Traffic Safety for Electric Bike Riders in China

Attitudes, Risk Perception, and Aberrant Riding Behaviors

Lin Yao and Changxu Wu

The use of electric bikes (e-bikes) in China has grown tremendously in the past decade. Traffic safety for e-bike riders is an issue of growing public concern because the number of fatalities and injuries is increasing. A study was conducted to identify risk factors affecting involvement of e-bike riders in accidents and to establish the relationships between safety attitudes, risk perception, and aberrant riding behaviors. The data used for analysis were obtained from a self-reported questionnaire survey of a sample of 603 e-bike riders in two large cities in China. The results showed that both gender and automobile driving experience were significantly associated with at-fault accident involvement. Males were more likely to have at-fault accidents than were females, and riders with an automobile driver's license were less likely to have accidents than were those without a driver's license. Two types of aberrant riding behaviors, errors and aggressive behaviors, were found to be significant factors for predicting at-fault accident involvement. Analysis with a structural equation model indicated that safety attitudes and risk perception both significantly affected aberrant riding behaviors. E-bike riders with stronger positive attitudes toward safety and more worry and concern about their traffic risk tended to be less likely to have aberrant riding behaviors. Practical implications for improving road safety of e-bike riders are discussed.

The electric bike (e-bike), a type of powered two-wheeled vehicle, is a widely used mode of transport in China. The e-bike provides a convenient and relatively inexpensive form of private mobility (*1*). E-bike use has grown tremendously in the past decade. In 2009, more than 20 million e-bikes were produced and sold in China, up from several thousands in 1998. The total number of e-bikes was estimated to exceed 120 million nationally in 2010, and the increase is expected to continue for the next few years (*2*).

E-bikes are classified as nonmotorized vehicles by traffic laws in China. Thus they are operated in bicycle lanes, and no license, insurance, or helmet use is required for e-bike riders. Most e-bikes in China fall into one of two categories: bicycle style and scooter style. Both styles are subject to the national e-bike standards, which include a top speed of 20 km/h, a maximum weight of 40 kg, and maximum power of 240 W.

The growing popularity of e-bikes raises safety concerns (*3*). The number of fatalities and injuries related to e-bikes has skyrocketed in the past few years. In 2004, 589 e-bikers were killed and 5,295 were seriously injured. The corresponding figures increased to 3,107 and 17,303 in 2008, 5.4% of total traffic fatalities and injuries (*4*). Because of their increasing popularity, e-bike safety will be an increasingly serious problem unless appropriate countermeasures are implemented.

Several studies have explored how to make plans and policies to regulate e-bikes. For example, Weinert et al. surveyed 751 bicycle riders and 460 e-bike users in a large city (Shijiazhuang) in China to investigate the use characteristics, mode choice behavior, and safety perception of bike and e-bike users (*1*). Their results showed that e-bikes allowed people to commute longer distances and were serving as an affordable, high-quality mobility alternative to public transport. Lin et al. presented a field investigation of the operating speed and its distribution characteristics for both e-bikes and bicycles in Kunming, China (*5*). The mean operating speed of e-bikes was found to be 47.6% higher than that of bicycles, and the speed distribution was affected by gender and age. Surveys also showed that most e-bike riders did not know the speed limit, and their expected maximum speed was much higher than allowed by law (*5*). These studies provide insight for understanding the use characteristics and safety perception of e-bike riders in China. However, because behavior of road users was found to be the primary determinant of traffic safety (*6*), more studies focusing on riding behaviors and the relevant psychological factors are needed to improve e-bike safety.

RESEARCH ON ABERRANT BEHAVIOR, SAFETY ATTITUDE, AND RISK PERCEPTION

Few research efforts have been made to investigate aberrant riding behaviors and the associated psychological factors of e-bike riders. Accordingly, the most relevant research on driving (riding) behaviors of car drivers, motorcyclists, and moped riders is reviewed and summarized here.

The most influential framework for assessing aberrant driving behaviors was proposed by Reason et al., who developed the driver behavior questionnaire and distinguished three types of behaviors: errors (failures of planned actions to achieve intended consequence), lapses (unwitting deviation of action from intention), and violations (deliberate deviations from normal safe practice or socially accepted code of behavior) (*7*).

A modified version of the driver behavior questionnaire has been used to study aberrant behaviors of users of two-wheeled vehicles, such as motorcyclists and moped riders. For example, Elliott et al. developed a behavior questionnaire for motorcycle riders and found a distinction between traffic errors, control errors, speed violations, stunts, and use of safety equipment for motorcyclists in Britain (*8*). Steg and van Brussel developed a behavior questionnaire for moped

L. Yao, Institute of Psychology, Chinese Academy of Sciences, 4A Datun Road, Chaoyang District, Beijing 100101, China. C. Wu, Chinese Academy of Sciences; Department of Industrial and Systems Engineering, State University of New York at Buffalo, 414 Bell Hall, Buffalo, NY 14228. Corresponding author: C. Wu, changxu.wu@gmail.com.

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riders and validated the distinction between errors, lapses, and violations for moped riders in the Netherlands (*9*).

Driving behavior is associated with safety attitudes and risk perception. For example, attitudes toward traffic safety were reported to correlate with aggressive driving behaviors, fast driving, and self-reported accident involvement (*10, 11*). Risk perception was also found to be negatively correlated with risk-taking behaviors (*12*), which means that a higher level of perceived risk for a particular behavior will result in a lower probability of taking part in that behavior.

However, few studies have focused on the aberrant riding behaviors, safety attitudes, and risk perception of e-bike riders in China. Unlike in North America and Europe, the e-bike is a major transportation mode in many big cities in China, and it is used mainly for commuting rather than mere leisure. This study identifies risk factors that affect the accident involvement of e-bike riders in China and establishes relationships between safety attitudes, risk perception, and aberrant riding behaviors. The findings provide information government authorities can use to design and implement policies and intervention programs that improve the safety of e-bikes.

METHOD

This study used the questionnaire survey approach, which has been widely used in traffic safety research to collect information about behaviors, safety attitudes, and risk perception (*13–15*).

Respondents and Procedure

The survey was conducted in March through June 2011 in two large Chinese cities: the capital city of Beijing, which has experienced rapid growth in e-bike use since 2006 and had a total of 0.7 million registered e-bikes in 2009, and Hangzhou, a tourist city in southeastern China that pioneered the use of e-bikes in China and had an estimated 1.4 million e-bikes in 2010. The survey was administered from 8:00 a.m. to 6:00 p.m. on both workdays and weekend days to collect as broad a range of respondent types as possible. Respondents were approached in centralized e-bike parking facilities, e-bike charging stations, and shopping centers. Those who made themselves available and were willing to participate were asked to complete the questionnaire. To be included in the study, a participant had to be older than 18 years and be a regular e-bike rider (riding at least once a week). Respondents were ensured that participation was voluntary and that their responses would be anonymous. The questionnaire took approximately 20 min to complete. After completing the questionnaire, respondents were offered a small gift as a token of appreciation.

Measurements

The questionnaire design was based primarily on an extensive review of the literature and the results of focus group discussions. The main content of the questionnaire related to this paper consisted of four parts: aberrant riding behaviors, safety attitudes, risk perception, and accident involvement information and demographics.

Aberrant Riding Behaviors

Aberrant riding behavior was measured with a self-developed questionnaire based on previous studies on riding (driving) behaviors of moped riders, motorcyclists, car drivers. Most of the items used were selected from the moped rider questionnaire developed by Steg and van Brussel (*9*), the motorcycle rider questionnaire developed by Elliott et al. (*8*), and the Chinese driving behavior questionnaire developed by Xie and Parker (*16*). Items that applied to e-bike riders or that could be modified to do so were retained, and the rest were dropped. Some new items that were specific to e-bike riding were added. The respondents were required to indicate how often they engage in each specific behavior by using a five-point Likert scale ranging from 1, "never," to 5, "almost always." A pretest was carried out with 20 e-bike riders having varying levels of riding experience. Their feedback was used to revise the questionnaire to improve clarity and readability.

Safety Attitudes

Attitudes toward traffic safety were measured with a 16-item, six-point Likert scale (from 1, "strongly disagree," to 6, "strongly agree") adapted from the work of Ulleberg and Rundmo (*13*) and Rundmo et al. (*17*). Safety attitudes were grouped into three dimensions: attitudes toward safety and personal responsibility, attitudes toward traffic rules, and attitudes toward risky riding behaviors. Attitudes toward safety and personal responsibility (five items) measured the extent to which the respondents felt responsible for traffic safety and accident prevention (for example, "I will feel guilty if an accident is my fault"). The five items for attitudes toward traffic rules measured the sense of obligation to obey traffic rules ("A rider should always obey the traffic rules, regardless of whether they seem logical or not"). Finally, six items were used to measure the respondents' attitudes toward risky riding behaviors (for example, "I think it is wrong to run a red light").

A higher score on safety attitude scales indicated a more positive attitude toward traffic safety and personal responsibility, a stronger sense of obligation to obey traffic rules, and lower preferences of risky riding behaviors.

Risk Perception

Risk perception was measured by an affect-based worry and concern scale (*18*) and a cognition-based scale (*19*). The worry and concern scale was adapted from the work of Rundmo and Iversen (*18*) and contained six items related to traffic injury and risk (e.g., "I often feel unsafe because I could be injured in a traffic accident"). The cognition-based scale included perceived likelihood of an accident and perceived danger. The perceived likelihood of an accident was examined by asking respondents to indicate their chance being involved in an accident in the next 12 months on a six-point scale (1 = very unlikely, 6 = very likely). Perceived danger was assessed through responses to questions about how dangerous respondents thought the following behavior is (1 = very safe, 6 = very unsafe): running a red light, riding when under the influence of alcohol, speeding, riding in the vehicle lane, riding against the traffic, and riding with overload.

A higher score on risk perception scales indicated that the respondents had more worry and concern about safety and perceived risky riding behaviors as more dangerous.

Accident Involvement and Demographics

Respondents were asked to indicate how many of the following accidents they had been involved in while riding e-bikes in the past year: (*a*) accidents resulting in serious injury, (*b*) accidents resulting in minor injury, and (*c*) accidents resulting in only property damage or conflicts. The number of at-fault accidents and not-at-fault accidents were reported separately. An at-fault accident in this study was defined as an accident in which the rider accepted some degree of blame according to the traffic laws.

Finally, a range of information regarding demographics, including age and gender, as well as riding experience, including ownership of an automobile driver's license, riding history in years, riding frequency, and riding distance per week in the past month, were also collected.

Data Analysis

The data analysis process consisted of three parts.

First, exploratory as well as confirmatory factor analyses were carried out to examine the structure of the underlying dimensions of the self-developed instrument used to measure aberrant riding behaviors. Several fit indexes, including the root-mean-square error of approximation (RMSEA), the goodness-of-fit index (GFI), the adjusted goodness-of-fit index (AGFI), and the comparative fit index (CFI), were used to examine the fit of the model. A RMSEA of .08 or less and a GFI, an AGFI, and a CFI of 0.90 or above indicated a good fit between the model and the data (*20*). Cronbach's alpha, a coefficient of consistency that measures the homogeneity of the items in a single dimension, was used to evaluate the reliability and internal consistency of the aberrant riding behavior, safety attitude, and risk perception scales. Following Nunnally's criteria, alpha values equal to or exceeding 0.7 indicated acceptable reliability (*21*).

Second, statistical analyses were performed to examine if respondents reporting at-fault accidents (at-fault accident involvement = yes) significantly differed from those reporting not at fault (at-fault accident involvement = no) for demographical variables, risk perception, safety attitude, and aberrant riding behavior scales. For the univariate analysis, chi-squared tests were conducted for categorical variables and one-way analysis of variance for continuous variables. For the multivariate analysis, a binary logistic regression model was used to identify factors that are significantly associated with at-fault accident involvement.

Third, a structural equation model was developed with AMOS 17.0 software to explore the causal relationships between safety attitudes, risk perception, and aberrant riding behaviors. The two-step procedure for structural equation modeling as recommended by Anderson and Gerbing (*22*) was used. First, confirmatory factor analysis was used to evaluate the measurement model and the fit of the safety attitude, risk perception, and aberrant riding behavior subscales to their respective latent constructs. In the second step, the structural equation model was tested for statistical acceptability. The model was estimated with maximum likelihood technique. Again, the commonly used fit indexes, such as RMSEA, GFI, AGFI, and CFI, were used to measure the model fit (*20*).

RESULTS

Respondent Characteristics

A total of 660 e-bike riders completed the questionnaire. However, 57 (8.6%) were eliminated because of incomplete (failure to respond to three or more items) or nonsensical responses (giving contradictory responses on two questions that measure the same behavior). For example, one respondent reported that he had run a red light in answer to one question, but in answer to another question he claimed that he had never violated any traffic rules. Thus, the final sample included 603 (91.4%) respondents. Table 1 is a summary of the demographic information of the respondents.

The sample consisted of 325 riders of bicycle-style e-bike (53.9%) and 278 riders of scooter-style e-bike (46.1%). About 65% of respondents were male and about 35% were female. The majority (n = 581, 96.4%) were young (<30 years) and middle-aged (30 to 50 years) riders. This population distribution of e-bike riders was consistent with another study that used field observations (*23*). Of the respondents, 225 (37.3%) reported having an automobile driver's license. On average, the respondents had ridden e-bikes for 4.7 years (standard deviation = 2.7, range = 0.5 to 13.9). Most respondents reported riding at least 3 days per week (83.3%) and at least 10 km per day (52.3%), implying that the respondents were active e-bike riders.

The mean number of self-reported at-fault accidents in the year preceding the study was .64. The distribution was highly positively skewed: 73.0% had no accident, 14.4% had one accident, 4.5% had two accidents, and 8.1% had three or more accidents. Therefore, accident involvement is dichotomized (0 = no accident, 1 = one or more accidents) in the following analysis.

TABLE 1 Summary of Respondents' Demographic Information (N = 603)

Demographic	Frequency	Percentage
E-bike type		
Bicycle style	325	53.9
Scooter style	278	46.1
Gender		
Male	393	65.2
Female	210	34.8
Age in years		
Young (<30)	401	66.5
Middle-aged (30–50)	180	29.9
Elder (>50)	22	3.6
Have automobile driver's license		
Yes	225	37.3
No	378	62.7
Riding frequency (n = 600)[a]		
5–7 days per week	375	62.5
3–4 days per week	125	20.8
1–2 days per week	102	17.0
Average riding distance per day		
<10 km	286	47.7
10–20 km	209	34.8
>20 km	105	17.5
At-fault accident involvement during the past year		
Yes	163	27.0
No	440	73.0
Severity of accidents		
Serious injuries	32	5.3
Minor injuries	94	15.6
Property damage only	96	10.6

NOTE: Riding history in years: mean = 4.7, standard deviation (SD) = 2.7, range = 0.5–13.9.
[a]Total number of responses was less than 603 because some subjects did not report on this item.

Reliability of Measurement Instruments

A new instrument was constructed for measuring the aberrant riding behaviors of e-bike riders as part of the study. To validate this instrument, the 603 respondents were divided into two groups: 200 randomly selected samples for exploratory factor analysis (EFA) and the remainder for a confirmatory factor analysis (CFA). The EFA process adopted the principal component and varimax rotation approach and indicated a five-factor solution. The CFA was then applied to validate the reliabilities and goodness of fit of the resulting factors. Table 2 shows the CFA results and a summary of the corresponding items for each factor. Most performance measures of the mode fit indexes satisfied the conventionally acceptable level (n = 403, χ^2/degrees of freedom (df) = 1.67, RMSEA = 0.04, CFI = 0.95, GFI = 0.90, AGFI = 0.87).

Items were categorized into five dimensions in the model. The first was mainly related to what Reason et al. defined as errors, that is, slips, lapses, and mistakes (10 items, Cronbach's alpha = 0.898) (*7*). The second dimension, impulse behavior, contained items measuring the ability of self-control and level of tolerance for other people's faults (eight items, Cronbach's alpha = 0.857). The third dimension, aggressive behavior, belongs to a general category of aggressive riding behaviors whereby respondents deliberately behave in a manner that increases the risk of conflicts (seven items, Cronbach's alpha = 0.877). Items in the fourth dimension, rule violation, related to behaviors such as running a red light, riding in the wrong direction, and riding in the vehicle lane (seven items, Cronbach's alpha = 0.865). The last dimension includes items related to pushing one's limits and engaging in stunt behaviors (five items, Cronbach's alpha = 0.823).

TABLE 2 Dimensional Structure of Aberrant Riding Behaviors

Measurement	Factor Loading	Cronbach's Alpha	Mean (SD)
Dimension 1. Errors (10 items)		0.898	1.76 (.62)
Fail to check other traffic before turning around	0.603		
Fail to notice or anticipate other riders' intentions and have to brake suddenly	0.589		
Ride in a very close position at the right side of large vehicles	0.635		
Attempt to overtake someone who signals a left turn	0.698		
Underestimate the speed of oncoming vehicles	0.685		
Fail to notice traffic coming from other directions	0.675		
Ride so fast into a corner that you almost lose control	0.686		
Fail to notice pedestrians waiting to cross when turning right	0.539		
Nearly hit someone because of being distracted	0.596		
Forget to slow down when rounding a sharp corner	0.753		
Dimension 2. Impulsive behavior (8 items)		0.857	2.47 (.73)
Be impatient when riding after others	0.603		
Be angry when those in front of you are moving slowly	0.645		
Feel good when successfully overtaking someone	0.726		
Try to blame others for bringing you inconvenience	0.651		
Feel frustrated when failing to overtake others	0.676		
Be impatient when trapped in traffic jam	0.567		
Exceed the speed limit when the traffic volume was low	0.494		
Exceed the speed limit (by more than 10 km/h)	0.509		
Dimension 3. Aggressive behavior (7 items)		0.877	1.74 (.69)
Ride closely to those in front deliberately to make them get out of your way	0.679		
Approach intersections without deceleration	0.645		
Weave through traffic	0.631		
Keep honking when irritated	0.589		
Have words or bodily conflict with other road users	0.693		
Give chase to someone who angers you	0.799		
Sound your horn to indicate your annoyance to other road users	0.681		
Dimension 4. Rule violation (7 items)		0.865	1.89 (.70)
Run a red light	0.699		
Ride against the traffic	0.722		
Ride in the motor vehicle lane	0.687		
Overload	0.705		
Speeding	0.694		
Illegal crossing	0.699		
Ride across the stop line when waiting for a green light	0.711		
Dimension 5. Pushing limits, stunts (5 items)		0.823	1.69 (.70)
Ride as fast as possible	0.615		
Ride an e-bike without brake	0.656		
Imitate the posture and movement used in a motorcycle race	0.646		
Try to break your speed record	0.613		
Try to overtake whenever possible	0.666		

NOTE: SD = standard deviation.

TABLE 3 Descriptive Statistics for Risk Perception and Safety Attitudes

Measurement	Number of Items	Mean	SD	Cronbach's Alpha
Risk perception scales				
Worry and concern	6	4.20	0.91	0.752
Perceived likelihood of accident and danger	7	4.34	0.84	0.812
Safety attitude scales				
Attitude toward safety and personal responsibility	5	5.04	0.90	0.823
Attitude toward traffic rules	5	4.49	0.87	0.789
Attitude toward risky riding behaviors	6	5.01	1.05	0.925

For each dimension, scores on separate items were averaged into one index. Higher scores reflected a stronger presence of the concerned behavior.

Descriptive statistics and Cronbach's alpha coefficients were also calculated for safety attitude and risk perception scales. The number of items, means, standard deviations, and internal consistency are listed in Table 3. The Cronbach's alpha coefficients varied from .75 to .93, indicating that the reliability of all the scales is acceptable.

Risk Factors Associated with Accident Involvement

Analysis of self-reported accident involvement showed that 27% ($n = 163$) of the respondents had been involved in at least one accident during the previous year. The percentages of respondents with at-fault accident history in each demographical variable are shown in Figure 1. Males were more likely to have at-fault accidents than were females (31.3% versus 24.5%, $\chi^2 = 10.41$, $p < .01$). Riders with an automobile driver's license were less likely to be involved in at-fault accidents than were those without one (21.8% versus 30.2%, $\chi^2 = 5.02$, $p < .05$). Accident involvement was found to decrease with age but increase with riding history; however, the trends were not statistically significant ($p > .05$).

The mean scores on risk perception, safety attitude, and aberrant behavior scales were compared for respondents with a history of at-fault accident involvement and those without such a history. The results, presented in Table 4, showed that e-bike riders with at-fault accident history had less positive attitudes toward traffic safety and reported significantly higher frequency of aberrant riding behaviors.

A binary logistic regression model was applied to identify significant factors predicting at-fault accident occurrence. At-fault accident involvement was represented as a response variable (yes = 1, no = 0). Gender, driver's license status, and scores on scales of safety attitudes and aberrant riding behavior were included as predictor variables. All predictor variables entered the model simultaneously, and each was automatically adjusted for confounding effects of the other variables. The results of the logistic regressions are summarized in Table 5.

Gender and driver's license status proved to be significant variables for predicting at-fault accident occurrence. The odds ratio showed that males were 1.79 times more likely to have at-fault accidents than were females. E-bike riders with an automobile driver's license were 1.51 times less likely to be involved in at-fault accidents than were those without a driver's license. Moreover, two scales of aberrant riding behavior (i.e., error and aggressive behavior) were found to predict significantly at-fault accident involvement, even after the effects of all other variables were statistically controlled for. The odds ratio showed that riders who reported more errors and aggressive riding behaviors had a higher chance of being involved in an at-fault accident.

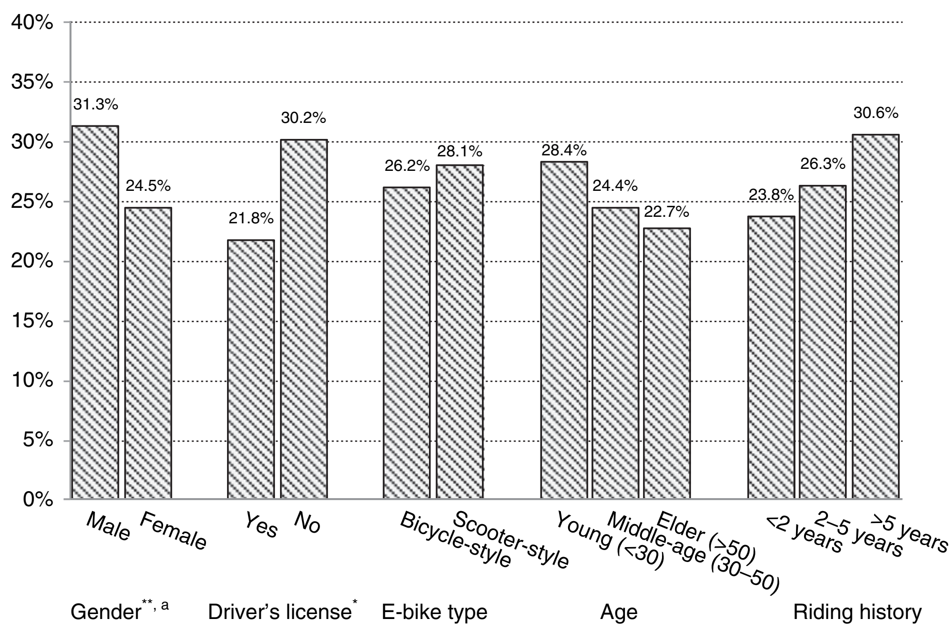

FIGURE 1 Percentages of respondents with history of at-fault accidents during previous year ([a]χ^2 test. *$p < .05$; **$p < .01$; all others $p > .05$).

TABLE 4 Comparison of Respondents with History of At-Fault Accident Involvement and Those Without

Measure	At-Fault Accident Involvement		
	Yes[a] [Mean (SD)]	No[b] [Mean (SD)]	F^c
Risk perception scales			
Worry and concern	4.22 (.92)	4.22 (.92)	1.38*
Perceived likelihood of accident and danger	4.32 (.83)	4.40 (.85)	1.09*
Safety attitude scales			
Attitude toward safety and personal responsibility	4.81 (.93)	5.13 (.89)	15.00****
Attitude toward traffic rules	4.32 (.88)	4.57 (.86)	10.57***
Attitude toward risky riding behaviors	4.79 (1.13)	5.09 (.99)	9.26***
Aberrant riding behavior scales			
Errors	2.00 (.68)	1.67 (.58)	29.31****
Impulse behavior	2.66 (.76)	2.41 (.71)	14.04****
Aggressive behavior	2.00 (.71)	1.65 (.66)	30.13****
Rule violation	2.07 (.73)	1.81 (.68)	15.87****
Pushing limits, stunts	1.89 (.74)	1.61 (.67)	17.69****

[a] $n = 163$.
[b] $n = 440$.
[c] ANOVA, Tamhane's T2 test was used to analyze the differences between the two groups when the results of Levene's tests indicated that the assumption of homoscedasticity was violated.
*$p > .05$; **$p < .05$; ***$p < .01$; ****$p < .001$.

Influences of Safety Attitudes and Risk Perception on Aberrant Riding Behaviors

A structural equation model was constructed to examine how safety attitudes and risk perception would affect aberrant riding behaviors. Because it was expected that perception of risk could influence safety attitudes (*24*) and that both safety attitudes and risk perception could influence aberrant riding behaviors (*11, 19*), the model was constructed with influential paths from risk perception to safety attitude, then from safety attitude to aberrant riding behavior, as well as with a direct path from risk perception to aberrant riding behavior. The estimated model with standardized path coefficients is presented in Figure 2. The model explained 37% of total variance in aberrant riding behaviors. The fit measures indicated that the proposed model fit the data well: $\chi^2/\text{df} = 4.61$ ($N = 603$), RMSEA = .08, CFI = .97, GFI = .96, and AGFI = .92.

The effect of safety attitudes on aberrant riding behaviors was significantly negative ($\beta = -.74$, $t = -7.98$), an indication that the more positive their attitudes on traffic safety, the less likely e-bike riders would engage in aberrant riding behaviors. Although a significant positive direct effect ($\beta = .26$, $t = 2.53$) was observed for the effect of risk perception on aberrant riding behaviors, the indirect effect through safety attitudes played a more critical role ($-.49 = -.74 * .66$). In other words, e-bike riders who scored higher on risk perception were less likely to engage in aberrant riding behaviors, largely because of more positive attitudes toward traffic safety.

TABLE 5 Logistic Regression Values of Significant Predicting Variables for At-Fault Accident Involvement (*N* = 603)

Variable	β	SE	Wald	Odds Ratio	95% CI
Gender (male vs. female[a])	0.58	0.22	6.98***	1.79	1.16–2.74
Having driver's license (yes[a] vs. no)	0.41	0.21	3.93**	1.51	1.01–2.27
Errors	0.62	0.26	5.81**	1.87	1.12–3.10
Aggressive behavior	0.43	0.20	4.52**	1.54	1.03–2.29

NOTE: CI = confidence interval; SE = standard error.
[a] Reference in that categorical variable.
**$p < .05$; ***$p < .01$; ****$p < .001$.

DISCUSSION OF RESULTS

E-bike-related fatalities and injuries are a rising traffic injury burden in China (*3*). A questionnaire survey of a sample of 603 e-bike riders in China was carried out to identify risky factors associated with self-reported accident involvement and to establish the relationships between safety attitudes, risk perception, and aberrant riding behaviors.

One of the primary purposes of this study was to identify risk factors that predict accident involvement by e-bike riders in China. First, the results showed that e-bike riders who had a driver's license were less likely to be involved in at-fault accidents. The possible contribution of automobile driving experience to the safety of two-wheelers was also reported in studies with motorcyclists (*25*). Such findings suggest that riding behavior may benefit from familiarity with traffic laws and driving skills learned as automobile drivers. Second, male riders were more likely to be involved in accidents than females. The gender difference in traffic safety is well documented in the literature. For example, as drivers, pedestrians, and two-wheeled vehicle riders, men take more risks and are more likely to be involved in fatal crashes than women do (*26, 27*). Third, accident involvement was found to increase with riding history, but this trend was not statistically significant, and the higher proportion of accident involvement for those with a longer riding history may be a reflection of increased exposure.

Errors and aggressive riding behaviors were also found to be significant predictors of accident involvement, even after the effects of all other variables were controlled for. Errors were mainly the result of lack of safety awareness (e.g., "Riding in a very close position at the right side of large vehicles") and poor skills in observing traffic (e.g., "Failing to notice the traffic coming from other directions").

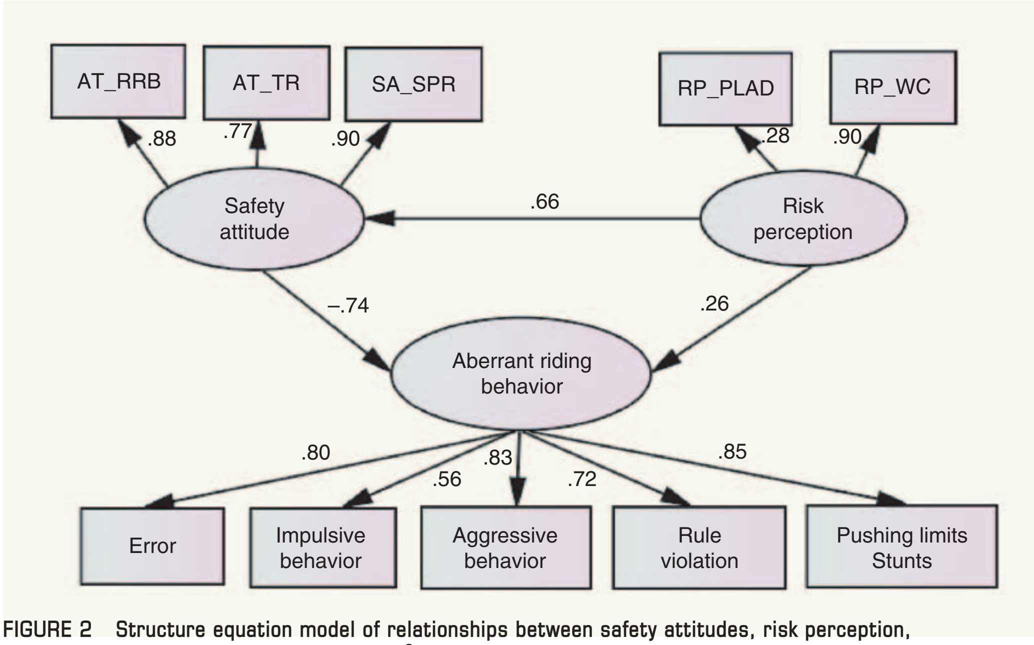

FIGURE 2 Structure equation model of relationships between safety attitudes, risk perception, and aberrant riding behaviors (N = 603; χ^2/df = 4.61; RMSEA = 0.08; CFI = 0.97; GFI = 0.96; AGFI = 0.92; AT_RRP = attitude toward risky riding behaviors; AT_TR = attitude toward traffic rules; AT_SPR = attitude toward safety and personal responsibility; RP_PLAD = perceived likelihood of accident and danger; RP_WC = worry and concern).

Aggressive behaviors are deliberate behaviors that increase the risk of conflicts and hostile acts in response to traffic disputes, which in a broad sense are considered to be violations. These behaviors must be targeted in road safety interventions aimed at improving e-bike safety.

Another aim of this study was to explore the relationships between safety attitudes, risk perception, and aberrant riding behaviors. A significant negative relationship between safety attitudes and aberrant riding behaviors was identified. E-bike riders who had a stronger sense of responsibility for safety, felt more obligated to obey traffic rules, and showed more negative attitude for risky riding behaviors were less likely to engage in aberrant riding behaviors. This result is consistent with previous studies investigating driver's attitudes and behaviors. It may imply that strategies intending to promote road safety can be aimed at changing the rider's attitudes towards safety. Second, in terms of risk perception, the results revealed a strong indirect effect on aberrant riding behaviors through the influence of safety attitudes. E-bike riders who scored high on risk perception tended to have positive attitudes toward traffic safety, which in turn caused them to be less likely to commit aberrant riding behaviors. However, risk perception was also found to have a positive direct effect on aberrant riding behaviors. A possible explanation for this finding is that two subscales were used to measure risk perception in this study. Whereas worry and concern about traffic risk are generally believed to be negatively correlated with risk-taking behaviors, the perception of the likelihood of an accident and danger may be made based on individual riding experience (*28*). Therefore, riders who take more aberrant riding behaviors may think of themselves as being at high risk for crashes, but not vice versa.

The findings of the study provide useful information for road safety interventions and the development of education and training programs for e-bike riders in China. That two types of aberrant riding behaviors significantly predict accident involvement has important implications about which safety interventions may be most effective. Training interventions can improve traffic skills, such as hazard perception and control skills, and thus could effectively reduce errors. Regarding aggressive behaviors, traffic laws related to e-bikes must be improved and enforced. The results suggest a need for road safety campaigns that target safety attitudes and risk perception, which were found to have significant effects on aberrant riding behaviors. For example, riders should be well informed of the risks involved in traffic accidents and their potential consequences. Efforts to educate riders about traffic safety should emphasize the importance of obeying traffic rules and stress the idea of personal responsibility on the road.

A possible limitation of the study is that it relied on self-reported accident involvement and riding behaviors. These kinds of information are susceptible to social desirability effects and recall bias (*15*). Effort was made to make the data as reliable as possible. For example, respondents were clearly informed of the purpose of the study and were assured that they would remain anonymous, which may have encouraged them to be honest in their answers. To make the recall process more accurate, accidents were classified into three categories according to the consequences. In addition, only at-fault accidents were used for analysis because these accidents were less easily forgotten (*29*). Nevertheless, a combined use of self-report data, police records, and data obtained by field observation are recommended in future studies of e-bike safety.

CONCLUSION

This study sought to identify risk factors affecting the accident involvement of e-bike riders in China and to establish the relationships between safety attitudes, risk perception, and aberrant riding behaviors.

Overall, 27% of the e-bike riders reported being involved in an at-fault accident at least one time during the previous year. Gender and automobile driving experience were identified as having significant influences on at-fault accident occurrence. Men were more likely to have at-fault accidents than women were. Riders with a driver's license were less likely to be involved in at-fault accidents than those without. In addition, two types of aberrant riding behaviors, errors and aggressive behaviors, proved to be significantly associated with at-fault accidents. E-bike riders reporting more errors and aggressive behaviors were more prone to at-fault accident involvement.

The structural equation model showed that safety attitudes had a significant negative effect on aberrant riding behaviors. For the influence of risk perception, both a positive direct effect and a negative indirect effect mediated by safety attitudes were found. E-bike riders who had stronger positive attitudes toward safety and showed more worry and concern about their traffic risks tended to be less likely to engage in aberrant riding behaviors.

These findings enhance the understanding of the risk factors associated with e-bike accidents and the relationships between safety attitudes, risk perception, and aberrant riding behaviors. The findings may help policy makers and traffic managers develop effective education and intervention programs to improve e-bike safety.

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