpha + \sum_{i=1}^{n} \beta_i x_i \tag{6}$$

where $P(X)$ is the probability that a motorcyclist experiences at least one accident during the one-year survey period, which is the function of a vector of independent variable X, where α is the constant of the equation and β_i is the coefficient of the ith independent variable.

The coefficients of the logistic model can be obtained from the maximum likelihood estimation (MLE) method. A Wald test, which follows an asymptotic χ^2 distribution with one degree of freedom, is usually used to test the statistical significance of each coefficient, β_i, that is:

$$\text{Wald} = (\hat{\beta}_i/\text{SE}(\hat{\beta}_i))^2 \sim \chi_1^2 \tag{7}$$

where $\hat{\beta}_i$ is the ith estimated coefficient, and SE($\hat{\beta}_i$) is the standard error of the ith estimated coefficient.

To interpret the model, logit (i.e. $\ln p/(1-p)$) can be converted easily into a statement about the odds ratio (OR) of the dependent variable simply by using the exponential function. Specifically, the x_i variable increases one unit while the remaining variables are held constant, the OR for these two values for x_i will be $\exp(\hat{\beta}_i)$.

4. Results

4.1. Two-step cluster analysis on risky behaviors

The three types of risky behaviors – negligence of potential risk, violation, and negligence of vehicle examination – were abbreviated to R-facet, V-facet, and N-facet, respectively. For each behavior type, the respondents were optimally divided into two clusters (a higher and a lower risk tendency) according to the two-phase estimator in the two-step cluster analysis (Table 2).

First, classification of respondents into the same cluster (either higher or lower risk tendency) in the R-facet was mainly due to the relative similarity of all the seven items in the cluster. The percentages in Table 3 were summed to 100% for the individual behavior question in each distinct cluster. For example, in the case of R1, 21.7% of motorcyclists in cluster 1 "occasionally" or "frequently" did not use their mirrors to notice other vehicles; in contrast, 78.3% in cluster 1 always used their mirrors. However, none of the motorcyclists in clus-

[2] According to Bacher et al. (2004), both c_1 and c_2 are based on simulation studies of the authors of SPSS Two Step Clustering through the personal information from SPSS Technical Support.

[3] The distance D_J can be computed from the SPSS output in the following way: $D_J = S_{J-1}S_J$ where $S_v = (m_v \log(N) - \text{BIC}_v)/2$ or $S_v = (2m_v - \text{AIC}_v)/2$ for $v = J-1, J$. However, using BIC or AIC may result in different solutions (Bacher et al., 2004).

Table 3
Percentages of respondents demonstrating the respective clustered risky behaviors

Behavior facet	Code number	Item category	Cluster 1 (Higher tendency) (%)	Cluster 2 (Lower tendency) (%)
Negligence of potential risk (R-facet)	R1	Never	78.3	100.0
		Occasionally+[a]	21.7	0.0
	R2	Never	95.9	99.3
		Occasionally+	4.1	0.7
	R3	Never	90.8	100.0
		Occasionally+	9.2	0.0
	R4	Never	42.9	100.0
		Occasionally+	57.1	0.0
	R5	Never	69.8	100.0
		Occasionally+	30.2	0.0
	R6	Never	87.2	98.2
		Occasionally+	12.8	1.8
	R7	Never	19.7	100.0
		Occasionally+	80.3	0.0
Frequency within R-facet (Percentage)			1040 (72.5%)	394 (27.5%)
Since $R(J_1)/R(J_2) = 1.87$ (2-clusters)/1.33 (4-clusters) $= 1.41 > 1.15$[b], the optimal number of clusters is 2.				
Violation (V-facet)	V1	Never	85.0	94.2
		Occasionally+	15.0	5.8
	V2	Never	47.2	70.1
		Occasionally+	52.8	29.9
	V3	Never	63.9	85.0
		Occasionally+	36.1	15.0
	V4	Never	18.5	54.2
		Occasionally+	81.5	45.8
	V5	Never	70.4	85.9
		Occasionally+	29.6	14.1
	V6	Without speeding	30.8	100.0
		Speeding	69.2	0.0
	V7	Without speeding	15.0	100.0
		Speeding	85.0	0.0
Frequency within V-facet (Percentage)			471 (34.1%)	912 (65.9%)
Since $R(J_1)/R(J_2) = 2.09$ (2-clusters)/1.70 (3-clusters) $= 1.23 > 1.15$, the optimal number of clusters is 2.				
Negligence of vehicle examination (N-facet)	N1	Never	38.2	100.0
		Occasionally+	61.8	0.0
	N2	Never	17.5	100.0
		Occasionally+	82.5	0.0
	N3	Never	52.8	100.0
		Occasionally+	47.2	0.0
Frequency within N-facet (Percentage)			707 (48.7%)	744 (51.3%)
Since $R(J_1)/R(J_2) = 3.06$ (2-clusters)/1.92 (6-clusters) $= 1.59 > 1.15$, the optimal number of clusters is 2.				

[a] The two-step cluster analysis was based on three-ordinal-scale questions within each behavior facet. To concisely demonstrate the responses, we pooled two item categories, "occasionally" and "frequently" into "occasionally+" (i.e. V6 and V7 items were divided into speeding or not).

[b] The ratio change for the two largest values of $R(J)$ see Section 3.3.1.

ter 2 forgot to use their mirrors. Since nearly all respondents in cluster 2 "never" exhibited the seven items of negligence of potential risk, we classed the motorcyclists in cluster 2 as having a "lower risk tendency". In contrast, motorcyclists in cluster 1 "occasionally" or "frequently" exhibited some of the seven behaviors, thereby revealing a higher risk tendency. Both R2 (not using the headlight) and R3 (not using the turning signals) had relatively fewer likelihood of being done, while for R4 (rush running at the start of the green light) and R7 (squeezing through an extremely narrow space between vehicles), showed a higher likelihood of being conducted. In all, 1040 (72.5%) respondents were classified as having an increased tendency to overlook potential risk.

Second, in the V-facet, only 471 (34.1%) respondents were clustered into a higher risk group. Some motorcyclists in cluster 2 with a lower violation tendency also had significant propensity for violations such as V4 (riding down a prohibited lane, 45.8%) and V2 (riding in the wrong direction down a lane, 29.9%), demonstrated by higher prevalence rates. However, the violation percentages were still lower than those in cluster 1, and although motorcyclists in cluster 2 admitted to several specific violations, they were less likely to exhibit several violation items simultaneously, say more than three among the seven items. Within the higher risk groups, more respondents exhibited the behavior for V4 (riding down a prohibited lane), V7 (speeding on rural roads) and V6 (speeding on urban roads), whereas there were fewer respondents exhibiting V1 (riding while intoxicated) and V5 (violating a two-phased left turning).

Third, in the N-facet, motorcyclists who never overlooked any items of vehicle safety were classified into cluster 2. About half of the respondents (48.7%) had greater propensity to overlook vehicle examination "occasionally" or "frequently". In addition, the likelihood of negligence in vehicle examination was sequentially ranked by N2 (not examining tire condition), N1 (not examining the brakes), and N3 (not examining the lights).

4.2. Exposure, clustered risky behaviors, and accident involvement among different ages and genders

There were differences in the mileages traveled by different age and gender cohorts (Table 4). Male riders traveled a mean distance of 16.1 km per day, which was about 5.6 km more than female riders. The difference between genders was statistically significant at $\alpha = 0.05$. Of male motorcyclists, younger riders traveled greater mileages: male riders aged less than 20 years traveled 23.9 km per day on average, whereas men aged 50 years or more traveled less than half this distance. There were no statistically significant differences among the four age groups for female motorcyclists, but women aged less than 20 years did the smallest mileage (8.8 km). In addition, within the same age groups, male motorcyclists traveled a greater distance than female motorcyclists, with the greatest difference being in the group aged less than 20 years.

The associations between age, gender, motorcycle type, and the three types of clustered risky behaviors are shown in Table 5. Four age groups were found to be significantly associated with risky tendencies in all of the three clustered behaviors (i.e. dichotomous level) based on Pearson's χ^2 test. It seems that lower age groups are

Table 4
Age, gender, and average mileage

Gender	Age	Mileage per day (km)	
		Mean (SD)	*F*
Male	<20	23.9 (20.1)	10.33[a] (among ages)
	20–29	18.7 (16.4)	
	30–49	16.0 (15.5)	
	50+	11.7 (13.9)	
	Subtotal	16.1 (15.8)	
Female	<20	8.8 (8.0)	1.67 (among ages)
	20–29	12.2 (13.0)	
	30–49	9.4 (12.5)	
	50+	11.3 (13.2)	
	Subtotal	10.5 (12.7)	
Total		14.2 (15.1)	44.16[a] (between genders)

[a] The *F* test statistics was significant at $\alpha = 0.05$.

Table 5
Associations between important factors and clustered risk behaviors

Variable	Category	R-facet risk tendency			V-facet risk tendency			N-facet risk tendency		
		Higher	Lower	χ^2	Higher	Lower	χ^2	Higher	Lower	χ^2
Age	<20	44 (85%[a])	8	17.5[b]	22 (43%)	29	21.0[b]	28 (54%)	24	11.3[b]
	20–29	312 (77%)	91		163 (43%)	220		222 (55%)	184	
	30–49	508 (72%)	202		216 (31%)	477		342 (47%)	379	
	50+	160 (64%)	89		66 (28%)	172		106 (42%)	146	
Gender	Male	669 (73%)	252	0.1	333 (37%)	562	11.9[b]	458 (49%)	475	0.2
	Female	350 (72%)	137		129 (28%)	334		236 (48%)	256	
Vehicle-type	Moped	389 (73%)	144	0.1	140 (28%)	363	13.6[b]	259 (48%)	279	0.1
	Light	651 (73%)	250		331 (38%)	549		448 (49%)	465	

[a] The percentage (85%) of higher-risk tendency (i.e. cluster 1) was calculated (i.e. 44/(44 + 8)) within the category of aged less than 20 years in the R-facet.
[b] The χ_2 test statistics was significant at $\alpha = 0.05$.

associated with greater incidences of risky behaviors. Individuals aged less than 20 years were more likely to exhibit higher-risk riding patterns (85% for R-facet, 43% for V-facet, and 54% for N-facet) than those aged 50 years or over (64% for R-facet, 28% for V-facet, and 42% for N-facet). However, risky tendency differences between genders and among riders of different motorcycle types were only evident in the V-facet. Male riders were more likely (37%) to exhibit violation behaviors compared with female riders (28%). Riders of light motorcycles had a higher propensity (38%) for violations than moped riders (28%).

The associations among age, gender, motorcycle type, clustered risky behaviors, and accident involvement are shown in Table 6. Motorcycle riders classified as having a higher-risk tendency in the R-facet, V-facet, and N-facet, had a greater likelihood of being involved in an accident (18%, 22%, and 18%, respectively) compared with those classified in the lower-risk groups (10%, 12%, and 13%, respectively). There were also corresponding differences in accident frequencies. For example, motorcycle riders in the higher-risk group of V-facet had an average of 0.32 accidents per rider in a year, which is markedly higher than for the riders in a lower-risk group (0.17 accidents). In addition, more female riders were significantly involved in accidents (19%) compared with male riders (14%), but the difference in accident frequency between genders was not statistically significant. Younger age groups also had obviously higher proportion and frequencies of accidents. More individuals aged less than 20 years had accidents compared with those aged 50 years or more (33% versus 9%), and the average accident frequency was also markedly greater for the younger riders (0.48 versus 0.11). However,

Table 6
Associations between important factors and accidents

Variable	Category	Accident occurrence			Accident frequency	
		Yes	No	χ^2	Mean (SD)	F
R-facet risk tendency	Higher	185 (18%)	849	14.73[a]	0.25 (0.65)	10.08[a]
	Lower	38 (10%)	356		0.14 (0.50)	
V-facet risk tendency	Higher	105 (22%)	365	25.13[a]	0.32 (0.71)	19.14[a]
	Lower	109 (12%)	798		0.17 (0.56)	
N-facet risk tendency	Higher	127 (18%)	575	6.21[a]	0.27 (0.69)	6.23[a]
	Lower	99 (13%)	644		0.18 (0.53)	
Gender	Male	132 (14%)	799	5.11[a]	0.21 (0.64)	1.24
	Female	92 (19%)	398		0.25 (0.58)	
Age	<20	17 (33%)	35	44.05[a]	0.48 (0.80)	14.28[a]
	20–29	95 (24%)	309		0.36 (0.80)	
	30–49	91 (13%)	629		0.17 (0.53)	
	50+	22 (9%)	229		0.11 (0.38)	
Vehicle-type	Moped	76 (14%)	457	1.22	0.20 (0.57)	1.16
	Light	150 (16%)	762		0.24 (0.64)	

[a] The χ^2 and F test statistics were significant at $\alpha = 0.05$.

there were no differences in accident occurrence and frequency among riders of different types of motorcycles. The relatively high involvement of young and female riders in motorcycle accidents is a serious issue that needs to be addressed.

4.3. Logistic regression results

The effects of age, gender, and risky behaviors on the accident involvement were examined using the logistic regression model after adjusting for other confounding variables. The individual contributions of each variable to accident risk is expressed as the odds ratio (that is, $\exp(\hat{\beta})$) in Table 7, while controlling for other variables.

Female motorcyclists were 1.7 times more likely to be involved in an accident than their male counterparts. Motorcyclists aged less than 20 years and those aged 20–29 years were 4.5 and 2.0 times more likely to be involved in accidents than those aged 50 years or more. In addition, motorcyclists with at least a college education were 60% more likely to have an accident than those without a college education. Individuals with a monthly income of less than NT$ 30,000 had an accident risk 52% greater than individuals earning more than NT$ 30,000 per month. On average, each additional increase of 10 km traveled per day increased the accident risk by 12.7% (calculated by $\exp(10 * 0.012)$). However, there was no statistical difference in accident risk between riders of light motorcycles and moped riders.

Table 7
Logistic regression model for accident occurrence

Independent variables	$\hat{\beta}$	$\exp(\hat{\beta})$
Gender (female = 1)	0.507[a] (0.196)	1.660
Age < 20	1.501[a] (11.608)	4.484
Age 20–29	0.699[a] (0.302)	2.011
Age 30–49	0.303 (0.290)	1.345
Education (college or above = 1)	0.471[a] (0.178)	1.602
Income (less than NT$ 30,000 per month =1)	0.421[a] (0.185)	1.523
KM (average daily riding kilometers)	0.011[a] (0.005)	1.012
Vehicle-type (light motorcycle = 1)	0.201 (0.195)	1.223
R-facet (higher risk tendency = 1)	0.640[a] (0.230)	1.897
V-facet (higher risk tendency = 1)	0.532[a] (0.174)	1.702
N-facet (higher risk tendency = 1)	0.124 (0.176)	1.132
Constant	−3.845[a] (0.386)	–
Number of observations	1252	
LL(0)	−512.98	
$LL(\hat{\beta})$	−468.47	
Degrees of freedom	11	

[a] $\hat{\beta}$ was significant at $\alpha = 0.05$.

Table 8
Comparisons between pooled age–gender effects and risky behavior effects on accident risk

Gender	Age	Odds ratio[a]				
		Risk behavior effect (1)	×	Age–gender effect (2)	=	Aggregate effect (1) × (2)
Male	<20	1.36	×	4.49	=	6.11
	20–29	1.19	×	2.01	=	2.40
	30–49	1.09	×	1.35	=	1.47
	50+	1.00	×	1.00	=	1.00
Female	<20	1.04	×	7.93	=	8.24
	20–29	1.14	×	3.56	=	4.06
	30–49	1.02	×	2.39	=	2.44
	50+	0.94	×	1.77	=	1.67

[a] Odds ratio was compared with the reference group (males aged 50 or over).

Among the three types of clustered risky behaviors, negligence of potential risk (R-facet) and violation (V-facet) were significantly associated with increased accidents ($\alpha = 0.05$), whereas negligence of vehicle examination (N-facet) was not significantly associated with increased accident risk. Motorcycle riders classed as higher-risk for the R-facet and V-facet had greater accident risk (90% and 70%, respectively) than their counterparts in the lower-risk group.

In summary, the results of the logistic regression model showed that females, young riders, those more likely to be negligent of potential risk and violation, with more riding exposure, higher education level, and lower monthly income tended to have a greater likelihood of being involved in an accident.

To further examine whether risky behaviors dominated the risk of accident involvement, the relative contributions by risky behaviors and by age–gender factors to the risk of accidents were separately calculated for different demographic cohorts, as shown in Table 8. First, we examined the contribution of risky behaviors (the two types of risky behavior significantly associated with increased accident occurrence, R-facet and V-facet) to accident risk. Second, we assessed the contribution of different age–gender combinations to accident risk, which might identify the latent characteristics (such as experience, skills, or competence that were not directly measured in this study) that are associated with accident involvement within a specific gender and age category. For the convenience of comparison, the relative accident risks for different groups due to these two pooled effects were compared with the risks for men aged 50 years or more (the reference group).

The risky behaviors shown by men aged less than 20 years and by those aged 20–29 years were associated with increases in accident risk of 36% and 19%, respectively, compared with the reference group. Female motorcycle riders aged less than 20 years and aged 20–29 years, however, had increases of only 4% and 14%, respectively, compared with the control group. In addition, female riders aged more than 50 years had the lowest accident risk due to their risky behaviors.

With regards to the effects of age–gender combinations on accident risk, the younger the motorcyclists, the higher the relative accident risk regardless of gender. Female motorcyclists had an apparently higher accident risk than their male counterparts of the same age. Female and male motorcyclists aged less than 20 years had the highest (7.93) and the second highest (4.49) odds ratios.

Two types of risky behaviors exhibited by young and male riders, which may account for the riding errors and violations, increased their likelihood of being involved in a crash. In addition to these two kinds of risky behaviors, analysis of aggregate age–gender factors showed that younger riders, in particular younger female riders, have higher accident risks. This indicates that there may be additional latent factors other than risky behaviors associated with the occurrence of an accident.

5. Discussion

5.1. Risky behaviors and accident risk for different motorcycle-type riders

The types of motorcycles included in this study were mopeds and light motorcycles (almost all the light motorcycles had engine capacities of less than 150 cc). Light motorcycle riders had more violation behaviors than moped riders, but no difference between these two kinds of riders in the other two facets of risky behaviors. In addition, there was no difference in incidence of accidents between riders of the two types of motorcycles. Unlike mopeds in Europe, which are designed to be limited to speeds of less than 45 kph (Schoon, 2004), the maximum speed of mopeds in Taiwan is often as fast as 70 kph. Mopeds and light motorcycles are prohibited from the expressways and freeways, and have speed limits of less than 50 kph on urban roads and of less than 60 kph on rural roads. These two types of motorcycles are also subject to the same riding regulations such as lane use and two-phased left turning. Therefore, there seems no evident risk difference between these two motorcycle types because their operating speed difference is limited.

5.2. Risky behaviors for the higher-risk group

Young motorcycle riders were more likely to violate the law and be negligent of potential risk and motorcycle examination, and male riders were more likely than female riders to violate traffic regulations. As previously mentioned, negligence of potential risk and violation behaviors are significantly associated with accident involvement in the regression model.

As for the individual elements of these two types of significant risky behaviors, the higher-risk group in R-facet were less likely to exhibit errors that required relatively little conscious attention, such as not using the headlights and not using the turning signals, than to exhibit errors requiring more conscious attention, such as rapidly accelerating at a green light, overtaking a blocked car, and squeezing through a narrow space between other vehicles. It might be that when riders are faced with a more complex situation, they have no routines available for handling the situation, and hence are inclined to make errors owing to their lack of the awareness of the consequences regarding safety.

In addition, within the V-facet, the higher-risk group was less likely to ride while intoxicated, ride through a red light, and violate a two-phased left turning, than to ride in the wrong direction down a road, ride down a prohibited lane, and exhibit speeding on urban and rural roads. It is speculated that more serious or easily identified violations such as riding while intoxicated, disobeying a red light, and a two-phased left turning regulation are conducted less because they usually have a more serious penalty or higher likelihood of being caught.

5.3. Accident risk among different age–gender cohorts

Consistent with previous studies (Harrison & Christie, 2005; Lin et al., 2003; Rutter & Quine, 1996), young riders were at a higher accident risk in this study. Female riders were more likely to be involved in an accident than male riders in this study, which is similar to previous research that female automobile drivers had a higher likelihood of being involved in injury or minor accidents (Massie, Green, & Campbell, 1995; Mercer, 1989). However, it should be noted that male automobile drivers experienced higher rates than females of involvement in fatal crashes (Laapotti, Keskinen, Hatakka, & Katila, 2001; Massie et al., 1995; Maycock, Lockwood, & Lester, 1991).

Thirty-three percent of motorcycle riders aged less than 20 years were involved in an accident. This indicates that about one-third of riders of this age group experienced at least one accident each year. In addition, on average, about 19% of female riders experienced at least one accident in a year, which is 5% more than men. Taking into account the mileage traveled, the average number of accidents per million kilometers traveled (43.4) in this study was high when compared with the average accident rate for car drivers (19.1) in Greater Taipei, data taken from another self-reported survey on passenger car use (MOTC, 2002b). One possible explanation for this discrepancy may be that car drivers tend to travel greater distances and the relationship between kilometers traveled and accident involvement is a negatively accelerating curve (Maycock et al., 1991), resulting in a lower accident rate for car drivers.

The underestimation of motorcyclist accident involvement should be noted. Most unreported motorcyclist accidents seem to be minor severity and single-vehicle crashes (MOTC, 2001). About three-quarters of the accidents in this study were not reported to the police. Hence, accident involvement for motorcyclists seems to be seriously underestimated and this underestimation may result in overlooking the safety problems with motorcycle riding.

5.4. Association between age, gender, risky behaviors and accident risk

The logistic regression model indicated that overlooking vehicle examination did not contribute to the accident risk. One possible reason for this is that careless riders who neglect the vehicle examination may not always own the motorcycle, and the owner may be more careful and perform safety checks, thereby compensating for the main user's neglect. Even though overlooking vehicle examination was not significant in our regression model, it is still important to note that young riders tend to overlook vehicle safety checks.

Two types of risky behaviors (negligence of potential risk and violation) associated with accident involvement, comparable with "errors" and "violations" (Parker et al., 1995), were exhibited by young riders and male riders and increased their accident likelihood. However, in addition to these two risky behaviors, some other latent factors represented by age and gender variables also contribute to the accident likelihood of young riders, in particular of young female riders. Hence, young male riders seem to have more accidents due to risky behaviors, whereas young female riders might have more accidents due to other latent factors. The possible latent factors include lack of experience and skills, although these were not directly measured in this study.

Some previous research has shown that the lack of experience results in poor driving skills for young automobile drivers (Benda & Hoyos, 1983; Matthews & Moran, 1986). Evans (1991) concluded that, in contrast with driving vehicles with more than two wheels, motorcycle riding required additional control and balance skills. In addition, McDavid, Lohrmann, and Lohrmann (1989) found that motorcycle training reduced motorcyclist crash rates.

The increased accident rates for novice riders, especially those aged less than 20 years, might be due to lack of proper riding skills or experience. As previously mentioned, no prior experience or compulsory training is required to attend the license tests for mopeds and light motorcycles. Therefore, groups of young motorcyclists who gained their skills and experience through a process of self-learning and trial-and-error could account for the over-representation of this group in the incidence of accidents.

Lack of proper experience seems to be more serious in young female riders. Women aged less than 20 years obtained the least riding experience in terms of the daily mileage, which may contribute to their increased experience-related accident risk. According to the hierarchical model of Laapotti et al. (2001), young novice drivers, and especially young males, demonstrated more problems related to the higher hierarchical levels (e.g. self-control, motives and emotions), and female drivers, however, showed more problems connected to the lower hierarchical levels (e.g. vehicle maneuvering and mastering traffic situations). They stated that this lack of skills for female drivers was connected to lower driving kilometers. It has been suggested that female riders may have more difficulty mastering complex traffic situations due to their lack of skills or experience.

In addition, inferior traffic orders in most of Taiwan's urban districts originate mainly from the intensely mixed use of motorcycles and cars, the high operational freedom of motorcycles, and the limited effectiveness of traffic engineering measures. Most safety riding concepts such as maintaining a suitable distance from the cars in front and alongside are hard to implement in these circumstances and "rule of the jungle" is probably a suitable metaphor for the description of some traffic situations in Taipei. It is speculated that motorcyclists may only learn that kind of rules by accumulating their riding experience on the roads, and hence female riders with less experience in dealing with these complex traffic situations are especially at greater risk of accident involvement.

6. Conclusions

Three types of risky behaviors exhibited by motorcyclists were optimally divided into dichotomous risk groups using a two-step cluster analysis. Young riders and male motorcycle riders were more likely to disobey traffic regulations, and young riders were also more likely to be negligent of potential risk and motorcycle safety checks.

Compared with their older and male counterparts, young and female riders were more likely to be involved in an accident. Young male riders were more likely to engage in risky behaviors to raise their accident likelihood, whereas young female riders might have more accidents due to their inferior driving skills and lack of experience.

A significant number of these accidents are likely to be unreported, and consequently the problems of riding safety have been seriously underestimated. It is speculated that the present motorcycle licensing system places little emphasis on the necessity of training and providing a reduced risk environment for novice riders. Therefore, to reduce motorcyclists' accident risk, the licensing system and traffic engineering system should be improved and training program provided.

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