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Age and contributing factors to unlicensed teen motorcycling

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Abstract

This study aims to examine the initial age when teenagers engage in unlicensed motorcycling in Taiwan and the factors contributing to their unlicensed behavior. Data were collected from the retrospective experience of a cohort of senior high school students and a Cox regression model was applied. The results indicated that an estimated 63.4% of the students had experienced riding before the legal age of 18 years. Contributing factors such as whether the students were in a vocational senior high school, male, and in households with higher motorcycle ownership rates led to an earlier riding age; in contrast, a higher degree of parental monitoring, fewer motorcycles in the household, living in Greater Taipei, and an increase in the bus density in the district delayed the ages of beginning motorcycling. The higher minimum licensing age of 18 in Taiwan has caused a debate about its effectiveness because of the high prevalence of unlicensed teenage riding. Measures such as parental monitoring, power- or speed-limited mopeds, training programs, and no duo-passengers should be carefully examined if a policy is to be made on lowering the age limit of motorcycling.

Keywords: Initial age of motorcycling; Minimum licensing age; Unlicensed riding; Cox regression method

1. Introduction

Motorcycle riders have an increased likelihood of accidents compared with other motor vehicle drivers (Mannering and Grodsky, 1995; Plasència et al., 1995). In particular, younger groups have a disproportionately higher accident risk when riding a motorcycle than when driving a car. For example, moped riders and car drivers aged 18–19 years experienced 1.58 and 0.12 casualties per million kilometers traveled, respectively, during 1995–1997 in the Netherlands (see Appendix 2 from Schoon, 2004), showing that young moped riders had 13 times the casualty risk encountered by car drivers of the same age. Adolescent riders exhibit higher risk behavior (Chesham et al., 1993; Rutter and Quine, 1996) and have less experience (Chang and Yeh, 2007), so the minimum licensing age and measures regulated by the licensing system may influence the accident risk experienced by these young riders.

The motorcycle licensing system in Taiwan classes motorcycles according to engine capacity: mopeds (≦50 cc), light motorcycles (>50 to ≦250 cc) and heavy motorcycles (>250 cc). The minimum licensing age for mopeds and light motorcycles in Taiwan is 18 years, whereas for heavy motorcycles the minimum age is 20 years (Ministry of Transportation and Communications, 2002). 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) (MOTC, 2004).

Disqualified motorcyclists under the legal age limit of 18 years are prevalent in Taiwan. Chang (1996) reported that around 38.8% of Taiwan's junior high school students and as many as 68.9% of senior high school students rode a motorcycle without a license at some stage. However,

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Taiwan appears not to be a special case around the world. Even though a learner license can be granted at age 15 in New Zealand, Reeder et al. (1995) pointed out that most licensed riders (86%) had ridden on public roads before being licensed.

Most western countries allow adolescents aged around 16 years or less to use speed-limited mopeds (Schoon, 2004) or restrict their riding to lower risk circumstances such as having curfews or no carriage of passengers, and a stricter blood alcohol concentration (BAC) limit for the learner's stage (Haworth and Mulvihill, 2005). On the other hand, Taiwan has set a higher entry age of 18 years to postpone adolescents from gaining access to motorcycle use. However, a higher age limit does not necessarily prevent adolescents who do not meet the required age from riding a motorcycle unlicensed.

These unlicensed young riders may have a higher likelihood of being involved in an accident because of their lack of experience or immature state of mind. This raises concerns over not only the safety problems of these very young groups but also the effectiveness of the motorcycle licensing system to set a stricter licensing age. It is valuable to investigate the age of beginning unlicensed riding, and contributing factors, to develop effective countermeasures to mitigate this problem. Therefore, this study aimed to examine the initial unlicensed age, associated with related factors, using retrospective self-report data from senior high school students. Differences in the initial unlicensed experience contributed by various factors were examined by a Cox regression method.

2. Methods

2.1. Data

We applied a retrospective self-report survey on the attitudes of senior high school students to motorcycle use, which was administered by Taiwan's Institute of Transportation (IOT), to collect the students' experience in motorcycle use and opinions on lowering the minimum motorcycle licensing age (IOT, 2006). A stratified random sampling method was employed, based on the population distribution of the 16–18 year cohort by districts. The pre-designated number of samples (overall sampling error was controlled within ±3%) was then distributed to the students affiliated with two randomly sampled schools in each of 23 distinct administrative districts, since most of them fall into this age range. A total of 1747 effective samples were collected.

Some answers in this study were retrieved from the questionnaire (Table 1). The core questions were whether the sampled students had experienced unlicensed motorcycle riding and, if so, what was their initial age and schooling stage. To explore the regression relationship between the beginning age of unlicensed riding and contributing factors, some variables such as school type, gender and family factors (i.e., living with parents, parents' attitude and household's motorcycle size) were also introduced.

The basic statistics of the sampled data are listed in Table 2. The mean age of the students was 17.2 years. Of these, 45.4% were vocational high school students and 54.6% ordinary high school students; 58.8% of them were male and 41.2% female. Most of the sampled students lived with both of their parents (85.3%). Those living with a single parent or with neither parent, however, comprised a smaller proportion. Of the sampled students, 40.6% perceived that their parents had a "neutral" attitude towards their motorcycling, 33.9% felt that their parents "approved" and 25.5% perceived that their parents "disapproved". Most students expressed that their household had one (34.0%) or two motorcycles (37.1%) and only 9.3% did not have any motorcycles in their household.

More than half of the sampled students (53.1%) had experienced unauthorized motorcycling and their initial age of unlicensed riding was around 16 years. Of those with unlicensed experience, most experienced riding a motorcycle at the junior high stage (49.4%), but 13.1% of students had experienced motorcycling at a very early stage in elementary school.

2.2. Cox regression and model specification

The initial unlicensed motorcycling age is a time-to-event process with two kinds of possible outcomes in this study: an event or censored states. An event observation for a sampled student indicates the initial age of experienc-

Table 1
Research related questions

1. Gender: ☐ male; ☐ female.
2. School type: ☐ vocational senior high; ☐ ordinary senior high.
3. Age: ___ years ___ months.
4. What is your parents' (or senior members in your family if parents are not available) attitude towards your riding a motorcycle? ☐ approval; ☐ neutral; ☐ disapproval.
5. Whom do you live with? ☐ with both parents; ☐ with father only; ☐ with mother only; ☐ with neither parent.
6. How many motorcycles in your household? ☐ none; ☐ one motorcycle; ☐ two motorcycles; ☐ three motorcycles or more.
7. Have you ever experienced unlicensed motorcycle riding? ☐ yes (continue no. 8); ☐ no;
8. If answered "yes" in no. 7 question, continue answering the following question:
   8-1. What was the schooling stage for your initial trial of unlicensed motorcycle riding? ☐ elementary school; ☐ junior high school; ☐ senior high school.
   8-2. What was your initial age of experiencing unlicensed motorcycle riding? ___ years ___ months.

Table 2
Basic statistics of the sampled data

Variable	Category	Frequency (percentage)/ mean (S.D.)
Age	Mean (S.D.)	17.18 (0.95)
School Type	Vocational senior high	793 (45.4%)
	Ordinary senior high	954 (54.6%)
Gender	Male	939 (58.8%)
	Female	658 (41.2%)
Living with parents	With both parents	1476 (85.3%)
	With father only	64 (3.7%)
	With mother only	119 (6.9%)
	With neither parent	72 (4.2%)
Parents' attitude	Approval	544 (33.9%)
	Neutral	653 (40.6%)
	Disapproval	409 (25.5%)
Household's motorcycle size	None	162 (9.3%)
	One	592 (34.0%)
	Two	646 (37.1%)
	Three or more	339 (19.5%)
Living district	Greater Taipei	586 (33.5%)
	Other districts	1161 (66.5%)
Unlicensed riding experience	Yes	868 (53.1%)
	No	766 (46.9%)
Schooling stage of the first unlicensed experience (if any)	Elementary stage (age 7–12)	111 (13.1%)
	Junior high stage (age 13–15)	418 (49.4%)
	Senior high stage (age 16–18)	317 (37.5%)
Initial unlicensed age	Mean (S.D.)	16.00 (1.79)

ing unlicensed motorcycling. A censored observation, however, indicates a sampled student has not yet experienced motorcycling and his/her age at the time of the survey was the censored time.

The Cox regression model is comprised of two parts: the baseline hazard and an exponential component. Since the baseline hazard part is unspecified, the Cox regression belongs to the semi-parametric class of models. Its functional form is expressed as (Kleinbaum, 1996):

$$h(t|X,\beta) = h_0(t) \times e^{X\cdot\beta} \tag{1}$$

where $h_0(t)$ is the baseline hazard function and X and β are vectors of the independent variables and their corresponding parameters.

The estimated parameters $\hat{\beta}$ are obtained by maximizing the joint probability of the partial likelihood function $L(\beta)$:

$$L(\beta) = \prod_{j=1}^{k} \left(e^{X_{(j)}\cdot\beta} \Big/ \sum_{l\in R_j} e^{X_l\cdot\beta} \right) \tag{2}$$

where k is the number of events (unlicensed riding) during the observation period; R_j is the set of students at risk (the risk set) at the jth rank of event time ($\leqq k$), which represents the set of students that have not had any unlicensed experience before the j^{th} rank of time; $X_{(j)}$ is the vector of independent variables corresponding to the event occurring at the jth rank of time (the number j in parentheses represents the rank order of time); and X_l is the vector of independent variables corresponding to the lth set of students in R_j.

The estimated parameters $\hat{\beta}$ drawn from the above function, while not fully statistically efficient, are consistent and in large samples also asymptotically normal and unbiased. When comparing the relative hazard contribution of two distinct independent variable vectors, it is conventional to use the hazard ratio. This is expressed by Eq. (3), which is constant since $h_0(t)$ cancels out the equation (the proportional hazard assumption).

$$HR = \hat{h}\left(t|X_1,\hat{\beta}\right) \Big/ \hat{h}\left(t|X_2,\hat{\beta}\right) = e^{(X_1-X_2)\cdot\hat{\beta}} \tag{3}$$

where X_1 and X_2 stand for the two values of the independent variable vector considered. If HR is significantly greater than 1, then the conditions described by X_1 are more likely to experience unlicensed motorcycling than the conditions given by X_2. In other words, the age of experiencing unlicensed riding is earlier under X_1. For convenience of comparison, we usually use one unit increase for each variable, one at a time, to estimate the hazard ratio, and thus HR in Eq. (3) reduces to $e^{\hat{\beta}_i}$ for the ith variable.

Since the independent variables gathered in this study mostly reflect the status of the students at the time of the survey, these one-wave investigation data assume the independent variables are time-invariant. However, time-varying independent variables obtained by multi-waves investigation may be more accurate for some predictors that change over time. The limitation of the time-invariant assumption in our Cox regression model should be released in future studies.

Table 3 indicates the independent variables introduced in the Cox regression model and their expected associations with the hazard of the occurrence of unlicensed riding. Since students in a vocational senior high school have less pressure to advance to a higher education, they are more expected to take part in extracurricular activities (Chang, 1996) and thus have a higher hazard in unlicensed motorcycling (or earlier experience). Male students are assumed to have a higher likelihood of exhibiting risky behavior than females (Harré et al., 1996; Lam, 2003) and this may lead to an earlier unlicensed experience. In addition, students living with both parents or with parents showing a disapproving attitude towards their motorcycling may represent a stricter monitoring from their parents compared with the reference groups, respectively (i.e., living with neither parent or with parents showing an approving attitude). According to Hartos et al. (2000), the higher degree of monitoring function is assumed to have a negative association with the unlicensed hazard. Students living in Greater Taipei have more convenient public transit systems and this is speculated to delay their average age of unlicensed riding. Also, according to Reeder et al. (1995),

Table 3
Independent variable notation and expected association with hazard

Variable notation	Variable description	Expected association
School type	1 if the school type is a vocational senior high school, otherwise 0	+
Sex	1 if the student is male, 0 if female	+
Living (1)	1 if the student lives with both parents, otherwise 0	–
Living (2)	1 if the student lives with his/her father only, otherwise 0	–
Living (3)	1 if the student lives with his/her mother only, otherwise 0	–
Parents' attitude (1)	1 if the parents have a disapproving attitude towards motorcycling, otherwise 0	–
Parents' attitude (2)	1 if the parents have neutral attitude towards motorcycling, otherwise 0	–
Greater Taipei	1 if the student lives in Taipei city or country, 0 if other districts	–
Household motorcycle size (1)	1 if the household of the student has no motorcycle, otherwise 0	–
Household motorcycle size (2)	1 if the household of the student has one motorcycle, otherwise 0	–
Household motorcycle size (3)	1 if the household of the student has two motorcycles, otherwise 0	–
District's passenger car density	Passenger cars owned per hundred residents in the residence district of the student in 2005	–
District's motorcycle density	Motorcycles owned per hundred residents in the residence district of the student in 2005	+
District's bus density	City buses owned per 10,000 residents in the residence district of the student in 2005	–

none or fewer motorcycles owned in a household may reduce motorcycle availability for the students and decrease the unlicensed hazard.

In addition, different district traffic compositions measured by passenger car, motorcycle and city bus ownership rate represent the diverse mobility patterns where the students live. Therefore, the substitute modes such as a greater number of passenger cars and city buses owned in a district reduce the amount of students' unlicensed motorcycling and delay their initial riding age. In contrast, in districts with a greater number of motorcycles owned, the students' hazard in experiencing unlicensed riding was higher.

3. Results

The age of beginning unlicensed motorcycling for a cohort of senior high school students was analyzed using a Cox regression method. Some associated factors affecting the age of beginning motorcycling were examined and the estimated survival curve offered the difference of initial age experienced by different groups.

3.1. Cox estimated results

Table 4 shows the Cox estimated results. The censored rate was 47.8%, which means over half of the sampled students had experienced unlicensed riding. As expected, the speculated associations contributed by the independent variables almost all agreed with our assumptions. The hazard ratio between two levels of an independent variable was expressed as e^{β}, one at a time while controlling for other variables. Students affiliated with a vocational senior high school had 36.8% ($=100\% \times (1.368 - 1)$) more hazard in experiencing unlicensed riding compared with those in an ordinary senior high school, indicating an earlier start at motorcycling. Males experienced 61.1% more hazard than females.

Students living with both of their parents had a hazard reduced by 37.9% compared with those living with neither parent. Living with single parent also had a negative association with the hazard but was not statistically significant. Parents perceived by their children as showing a disapproving or neutral attitude also decreased the hazard by 26.8% and 16.5%, respectively, compared with children of parents with an approving attitude. Fewer motorcycles in a household also reduced the likelihood of unlicensed riding. Compared with households with three motorcycles or more; none, one and two motorcycles reduced the hazard by 49%, 45.1% and 15.8%, respectively. In addition, students living in Greater Taipei had the unlicensed hazard decreased by 31.4%.

From a regional perspective, district traffic compositions, except passenger car ownership rate, also showed a mild association with the unlicensed riding of the district's students. An increase in one motorcycle owned for 100 residents raised the district's unlicensed hazard by 0.7%, while an increase of one city bus for 10,000 residents reduced the district's hazard by 2.4%.

3.2. Initial age of unlicensed motorcycling by factors

To compare the different initial ages of unlicensed riding experience by groups, we further applied the adjusted survival curve based on the previous Cox estimated results. The adjusted curve means we compared different categories of each variable one at a time while controlling for other variables as mean values. The cumulative probability before specific ages and the median age for unlicensed motorcycling by different groups are displayed in Table 5.

The median age, which stands for the age when half of the students had experienced unlicensed motorcycling, for the overall samples was 17.03 years. Stratified by school type, the median value for vocational school students (16.74 years) was 0.64 years earlier than ordinary school students (17.38 years). Male students (16.55 years) started motorcycling 1.43 years earlier than females (17.98 years). Students living with both parents obviously engaged in motorcycle riding later compared with students living with neither parent (17.22 vs. 15.87 years). Students living with a single father had a slightly higher median age than those

Table 4
Estimated results for the Cox regression model

Independent variable	β	(S.E.)	e^{β}
School type	0.314[a]	(0.073)	1.368
Sex	0.477[a]	(0.074)	1.611
Living (1)	−0.477[a]	(0.161)	0.621
Living (2)	−0.096	(0.228)	0.908
Living (3)	−0.106	(0.198)	0.899
Parents' attitude (1)	−0.313[a]	(0.095)	0.732
Parents' attitude (2)	−0.181[a]	(0.080)	0.835
Household motorcycle size (1)	−0.674[a]	(0.161)	0.510
Household motorcycle size (2)	−0.600[a]	(0.098)	0.549
Household motorcycle size (3)	−0.171[b]	(0.089)	0.842
Greater Taipei	−0.377[a]	(0.098)	0.686
District's passenger car density	0.002	(0.010)	1.002
District's motorcycle density	0.007[b]	(0.004)	1.007
District's bus density	−0.025[b]	(0.014)	0.976
Number of observations	1594		
Censored observations (rate)	762 (47.8%)		
LL(β)	−5645.6		
LL(0)	−5755.9		
Degrees of freedom	14		

Notes: "a" and "b" denote that β is significantly different from 0 at the $\alpha = 0.05$ and $\alpha = 0.1$ levels, respectively.

Table 5
Cumulative probability and median age of unlicensed experience by groups

Factor	Group	≦Age 14 (%)	≦Age 16 (%)	≦Age 18 (%)	Median age (years)
Overall	–	12.5	36.2	63.4	17.03
School type	Vocational senior high	16.4	42.0	69.6	16.74
	Ordinary senior high	9.4	31.6	58.1	17.38
Sex	Male	14.1	41.2	73.3	16.55
	Female	11.0	31.5	51.4	17.98
Living with parents	With both parents	11.4	34.5	62.7	17.22
	With father only	21.0	45.5	70.1[a]	16.27
	With mother only	16.1	44.1	68.9[a]	16.15
	With neither parent	25.2	53.2	64.1[b]	15.87
Parents' attitude	Approval	10.7	32.8	57.4	16.75
	Neutral	12.1	35.0	61.3	17.10
	Disapproval	14.6	40.5	70.7	17.46
Household motorcycle size	None	10.8	30.2	46.9	18.32
	One	10.0	30.8	47.7	18.26
	Two	14.3	39.4	71.3	16.81
	Three or more	16.4	47.5	79.9	16.13
Living district	Greater Taipei	8.6	30.3	54.6	17.94
	Other districts	14.7	39.6	67.9	16.92

Notes: "a" and "b" denote that the cumulative probability is less than 17.25 and 17.17 years of age, respectively.

living with a single mother (16.27 vs. 16.15 years). The unlicensed median age increased with the parents' disapproving attitude. Students experienced unlicensed riding 0.71 years later if their parents had a disapproving attitude compared with the students who gained their parents' approval. In both households with no motorcycle or only motorcycle, students had a median age greater than the minimum licensing age of 18. However, a household with three motorcycles or more reduced the median age to 16.13 years. Students living in Greater Taipei also showed a delayed age of riding (17.94 years) when compared with other districts (16.92 years).

In addition, students undergoing unlicensed riding revealed different distributions of cumulative probability before specific years of age by groups. The overall probabilities of unlicensed experience before the ages of 14, 16, and 18 were 12.5%, 36.2%, and 63.4%, respectively. Similar to previous results, students in a vocational senior high school, male students, students living with both parents, students perceiving a disapproving attitude in parents, students in households with no motorcycles, and living in Greater Taipei had a lower probability of unlicensed riding compared with their counterpart groups. For example, 73.3% of male students had experienced unlicensed riding before the age of 18, while only 51.4% of females had the same experience; 79.9% of the students living in a household that held more than three motorcycles had unlicensed experience before the age of 18, while only 46.9% of the students in a household owning no motorcycles had this experience.

4. Discussion

The Cox regression results indicated that students affiliated with a vocational senior high school, male students, and students in districts with a higher motorcycle ownership rate had a greater chance of experiencing unlicensed riding and thus had an earlier riding age. In contrast, the beginning age of motorcycling was delayed in students having a higher degree of monitoring by their parents (living with both parents or perceiving that their parents had a disapproving attitude), living in households with fewer motorcycles, living in Greater Taipei, and living in districts with a greater bus density.

The onset of motorcycle riding at an earlier age raises concerns over a disproportionately higher likelihood and severity of an accident produced by these young children. The over-represented risk of accident for the youths has been identified by many studies (Lin et al., 1998; Schoon, 2004; IOT, 2006). The increased crash risk of these young riders may be contributed to by the factors of less experience and immaturity. The youngsters' immaturity appears to receive more attention than their inexperience. Studies indicated that the immaturity may result from their weaker cognitive ability (Eby and Molnar, 1998) and lead to a stronger propensity towards risky behavior (Zuckerman and Neeb, 1980; Russo et al., 1993; Rutter and Quine, 1996; Mullin et al., 2000; Lin et al., 2003).

The minimum licensing age for motorcycling in most countries is 16 years or lower but Taiwan has set a higher

licensing age of 18, aiming to postpone the time that adolescents ride a motorcycle. This delaying strategy appears ineffective because unlicensed riding experience is prevalent and the possibility of starting motorcycling is significant from about 14 years of age. The high prevalence and low age of unlicensed behavior in Taiwan may have caused many legal or safety problems resulting from the immaturity and inexperience of young people. In addition, mopeds with no speed limitation, combined with the immaturity of the young riders in Taiwan, may raise the likelihood and severity of an accident.

The prevalence of authorized riding appears hard to suppress if the mobility needs, especially for their weekend activities, cannot be satisfied by other suitable alternative modes of transport (Yeh et al., 2007). However, a certain number of accidents may be controlled by the overall reduction in riding exposure if the current licensing age is maintained (IOT, 2006). Therefore, whether the current minimum age for motorcycle riding should be lowered depends on the establishment of effectively matched countermeasures.

Some measures combined with a lower licensing age in some advanced countries may be considered to control the risk of teen motorcycling accidents. Specifically, either speed-limited mopeds (i.e., mopeds having speeds lower than 45 kph or light-mopeds lower than 25 kph) (Schoon, 2004) or a lower risk riding situation such as mandatory training and instruction, no carriage of passengers, a maximum speed restriction, and a stricter BAC based on a graduated licensing system is requested to regulate the behavior of young novice riders (Haworth and Mulvihill, 2005).

In addition, as indicated by Hartos et al. (2000), low parental monitoring and control were associated with higher risk behavior, violations and crashes among teenagers driving an automobile. Promoting parental management of teenage driving at the stage of the learner's permit or provisional license has been suggested because of the significant limits on teenage driving in the first few months (Simons-Morton et al., 2002, 2003). Our results also showed that a higher degree of parental monitoring delays the unlicensed age of motorcycling. Therefore, much attention should be paid to countermeasures of parental monitoring, power- or speed-limited mopeds, training programs, and no carriage of passengers if the government considers lowering the minimum licensing age of motorcycling.

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