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Unsafe riding behaviors of shared-bicycle riders in urban China: A retrospective survey

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ABSTRACT

Shared-bicycle use has skyrocketed in urban China, but little is known about the safety of bicycle users. The Chinese popular media reports multiple risky riding behaviors among shared bicycle riders, but scientific research on the topic is lacking. Therefore, we conducted a retrospective WeChat-based online survey to examine how often shared bicycle riders report engaging in risky cycling behaviors in urban China. Eight unsafe shared bicycle riding behaviors were assessed: not wearing helmets, running red lights, cycling against the traffic flow, riding in lanes designed for motor vehicles, riding in lanes designed for pedestrians, carrying passengers on bicycles, using cell phones while riding, and eating while riding. In total, 1960 valid questionnaires were collected. The proportion of participants who reported always or often having unsafe riding behavior in the past month, ranged from 1.1% for carrying passengers on the bicycles to 97.6% for failing to wear a helmet. Demographic characteristics were associated with unsafe behaviors through multivariate logistic regression, with male riders and riders aged 25 years or younger more likely to ride while using cell phones than females (AOR = 2.94) and those 36 years or older (AOR = 3.57). Cyclists with undergraduate education were more likely to wear helmets than those with postgraduate education or higher (AOR = 0.21). Compared to riders from central municipalities governed directly by the central government, riders from provincial capitals, deputy provincial cities, and smaller cities were at higher risks of riding in lanes for pedestrians, respectively (AOR = 1.59, 2.82 and 1.61). Riders who rode over 5 h a week and who rode on weekends were more likely to carry passengers than those who rode less than 1 h a week (AOR = 4.72) and those who rode only on weekdays (AOR = 3.93). We conclude that shared-bicycle riders frequently engage in some unsafe riding behaviors in urban China. Younger age, lower level of education, and longer hours of riding each week are associated with greater risks of some unsafe riding behaviors. Shared bicycles offer substantial benefit to societal health and transportation, but evidence-based interventions should be considered to reduce risks from unsafe shared bicycle riding behaviors. A well-designed road infrastructure with dedicated on-road bicycle lanes and readily-accessible comfortable, low-cost, and safe helmets may also reduce unsafe riding behaviors and unwanted crashes and injuries for shared bicycle riders.

1. Introduction

New-generation dock-less, internet- and smartphone-based, low-cost shared bicycles have skyrocketed in popularity in China. These shared bicycles offer a unique transportation option for citizens. They can be rented and returned anywhere, they are convenient and low-cost to use, and they require only a simple smartphone application to use. In many Chinese cities, the shared bicycles are omnipresent – in most cases, users can find a shared bicycle available to rent within a 20 m radius of where they are located.

Data concerning frequency of shared bicycle use are kept confidential by industry, but one research network estimates the

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proportion of kilometers travelled by cycling in China rose from 5.5% to 11.6% following the introduction of shared bicycles in 2016 (Beijing Tsinghua Tongheng Innovation Institute of Planning, Design, and Research Technology, 2017). During that same time period, the proportion of kilometers travelled by private car, taxi (both shared rides and private cars), bus and train decreased.

Shared bicycles offer several benefits, including increased physical activity for citizens, alleviation of air pollution and traffic jams in busy urban centers, and opportunities for economic development (Cao et al., 2015). They provide a convenient, efficient, and low-cost means of transportation in busy Chinese urban environments. However, shared bicycles also create risks. Researchers in other countries report significant risks to all cyclists from lack of helmet use (Fischer et al., 2012; Goodman et al., 2014; Kraemer et al., 2012; Nanapragasam, 2014), red-light running behavior (Pai and Jou, 2014), cycling against the traffic flow (Useche et al., 2018b), and distracted riding (Wolfe et al., 2016; Useche et al., 2018a). The global road injury incidence for cyclists has increased recently, reaching a rate of 156 per 100,000 persons in 2017 according to the estimates from the Global Burden of Disease (GBD) 2017 update (GBD Compare, 2018). In China, about 8.5% of road traffic deaths and 19.1% of prevalent cases for road injuries occurred among cyclists in 2017 (GBD Compare, 2018).

Shared bicycle use presents somewhat different risks than private bicycle risk, as their use may be less planned, users are extremely unlikely to carry helmets with them, and their use may be for short-distance efficient commuting rather than longer-distance riding for pleasure or exercise. Scholarly research on risks specific to shared bicycle users in China is sparse, but the domestic popular media in China reports substantial risks from multiple factors, including traveling in motor vehicle and/or pedestrian lanes, carrying passengers on bicycles (CCTV, 2017), and lack of helmet use (Wang, 2017).

This study was designed, therefore, to quantify the extent of shared bicycle riding risks in urban China through epidemiological strategies. We used internet-based survey strategies to gather data from a large sample of shared-bicycle users in urban areas throughout China.

2. Methods and materials

2.1. Study recruitment

Because almost all shared bicycles in urban China are based on smartphone applications (Liu and Chen, 2018), we used an iterative sampling process to recruit study participants through WeChat, the most popular smartphone-based social media program in China. Non-probability sampling is preferred over random sampling to recruit a study sample when a random sample that is representative of the population is unlikely to be obtained (Sun and Xu, 2014), as is the case for social media-based sampling. To recruit our sample, initial survey invitations were sent to a convenience sample of colleagues, family members, classmates, and friends who had WeChat contact with members of the research group. Many of these individuals chose to participate, and then were asked to send the information about the survey to people included in their own WeChat contact list. This "snowball" recruitment process was iterated for a month, at which point the sample size was deemed sufficient and data collection was halted.

We recruited a total of 1960 respondents. Among them, riders aged 25 years and younger accounted for 54% of the sample, followed by age groups 26–35 years old (32% of sample) and ≥36 years old (14%). Males comprised 36%, 47% and 56% of the sample in the age groups of 25 years and younger, 26–35 years old, and ≥36 years old, respectively. 39% of respondents reported having received postgraduate education or higher (769 participants; 41% male and 59% female), 50% reported having an undergraduate education (970 participants; 42% male and 58% female), and the remainder of the sample reported an education less than an undergraduate degree (221 participants, 11% of the sample; 48% male and 52% female).

2.2. Ethical statement

Informed consent was provided by all participants online and all data were collected anonymously. The research plan was approved by the Medical Ethics Committee of Central South University (No. XYGW-2017-39).

2.3. Outcome measures

We assessed eight self-reported unsafe shared bicycle riding behaviors: (1) not wearing helmets, (2) running red lights, (3) cycling against the traffic flow, (4) riding in a motor vehicle lane where bicycles are prohibited, (5) riding in a pedestrian lane where bicycles are prohibited, (6) carrying passengers on a shared bicycle with only one seat, (7) using a cell phone while riding a shared bicycle, and (8) eating while riding a shared bicycle. The eight risky behaviors were identified through a series of steps involving a thorough review of existing scientific literature and popular media sources, multi-round group discussions among the research team, and pilot testing. In each case, respondents answered concerning the frequency with which they engaged in the risky behavior on a 4-point scale (always, often, sometimes, or never).

Of the eight risky behaviors, two are prohibited by national law in China, running red lights (State Council of the People's Republic of China, 2004) and riding in a motor vehicle lane or pedestrian lane (Standing Committee of the National People's Congress of the People's Republic of China, 2011). A third, cycling against the traffic flow, is prohibited for motor vehicles but not bicycles (State Council of the People's Republic of China, 2004).

2.4. Independent variables

Participants reported basic demographic information (sex, age, level of education), the type of city where they lived and rode shared bicycles, and shared bicycle travel-related information (typical purpose of shared bicycle travel, number of shared bicycle riding hours a week, and riding time for average shared bicycle rides).

2.5. Data collection

The WeChat-based online survey was active for one month, from September 7, 2017 to October 6, 2017. We estimated *a priori* that a one-month survey period would be sufficient to obtain a moderate or large sample size, and our estimation proved true after the month had passed. Minimal sample size was not calculated due to lack of information concerning relevant parameters.

2.6. Statistical analysis

Data analysis proceeded in several steps. First, tables and percent bar charts were created to present the frequency of each of the eight unsafe riding behaviors that participants self-reported. We combined responses of "often" and "always" to ease interpretation of the tabled results. Second, Chi-square tests were conducted to examine differences in the proportion of riders often/always having unsafe behaviors based on demographic and travel-related variables. Third, we used multivariate binary logistic regression to examine associations between the eight unsafe behaviors and demographic and travel-related variables. The adjusted odds ratio (AOR) was calculated to quantify the associations. SPSS (Statistical Product and Service Solutions) statistical software version 22.0 (IBM Corp, Armonk, NY, US) was used to perform all statistical analyses. P values < 0.05 were considered statistically significant (Sun and Xu, 2014).

Table 1
Proportion of sharing-bicycle riders who reported always or often having unsafe riding behaviors in the past month.

Variable	Number (%)	Proportion of riders reporting unsafe riding behaviors							
		A	B	C	D	E	F	G	H
Total	1960 (100)	97.6	1.9	3.4	6.1	24.9	1.1	5.4	2.1
Sex									
Male	833 (43)	96.3	2.4	4.8	7.2	26.7	1.3	8.3	3.8
Female	1127 (58)	98.6*	1.6	2.4*	5.2	23.7	1.0	3.3*	0.9*
Age group									
≤25 years	1056 (54)	99.1	1.7	3.0	6.9	24.5	0.9	6.1	2.2
26-35 years	623 (32)	97.3*	1.8	3.7	5.1	24.6	1.6	5.8	2.1
≥36 years	281 (14)	92.9*	3.2	4.3	5.0	27.4	0.7	2.1*	2.1
Level of education									
Postgraduate or higher	769 (39)	99.0	2.2	3.4	5.2	23.5	0.5	5.1	1.6
Undergraduate	970 (50)	98.5*	1.6	3.2	6.4	26.1	1.0*	5.7	2.3
All others	221 (11)	89.1*	2.3	4.5	7.7	24.9	3.6*	5.4	3.6
Type of urban area of bicycle use									
Central municipality	450 (23)	98.4	1.6	3.8	4.9	18.0	2.2	6.4	2.0
Provincial capital	1092 (56)	98.6	1.6	2.8	6.1	26.0*	0.5*	4.9	1.6
Deputy provincial city	90 (5)	96.7	2.2	4.4	6.7	38.9*	0.0	6.7	3.3
All others	328 (17)	93.3*	3.4	4.6	7.3	27.1*	1.8	5.5	3.7
Province/City of bicycle use									
Hunan	579 (30)	97.4	1.7	2.6	8.5	25.9	1.2	3.5	1.7
Guangdong	230 (12)	97.8	0.9	3.9	7.0	33.9	0.0	5.7	2.6
Beijing	164 (8)	98.8	2.4	6.1	3.7	18.3	1.2	6.7	2.4
Tianjin	144 (7)	100.0	0.7	2.1	6.2	16.7	0.7	9.7*	2.1
All others	843 (43)	97.0	2.5	3.6	4.6*	24.6	1.4	5.7	2.3
Reason for travel									
Commuting to work/school	1070 (55)	98.7	2.1	4.2	6.6	23.9	1.0	6.6	2.1
Entertainment	544 (28)	98.2	1.8	2.2	4.8	26.1	1.5	5.0	2.6
Physical exercise	180 (9)	90.0*	2.8	3.9	6.7	28.3	1.7	3.3	2.8
Others	166 (9)	97.0	0.6	1.8	6.0	24.1	0.0	1.2*	0.6
Riding hours per week									
< 1 hour	240 (12)	99.2	0.8	2.9	5.0	24.6	0.0	4.2	0.8
1-2 hours	732 (37)	98.9	1.9	3.7	5.6	25.1	1.0	4.9	1.9
3-5 hours	877 (45)	96.5	1.8	2.6	6.0	24.7	1.3	5.9	2.3
> 5 hours	111 (6)	94.6	5.4	9.0*	11.7	26.1	3.6*	7.2	5.4
Type of typical riding days									
Weekday	1105 (56)	98.6	2.1	4.1	7.0	23.3	0.6	6.2	2.2
Weekend or holiday	855 (44)	96.3*	1.8	2.6	4.9	27.0	1.8*	4.3	2.1
Typical riding time									
Morning rush hours	399 (20)	96.2	2.0	6.0	6.8	24.1	0.8	5.3	1.5
Evening rush hours	698 (36)	98.1	2.6	2.7*	5.9	25.4	1.1	5.7	3.2
Other times	863 (44)	97.8	1.4	2.8*	5.9	25.0	1.3	5.2	1.6

Note: Post hoc multiple comparisons were performed between the first category and the rest of the categories for each variable respectively, based on Chi-square tests. Significance levels were adjusted for post hoc multiple comparisons.
Abbreviations of eight unsafe behaviors: A. Not wearing helmets; B. Running red lights; C. Cycling against the traffic flow; D. Riding in a motor vehicle lane; E. Riding in a pedestrian lane; F. Carrying passengers; G. Using a cell phone while riding; H. Eating while riding.
* $p < 0.05$.

3. Results

3.1. Characteristics of the study sample

In total, 1960 persons participated in the survey (Table 1). The mean age of participants was 27.63 years, with a standard deviation (SD) of 9.50 years. Of them, persons aged ≤25 years old, 26–35 years old, and ≥36 years old accounted for 54%, 32%, and 14% of participants, respectively. Males constituted 43% of participants. 50% and 39% of respondents respectively reported having received undergraduate education and having postgraduate education or higher. The majority of respondents came from provincial capitals (56%) and central municipalities (23%). Geographically, the participants came primarily from Hunan Province (29.5%), Guangdong Province (11.7%), Beijing city (8.4%) and Tianjin city (7.3%), with the remainder spread across China.

The most common reasons to ride shared bicycles were commuting to work/school (55%), entertainment (28%), and physical exercise (9%). Ninety-four percent of respondents reported riding 5 h or less per week. A little over half of participants reported their typical use of shared bicycles on weekdays (56%), with the remainder (44%) reporting they typically used the shared bicycles on weekends/holidays (44%). Rush hours (both morning and evening rush hours) were the most common time for people to ride shared bicycles (56%).

As shown in Table 1, the proportions of self-reported unsafe riding behaviors were significantly associated with several demographic and travel-related factors. Univariate analyses showed that (a) the proportion of behavior A (not wearing helmets while riding a shared bicycle) was significantly related to sex, age group, level of education, type of urban area of bicycle use, reason for travel and type of typical riding days; (b) the occurrence of behavior C (cycling against the traffic flow) was significantly associated with sex, riding hours per week and typical riding time; (c) the proportion of behavior D (riding in a motor vehicle lane) was associated with province/city of bicycle use; (d) the proportion of behavior E (riding in a pedestrian lane) was significantly associated with type of urban area of bicycle use; (e) the proportion of behavior F (carrying passengers while riding) significantly correlated with type of level of education, type of urban area of bicycle use, riding hours per week, and type of typical riding days; (f) the proportion of behavior G (using a cell phone while riding) was significantly related to sex, age group, province/city of bicycle use and reason for travel; and (g) the proportion of behavior H (eating while riding) was significantly

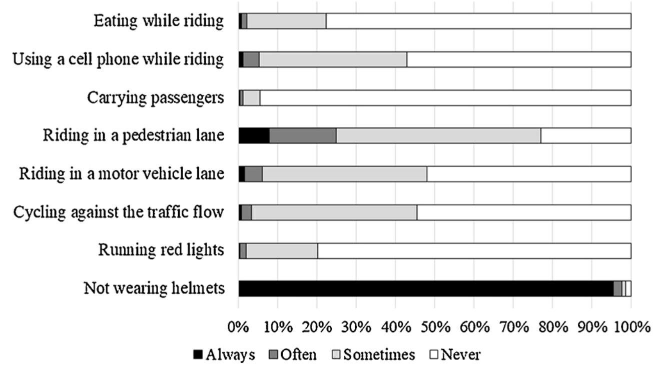

Fig. 1. Self-reported unsafe riding behaviors among 1960 shared-bicycle riders in the prior month in China.

associated with sex (Table 1).

3.2. Proportion of unsafe riding behaviors

The frequency with which participants reported unsafe shared bicycle riding behaviors in the past month differed greatly across the behaviors (Fig. 1). The most common unsafe riding behavior self-reported as often or always occurring in the past month was not wearing helmets (97.6% often/always reported doing this; 95% CI: 96.9–98.3%), followed by riding in a pedestrian lane (24.9%, 95% CI: 23.0–26.9%), riding in a motor vehicle lane (6.1%, 95% CI: 5.0–7.1%), using a cell phone while riding (5.4%, 95% CI: 4.4–6.4%), cycling against the traffic flow (3.4%, 95% CI: 2.6–4.2%), eating while riding (2.1%, 95% CI: 1.5–2.8%), running red lights (1.9%, 95% CI: 1.3–2.5%), and carrying passengers (1.1%, 95% CI: 0.7–1.6%).

3.3. Associations between unsafe riding behaviors and demographic and travel-related variables

The differences in the proportions of participants reporting unsafe riding behaviors were generally insignificant across the demographic and travel-related variables we examined, with a few exceptions outlined below (Table 2). Specifically, multivariate logistic regression showed that (a) after adjusting for other variables, females were more likely than males to not wear helmets (AOR = 2.28) and less likely to cycle against the traffic flow (AOR = 0.54), use a cell phone while riding (AOR = 0.34), and eat while riding (AOR = 0.23); (b) riders aged over 35 years were less likely to use a cell phone while riding compared to those aged 25 years or younger (AOR = 0.28); (c) compared to riders with postgraduate education or higher, those with undergraduate education had a higher likelihood of carrying passengers (AOR = 8.52) but lower likelihood of not wearing helmets (AOR = 0.21); (d) compared to riders from central municipalities, those from the other three types of urban areas had a higher proportion of riding in a pedestrian lane (AOR = 1.59, 2.82, and 1.61), and those from provincial capitals had a lower proportion of carrying passengers (AOR = 0.19); (e) the proportion of individuals not wearing helmets was lower among those who rode shared bicycles for physical exercise than those for commuting to work/school (AOR = 0.33); (f) shared-bicycle users who rode for more than 5 h a week were more likely to carry passengers than those who rode less than 1 h (AOR = 4.72); and (g) participants who typically rode on weekends or holidays had a lower proportion of not wearing helmets (AOR = 0.35) but a higher proportion of carrying passengers (AOR = 3.93) than those who typically rode on weekdays (Table 2).

4. Discussion

4.1. Primary findings

We found that 97.6% of participants in China reported they often or always failed to wear a helmet while riding shared bicycles in the past month. Additionally, 24.9% of participants admitted to riding bicycles in a pedestrian lane, 6.1% to riding bicycles in a motor vehicle lane, 5.4% to using cell phones while riding, 3.4% to cycling against the traffic flow, and a small number to taking other risks while riding shared bicycles. With a few exceptions, the proportions of unsafe riding behaviors were generally similar across sex, age, and level of education groups, as well as across types of city, and reasons and hours of riding.

The extremely high proportion of participants who reported they did not wear helmets on shared bicycles concords with findings elsewhere, mostly with private bicycles, such as in South Korea (81%) (Son et al., 2018), Paris (98%) (Osberg et al., 1998), and Germany (88%) (Ritter and Vance, 2011), but is somewhat higher than reports in Italy (78%) (Popa et al., 2017) and in Vancouver, Canada (about 67%) (Zanotto and Winters, 2017). Helmets are widely documented to reduce serious head injuries and deaths among cyclists (Thompson et al., 2000; Olivier and Creighton, 2017), but are often cited by cyclists as uncomfortable, unsightly, and logistically a hassle to use (Chow et al., 2016; Finnoff et al., 2001; Secginli et al., 2014).

Our data indicate that the shared bicycle riders we studied were more likely to wear helmets when they used the bicycles for physical exercise than when they used the bicycles for commuting. This may be attributed to the goals and circumstances of shared bicycle usage. When exercising, shared bicycle users may be expecting and prepared to rent the bicycle, and may view their activity as longer, more involved, and requiring greater safety precautions. When commuting, shared bicycle users may rent the bicycle without forethought or planning, may be desiring an efficient and convenient means of transportation, and may view their use of the bicycle to be short and directed; all of these factors may diminish the likelihood of helmet use. Our findings from urban China concord with those from a 2012 study of shared bicycle users in the United States, which reported significantly lower helmet use among shared bicycle riders than among personal bike riders using their bicycles for commuting or for casual/leisure riding (Kraemer et al., 2012).

Some scholars attribute low helmet use among private bicycle riders to the existence of a quality road infrastructure (e.g. bike lane and traffic lights), creating a cycling environment that cyclists perceive as safer and overriding the need to wear helmets (Finnoff et al., 2001). Mandatory helmet use laws, absent in China (World Health Organization, 2015), are documented to increase bicycle helmet use somewhat (Friedman et al., 2016; Karkhaneh et al., 2013; Meehan et al., 2013). As an example, the introduction of legislation requiring helmet use generated a substantial positive change in Canada, with the proportion of helmet use rising from 38% in 1996 to 75% in 1997 (Leblanc et al., 2002). One challenge is enforcement of helmet laws, which is generally poor.

Strikingly, quite a few participants in our study responded that they often or always rode in lanes designated for pedestrians and/or motor vehicles. Two previous studies highlighted the dangers of such behaviors for cyclists (Beck et al., 2016; Wee et al., 2012). In China, shared-bicycle users may use those lanes because specific bicycle lanes are unavailable or because available bicycle lanes are impeded by parked cars or street vendors; the solution, of course, is to create the strong road infrastructure and to enforce policies to ensure the use of lanes for their designated purposes (World Health Organization, 2017).

Matching results concerning cyclists riding private bicycles in Groningen, the Netherlands (de Waard et al., 2010), we found a small portion of shared-bicycle riders reported using a cellphone while riding. Although the risks of distracted driving and distracted pedestrian behavior are well documented, few studies have addressed distracted

Table 2
Associations of eight unsafe riding behaviors with relevant variables based on multivariate binary logistic regression models.

Variable	Adjusted odds ratio (95% CI)							
	A	B	C	D	E	F	G	H
Female (ref = male)	2.28 (1.17, 4.43)*	0.76 (0.39, 1.47)	0.54 (0.32, 0.90)*	0.72 (0.49, 1.05)	0.90 (0.73, 1.12)	0.84 (0.35, 2.03)	0.34 (0.22, 0.51)*	0.23 (0.11, 0.47)*
26˜35 years (ref = ≤25 years)	0.52 (0.22, 1.21)	0.87 (0.39, 1.94)	1.07 (0.60, 1.92)	0.68 (0.44, 1.07)	1.02 (0.80, 1.29)	1.86 (0.70, 4.92)	0.86 (0.55, 1.35)	0.79 (0.38, 1.66)
≥36 years (ref = ≤25 years)	0.41 (0.17, 1.00)	1.68 (0.68, 4.15)	1.07 (0.51, 2.27)	0.57 (0.30, 1.09)	1.21 (0.87, 1.67)	0.45 (0.09, 2.33)	0.28 (0.12, 0.67)*	0.65 (0.24, 1.74)
Undergraduate (ref = postgraduate or higher)	0.21 (0.09, 0.53)*	0.67 (0.22, 2.03)	1.27 (0.56, 2.89)	1.53 (0.81, 2.88)	0.91 (0.63, 1.32)	8.52 (2.26, 32.15)*	1.37 (0.67, 2.79)	1.95 (0.72, 5.29)
All others (ref = postgraduate or higher)	0.76 (0.31, 1.91)	0.68 (0.33, 1.41)	1.02 (0.58, 1.79)	1.14 (0.74, 1.76)	1.10 (0.87, 1.39)	2.38 (0.70, 8.14)	1.13 (0.72, 1.77)	1.32 (0.62, 2.80)
Provincial capital (Ref = central municipality)	1.36 (0.53, 3.54)	1.20 (0.49, 2.95)	0.77 (0.41, 1.43)	1.28 (0.77, 2.12)	1.59 (1.20, 2.11)*	0.19 (0.07, 0.54)*	0.70 (0.43, 1.13)	0.78 (0.34, 1.79)
Deputy provincial city (Ref = central municipality)	0.65 (0.15, 2.73)	1.40 (0.28, 7.04)	1.01 (0.32, 3.15)	1.29 (0.50, 3.32)	2.82 (1.72, 4.62)*	–	0.84 (0.33, 2.13)	1.27 (0.33, 4.89)
All others (Ref = central municipality)	0.55 (0.21, 1.43)	2.51 (0.90, 6.97)	1.17 (0.55, 2.51)	1.60 (0.85, 2.99)	1.61 (1.13, 2.30)*	0.39 (0.13, 1.23)	0.89 (0.46, 1.69)	1.55 (0.60, 3.98)
Entertainment (ref = commuting to work/school)	1.53 (0.55, 4.23)	0.99 (0.38, 2.57)	0.67 (0.30, 1.49)	0.87 (0.49, 1.53)	0.99 (0.73, 1.34)	0.58 (0.19, 1.76)	0.82 (0.46, 1.45)	1.28 (0.54, 3.05)
Physical exercise (ref = commuting to work/school)	0.33 (0.13, 0.81)*	0.99 (0.32, 3.11)	0.90 (0.36, 2.28)	1.16 (0.57, 2.36)	1.07 (0.72, 1.59)	0.41 (0.10, 1.66)	0.59 (0.24, 1.47)	1.10 (0.36, 3.38)
Others (ref = commuting to work/school)	0.49 (0.15, 1.60)	0.36 (0.05, 2.82)	0.51 (0.15, 1.77)	1.07 (0.52, 2.23)	0.89 (0.59, 1.35)	–	0.18 (0.04, 0.74)*	0.31 (0.04, 2.41)
1-2 hours (ref = < 1 hour)	0.95 (0.19, 4.85)	1.93 (0.43, 8.66)	1.07 (0.45, 2.53)	1.11 (0.57, 2.17)	1.03 (0.73, 1.45)	–	1.00 (0.48, 2.08)	1.71 (0.38, 7.71)
3-5 hours (ref = < 1 hour)	0.31 (0.07, 1.39)	2.02 (0.45, 8.97)	0.75 (0.31, 1.80)	1.20 (0.62, 2.30)	1.04 (0.74, 1.46)	1.35 (0.50, 3.61)	1.26 (0.62, 2.55)	2.20 (0.50, 9.68)
> 5 hours (ref = < 1 hour)	0.27 (0.05, 1.62)	5.02 (0.96, 26.19)	2.18 (0.78, 6.12)	2.18 (0.93, 5.08)	1.12 (0.66, 1.90)	4.72 (1.25, 17.88)*	1.21 (0.45, 3.24)	3.83 (0.73, 20.19)
Weekend or holiday (ref = Weekday)	0.35 (0.15, 0.79)*	0.78 (0.33, 1.83)	0.88 (0.45, 1.72)	0.68 (0.42, 1.11)	1.16 (0.89, 1.52)	3.93 (1.29, 11.97)*	0.76 (0.45, 1.29)	0.70 (0.31, 1.55)
Evening rush hour (ref = morning rush hour)	2.32 (0.95, 5.63)	1.59 (0.64, 3.94)	0.55 (0.28, 1.06)	1.02 (0.60, 1.74)	1.02 (0.75, 1.39)	1.31 (0.31, 5.57)	1.38 (0.77, 2.46)	2.56 (0.97, 6.77)
Other time (ref = morning rush hour)	2.05 (0.88, 4.77)	0.95 (0.36, 2.46)	0.60 (0.32, 1.12)	1.03 (0.61, 1.73)	1.05 (0.78, 1.42)	1.49 (0.37, 5.98)	1.31 (0.75, 2.31)	1.40 (0.51, 3.87)

95% CI: 95% confidence interval.

–: Statistical comparisons were not conducted due to zero proportion of unsafe behaviors.

Due to extremely small number of unsafe behaviors, we combined some categories for unsafe behavior of carrying passengers on a shared bicycle with only one seat in binary logistic regression models: for type of urban area of bicycle use, we combined deputy provincial city with provincial capital; for reason for travel, we combined physical exercise with others; and for length of time riding per week, we combined < 1 h with 1–2 hours.

A: Not wearing helmets; B: Running red lights; C: Cycling against the traffic flow; D: Riding in a motor vehicle lane; E: Riding in a pedestrian lane; F: Carrying passengers; G: Using a cell phone while riding; H: Eating while riding.

* $p < 0.05$.

bicycle riding (Stavrinos et al., 2018; World Health Organization, 2015). One observational study by Wolfe et al. (2016) reported that nearly one third of observed bicyclists were distracted in some way, including listening to headphones or carrying cell phones in their hand while cycling. Males were more likely to ride bicycle distracted than females in that study, a result that matches our results as well as recent findings by Useche et al. (2018a). Similarly, we and others (Goldenbeld et al., 2012) found that teen and young adult cyclists are more likely to use a phone while cycling than middle-aged and the older adult cyclists. Legislation to prohibit distracted bicycle riding, similar to legislation in many jurisdictions worldwide to prohibit distracted motor vehicle riding, would likely be effective in China, as would campaigns to promote education and behavior change.

We also found cycling against the traffic flow, eating while riding and other unsafe riding behaviors among some surveyed riders. These findings generally replicate the results of previous observational studies (Yang et al., 2014), although they differ somewhat in the frequency of occurrence (Wu et al., 2012). Previous publications have attributed risky cycling against the traffic flow to poor road design/infrastructure, and eating while riding to low awareness of the safety risks (Wu et al., 2012; Zamani-Alavijeh et al., 2010). Our focus on shared bicycle riders rather than all bicyclists may also have contributed to somewhat different results.

Although we found the frequency of unsafe shared bicycle riding was similar across most demographic groups and bicycle travel variables we studied, a few differences did emerge. As has been reported by others, we found comparatively lower helmet use among females compared to males (Ethan et al., 2016; Popa et al., 2017; Ritter and Vance, 2011; Son et al., 2018). This mechanism behind the phenomenon is unclear and may be related to different perceptions concerning the value of using helmets between males and females. In contrast with previous researches (Bolen et al., 1998; Ritter and Vance, 2011; Teschke et al., 2012), we found comparatively lower helmet use among riders with higher levels of education. Such results are perplexing, conflicting with reports that riders with lower education levels may be less safety conscious compared to those with higher education levels. (Bolen et al., 1998). Future research is recommended to replicate our results and evaluate potentially relevant variables like safety consciousness, but they may reflect the fact that our sample was not representative, with just 11% having less than an undergraduate degree, or that shared bicycle riders follow trends different from private bicycle riders.

4.2. Implications

Our findings have multiple implications. First, they highlight the need for the government of China to promote the implementation of well-designed road infrastructure that permits safe transportation by bicycle as well as other modes of transportation. Currently, very few Chinese cities have road infrastructures designed to promote bicycling (Yang et al., 2018; Zhang et al., 2018) despite the facts that cycling rates are sharply increasing with the advent of shared bicycles and research indicates the presence of a road infrastructure with dedicated on-road bicycle lanes decreases crash risk by as much as 60% (Hamann and Peek-Asa, 2013).

A second implication of our results is to consider innovations that might increase helmet use by shared bicycle riders. One option future research could consider is engineering of new bicycle helmets that are comfortable, low-cost, and hygienic for use with shared bicycles. These helmets might be rented with shared bicycles or carried by cyclists, but should be durable, comfortable, and have minimal impact on hairstyle when removed. A recent study (Kurt et al., 2017) showed that airbag helmets have potential to reduce cyclist head injury compared to more commonly-used helmets made of expanded polystyrene (EPS) foam. Another study (DeMarco et al., 2016) found that increased helmet liner thickness reduces peak headform acceleration. These innovations may improve helmets, thus raising the use of helmet among riders of shared bicycles as well as private bicycles.

Finally, our results suggest future research should be conducted to consider why some behavioral differences emerged across demographic factors and riding characteristics. Such research could reveal trends or information that are valuable to generate individualized solutions to reduce unsafe riding behaviors.

4.3. Limitations of the study

This study is primarily limited by the selection of study participants. Our use of the snowball technique (non-probability sampling) yielded a large sample, but one that may have led to selection biases. Second, our use of a self-administered online survey may have created biased results in any number of ways. We may have omitted some riders who were unwilling or uncomfortable to participate in the survey, or we may have created a situation where anonymous surveys were completed dishonestly. Third, we did not collect information on participants' bicycle injury history. This would be valuable data for future research to collect, but since the base rate for cycling injuries is low, a very large sample size would be required to gather meaningful information on shared bicycle use and actual injury events.

5. Conclusions

Shared-bicycle riders in urban China report that they frequently engage in unsafe bicycle riding behaviors. Riders with younger age, lower levels of education, and longer hours of riding each week were found to be more likely to engage in some unsafe riding behaviors. In particular, they do not wear helmets often and they frequently use pedestrian and/or motor vehicle lanes for bicycling. Further research is recommended to extend our results and develop solutions to reduce risky shared bicycle riding.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.aap.2019.06.002.

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