Journal of Community Medicine & Health Education

Chaney and Payne, J Community Med Health Educ 2017, 7:2
DOI: 10.4172/2161-0711.1000519

Research Article OMICS International

Urban College Student Bicycle Commuting: A Look at Differences in Riding Behavior by Gender

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Received date: March 06, 2017; **Accepted date:** April 20, 2017; **Published date:** April 24, 2017

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Abstract

Many bicycling collisions are attributable to individual rider behavior. Prior research demonstrates gender differences in active transportation. Research for on-road, in-traffic riding behavior between genders is limited. In this study, bicycle commuters (n=671) traveling to a large, metropolitan university in Provo, Utah were directly observed over two weeks during fall, 2014 at peak morning and peak night commute times. Data were collected for passing bicyclists: Rider characteristics and behaviors. 23.10% of bicycle commuters were female, 22.21% wore bicycle helmets, 3.24% used hand signals to indicate turning or slowing, and 10.94% used both a front and rear light while riding at night. Significant associations were observed between gender and road position even after controlling for rider and environmental factors (women more often used the crosswalk (OR=1.72, 95% CI [1.22, 2.34]), sidewalk (OR=1.39, 95% CI [1.01, 1.93]), and traveled in the wrong-direction (OR=1.41, 95% CI [1.01, 1.94])); and use a night headlight (OR=1.40, 95% CI [1.40, 5.76]). Bicyclists' behavior changed with traffic volume and day/night conditions. Understanding gender differences will be important for targeting different risk factors and promoting safe commuting among all genders.

Keywords: Women; Gender differences; Traffic; Bicycling; Safety behavior; Commuting; Urban; Injury prevention

Introduction

Urban bicycle commuting has inherent dangers that range from environmental exposure to collisions with motor vehicles. The latter danger is of particular concern because bicyclists, by their nature of being smaller and less protected, experience greater vulnerability than other vehicles on the road. Importantly, individual riding behavior has been cited to be responsible for many collisions [1].

Recent work by Basch et al. [2] found that 14.7% of bike-share bicyclists wore a helmet. A second study showed that 50.0% of all riders wore a helmet and that the proportion of helmet wearers was lower among bike-share (21.7%) or bicycle rental riders (15.3%) [3]. Helmet use was more prevalent among men (52.7%) than women (41.2%); and bicyclists observed during recreational mid-day times were less likely to wear helmets than bicyclist during commuting times. These findings help us understand the prevalence of bicycle safety gear used in urban areas. Understanding rider behavior can lead to injury prevention and contribute to creating bicycle-friendly environments. Relatedly, Bopp et al. reported unique considerations to women using active transportation, namely number of children, traffic, socioeconomics and social supports [4]. Our study sought to directly observe several gender differences in bicycle commuter behaviors in-traffic and en-route to their university campus destination.

Urban bicycle riding is becoming an increasingly attractive means of transportation in the United States of America (USA). While bike trips only account for roughly 1% of all commuting transport trips in the USA, they increased on average by 62% from 2000-2013 [5]. Among the top 70 cities with the highest proportion of bicycle commuters, 17 have more than 10,000 bicycle commuters per day [6]. Nationally more than 40 million adults commute by bike monthly [7]. Population growth and increases in on-road cycling underscore the importance of revisiting guidance on how vehicles share road space [8] Seven out of ten bicycling fatalities occur in urban areas [9]. The trend in urbanization is illustrated by the prediction that by 2030, 60% of all people will live in urban areas [10].

Bicycle commuter ridership is increasing in the Intermountain West. Seven of the top ten states by proportion of commuters using bicycles are in the Western USA, and three of these being in the Intermountain West [6]. Utah is ranked ninth nationally for proportion who commute via bicycles and experienced a 59.8% increase in commuter ridership from 1990-2012. Likewise, Colorado is ranked third (61.3% increase in commuter ridership) and Wyoming is ranked fourth (82.1% increase in ridership) [6]. Additionally, the study locale is among the top 25 municipalities in the USA with 4.05% bike commuter share, roughly 2,387 bicycle commuters, over 1,200 bicycle commute specific trips per day [6,11]. Despite the growth in bicycle ridership, safety programs and safety education have not matched this growth. Unlike motor vehicle transportation, there exists no uniform education system to instruct individuals how to ride safely.

Road transportation injuries are among the World Health Organization's leading causes of death [8,12]. On-road bicycle safety to reduce death and injury presents a challenging public health problem primarily because it deals with different vehicles types sharing the same road space. Although the majority of these bicycle-vehicle collisions result in soft-tissue injuries, like abrasions, other outcomes include severe injury, days off from work/school, emotional trauma, property damage, and even death [1,13]. Factors that pose increased risk bicycling injuries include roadways with high traffic volume, major road crossings, traffic speed, lack of bicycling infrastructure, and personal behavior of bicycle riders and drivers [1,14].

Several studies report the health benefits of bicycling. Of particular mention are the added benefits resulting from physical activity and leading causes of disease such as cardiovascular fitness [10,12,15-17]. An association between increased bicycle use and reduced environmental pollution was demonstrated in light of the benefits of bicycling far outweighing the exposure risks [18]. While on-road bicycle commuting has inherent risks, including emissions exposure, risk of collisions, and personal risk-taking, the literature supports that the health benefits outweigh these risks [19,20].

Bicycle safety promotion research has largely focused on helmet use, particularly among youth riders [21]. Lack of helmet use is related to injury severity in that helmets can help prevent serious head injuries, including death. Despite this, evidence suggests that fewer than one third of adult bicyclists use helmets [2,22,23]. Although helmets can prevent serious head injuries other evidence suggests individual rider behavior is significantly linked to accident likelihood and severity [1] the more at fault the bicyclist was, the higher the likelihood of the accident being severe. On the other hand, safer individual bicyclist behavior and an environment that is inviting for bicyclists can aid in promoting health and preventing injuries [1,24].

There is emerging understanding of gender differences in bicycle commuting. For example, that there are differences in perceived safety [25], concerns for being “seen” while riding [12] and traditional gender roles that contribute to differences in active transportation [26]. Likewise, little is known about the environment or related demographics of these behaviors. We anticipate there to be some environmental interaction with behavior (i.e. that environment influences behavior) as is seen in other studies. For example, Durand et al. [27] and McCormack et al. [28] describe how built, physical environments are associated with physical activity.

In this article we report the prevalence of bicycle safety behaviors, and how they differ demographically and environmentally. We sought to answer the following research questions in this study: (1) Are bicycle commuter safety behaviors independent of bicyclists’ gender? (2) Are bicycle commuter safety behaviors independent of different environmental conditions: traffic volume and daylight conditions? Findings from this research will inform efforts to promote bicycle commuting use and bicycle safety.

Methods

Data collection

This study employed direct or unobtrusive observation of bicycle commuters during peak daytime and peak night time commuting times on business days: 8:00 AM-10:00 AM and 7:30 PM-9:00 PM. Data was collected among adult bicycle commuters, estimated to be 18 years of age or older, at seven locations around the perimeter of campus. Two coders worked to collect data together and were trained to identify variables measured by the data collection instrument during a pilot period. These locations were selected because they were access points to buildings commonly used for classes and because of their proximity to bicycle parking. Data were collected over 15.3 hours across two weeks during Fall, 2014. The protocol for this study was reviewed and approved by the University Institutional Review Board.

Measures

The data collection instrument measured bicycling behaviors, demographics, and environmental conditions. The work of [23,29] provided insight into observing bicycle safety variables with specific respect to bicyclist behavior and environmental conditions. We used this prior work as the basis for developing our data collection instrument in terms of variables to measure and creating a functional data collection sheet. The instrument was pilot tested during two observation periods to ensure validity and functionality in collecting data. Bicycling behaviors measured included helmet use, hand-signal use (use during slowing, stopping or turning), sidewalk or crosswalk riding, direction of travel, headphone use while bicycling, front or rear light use at night, and use of reflective/highly visible clothing at night. Demographic variables included estimated age (e.g. college age, middle-aged, etc.), gender, rider type (e.g. commuter, exerciser, etc.) and bicycle type (e.g. road bike, mountain bike, etc.). For this reason, these two variables were not included in analysis. Environmental data included daylight (e.g. day or night), and traffic volume during data collection.

Assessment of research questions

R statistical software (version 3.2.1) was used for statistical analysis [30]. Determining independence of bicycle commuter safety behaviors between gender and among different environmental conditions was achieved using the χ^2 test for this same purpose. The assumptions of contingency table analysis were checked and met; namely, observations were independent of one another and cell counts were greater than five or Yates’ Continuity Correction was used. Those bicycle commuter safety behaviors that showed significant associations with gender based the χ^2 analysis on were verified using logistic regression models, where each dependent variable was examined in a succession of models. Model 1 showed a bivariate relationship between gender and the bicycling behaviors. Prior research has identified different factors that commonly relate to bicyclist crashes, namely rider attributes [1,23,29] and environmental factors [1,31,32]. Due to the observational nature of this study, we were able to control for some individual bicyclist and environmental factor variables. Model 2 controls for bicyclist characteristics (namely those we could collect via observation) which include rider type, bicycle type being ridden, and age of rider [1]. Model 3 controls for the environmental factors of daylight, location, and traffic volume [1,31,32]. The goodness of fit for these models was determined Likelihood Ratio Test, where the difference in deviance follows a chi-squared distribution and degrees of freedom equals difference in parameters between the models [33]. Odds ratios and 95% confidence intervals were also computed for each factor.

Results

A total of n=671 cases were observed over two weeks. The majority of cases were recorded during morning, daylight peak traffic time (n=470), as opposed to peak commuting after sunset (n=201). Among all bicyclists observed, 23.10% were female.

The prevalence of safe bicycle commuting behaviors was generally low. Only 22.21% of individuals wore helmets, and 3.24% used hand signals to indicate a turn or slowing. Likewise, only 10.94% used both a front and rear light during night riding, and 1.94% used noticeable reflective gear. Table 1 presents the prevalence of safety behaviors among commuters.

Variables	Overall Prevalence	Gender (M/F)	Traffic (H/M/L)	Daylight (day/night)
Gender	23.10% female (n=155)	---	χ^2(1, N=530)=1.062	χ^2(1, N=671)=0.171
Helmets	22.21% used (n=149)	χ^2(1, N=671)=0.809	χ^2(2, N=530)=14.317***	χ^2(1, N=671)=0.0528
Hand signals	3.24% performed (n=19)	χ^2(1, N=587)=1.138	χ^2(2, N=451)=5.336⊥	χ^2(1, N=671)=1.707
Crosswalk	33.65% used (n=211)	χ^2(1, N=627)=10.389**	χ^2(2, N=490)=114.182***	χ^2(1, N=627)=21.930***
Sidewalk	34.87% used (n=234)	χ^2(1, N=671)=5.722*	χ^2(2, N=530)=88.995***	χ^2(1, N=671)=17.131***
Wrong way	23.10% traveled (n=155)	χ^2 (1, N=671)=7.612**	χ^2 (2, N=530)=7.548*	χ^2(1, N=671)=2.604
Stopping (stop, no-stop, yield)	34.56% (n=178) did not stop	χ^2(2, N=515)=4.654⊥	χ2(4, N=380)=144.665***	χ2(2, N=515)=30.793***
Stopping (stop, no-stop, yield)	38.83% (n=200) stopped completely; 26.60% (n=137) yielded	χ^2(1, N=515)=1.909	χ2(2, N=380)=46.128***	χ2(1, N=515)=11.041***
Head phones	4.48% wore (n=30)	χ^2(1, N=670)=0.407	χ^2(2, N=529)=1.954	χ^2(1, N=670)=2.036
Bike type	Mountain-54.40% (n=365) Road-22.35% (n=150) Hybrid-15.35% (n=103)	χ^2(4, N=670)=76.565***	χ^2(8, N=529)=16.219*	χ^2(4, N=670)=23.742***
Night riding behaviors				
Reflective clothing	1.49% wore (n=3)	Insufficient data	Insufficient data	---
Any light (head or rear)	25.87% used (n=51)	χ^2(1, N=201)=2.057	Insufficient data	---
Head light	16.41% used (n=33)	χ^2(1, N=201)=5.853*	Insufficient data	---
Tail light	20.40% used (n=41)	χ^2(1, N=201)=0.376	Insufficient data	---
Both (head and tail)	10.94% used (n=22)	χ^2(1, N=201)=2.724	Insufficient data	---
^p<0.10, *p<0.05, **p<0.01, ***p<0.001				

Table 1: Dependent relationships of bicycle commuting behaviors with gender and environmental conditions.

Gender and bicycle safety behaviors

Gender and riding position: Examining whether bicycle commuter safety behaviors was independent of bicyclists' gender was determined by using χ^2 test for independence. Gender was statistically dependent with several bicycle commuting behaviors that demonstrate position on the road, including crosswalk use (χ^2(1, N =627)=10.39, p=0.001), sidewalk use (χ^2(1, N=671)=5.72, p=0.017), and wrong direction of travel (χ^2(1, N=671)=7.61, p=0.006). A higher proportion of female riders used crosswalks (45.14% female compared to 30.23% male), sidewalks (43.23% female compared to 32.36% male), and traveled in the wrong direction (31.61% female compared to 20.54% male). The full results are presented in Table 1. These results remained after controlling for rider characteristics and environmental factors. Female riders were more likely to use the crosswalk (OR=1.72, 95% CI [1.14, 2.07]), ride on the sidewalk (OR=1.39, 95% CI [1.01, 1.93]), and travel in the wrong direction (OR=1.41, 95% CI [1.01, 1.94] compared to male riders). Tables 2 and 3 outline the full logistic regression results.

Variables	Crosswalk use						Sidewalk use					
	Model (1)		Model (2)		Model (3)		Model (1)		Model (2)		Model (3)	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Female	1.57***	1.20-2.06	1.54**	1.14-2.07	1.72**	1.22-2.43	1.39**	1.07-1.80	1.34*	1.01-1.79	1.39*	1.01-1.93
Rider Characteristics												
Rider												
Exercise	-	-	1.19	0.28-4.29	0.30	0.06-1.40	-	-	0.76	0.15-2.81	0.23^	0.03-1.06

Bike												
Fixed-gear	-	-	1.31	0.35-4.74	1.57	0.33-7.28	-	-	1.08	0.30-3.74	1.15	0.25-5.14
Hybrid	-	-	2.16	0.91-5.28	1.21	0.41-3.54	-	-	2.55^{*}	1.10-6.12	1.12	0.39-3.27
Mountain	-	-	0.97	0.43-2.27	1.02	0.40-2.67	-	-	0.99	0.45-2.25	0.86	0.34-2.24
Road	-	-	0.56	0.23-1.38	0.53	0.19-1.50	-	-	0.74	0.32-1.77	0.56	0.20-1.57
Age												
30-40s	-	-	1.31	0.16-12.55	1.01	0.07-15.47	-	-	0.97	0.12-9.36	0.55	0.04-7.77
20s	-	-	0.82	0.13-6.67	0.58	0.05-6.67	-	-	0.90	0.14-7.34	0.78	0.09-8.31
Environmental Factors												
Daylight												
Cloudy	-	-	-	-	0.55	0.10-2.78	-	-	-	-	0.79	0.16-3.86
Sunny	-	-	-	-	0.23	0.02-2.34	-	-	-	-	0.03^{**}	0.01-0.32
Night	-	-	-	-	0.78	0.19-2.91	-	-	-	-	1.45	0.39-5.24
Location												
Campus Dr.	-	-	-	-	42.28^{**}	3.07-668.38	-	-	-	-	21.45^{*}	1.74-274.58
800 N	-	-	-	-	2.27	0.83-7.01	-	-	-	-	1.26	0.45-3.93
850 N	-	-	-	-	15.70	0.53-527.79	-	-	-	-	160.33^{**}	6.33-4755.74
Heritage	-	-	-	-	19.15^{**}	2.46-169.01	-	-	-	-	29.61^{***}	4.34-224.59
Univ. Ave.	-	-	-	-	3.89	0.63-24.39	-	-	-	-	9.45^{*}	1.62-58.86
Canyon Rd.	-	-	-	-	1.50	0.36-6.21	-	-	-	-	$3.37^{\wedge}$	0.91-13.37
Traffic												
High	-	-	-	-	3.98	0.63-24.39	-	-	-	-	1.96	0.58-6.84
Medium	-	-	-	-	0.07^{*}	0.01-0.68	-	-	-	-	$0.16^{\wedge}$	0.02-1.34
Low	-	-	-	-	0.73	0.13-3.93	-	-	-	-	4.33^{*}	1.09-18.73
Likelihood Ratio Test	(*vs.* Null) $\chi^2(1, N=627)=10.72, p=0.001$		(*vs.* Model 1) $\chi^2(7, N=627)=29.88, p<0.001$		(*vs.* Model 2) $\chi^2(12, N=627)=168.65, p<0.001$		(*vs.* Null) $\chi^2(1, N=671)=6.06, p=0.013$		(*vs.* Model 1) $\chi^2(7, N=671)=30.81, p<0.001$		(*vs.* Model 2) $\chi^2(12, N=671)=170.75, p<0.001$	
$^{\wedge}p<0.10$, $^{*}p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$												

Table 2: Odds ratio (or and 95% confidence intervals (ci) for predictors of crosswalk use and sidewalk use.

Variables	**Wrong direction of travel**					
	Model (1)		**Model (2)**		**Model (3)**	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Female	1.51^{**}	1.13-2.00	1.41^{*}	1.03-1.92	1.41^{*}	1.01-1.94
Rider Characteristics						
Rider						
Exercise	-	-	0.73	0.10-3.26	0.53	0.07-2.49

Bike						
Fixed-gear	-	-	1.00	0.25-3.61	0.97	0.23-3.75
Hybrid	-	-	1.41	0.60-3.46	1.04	0.41-2.76
Mountain	-	-	0.67	0.30-1.59	0.63	0.27-1.58
Road	-	-	0.39^*	0.16-1.00	0.36^*	0.13-0.96
Age						
30-40s	-	-	0.75	0.09-7.30	0.61	0.07-6.33
20s	-	-	0.42	0.06-3.46	0.39	0.05-3.29
Environmental Characteristics						
Daylight	-	-	-	-		
Cloudy	-	-	-	-	0.13	0.03-0.65
Sunny	-	-	-	-	0.30	0.03-2.63
Night	-	-	-	-	0.42	0.13-1.27
Location						
Campus Dr.	-	-	-	-	1.31	0.12-14.59
800 N	-	-	-	-	$0.36^\wedge$	0.11-1.17
850 N	-	-	-	-	0.35	0.02-7.89
Heritage	-	-	-	-	0.97	0.18-5.37
Univ. Ave.	-	-	-	-	2.70	0.51-15.02
Canyon Rd.	-	-	-	-	$3.56^\wedge$	0.98-13.81
Traffic						
High	-	-	-	-	0.46	0.13-1.56
Medium	-	-	-	-	2.44	0.38-16.02
Low	-	-	-	-	2.16	0.46-10.66
Likelihood Ratio Test	(*vs.* Null) $\chi^2(1, N=671)=7.83, p=0.005$		(*vs.* Model 1) $\chi^2(7, N=671)=23.81, p<0.001$		(*vs.* Model 2) $\chi^2(12, N=671)=62.25, p<0.001$	
$^\wedge p<0.10$, $^*p<0.05$, $^{**}p<0.01$, $^{***}p<0.001$						

Table 3: Odds ratio (OR and 95% confidence intervals (CI) for wrong direction of travel.

Gender and bicycle type: Bicycle type was dependent on gender ($\chi^2(1, N=670)=76.57$, $p<0.001$). Female commuters tended to ride different types of bikes than male riders; a higher proportion of females rode cruiser bikes (16.88% female *vs.* 0.97% male) and hybrid bikes (20.78% female *vs.* 13.84% male). There were a higher proportion of male riders for all other bike types. The most common bike type ridden for both males and females was the mountain bike (42.21% female *vs.* 58.48% male).

Gender and light use: Using a front light during night commuting was dependent on gender ($\chi^2(1, N=201)=5.85$, $p=0.016$). Female riders were more likely to use front lights (28.57% female *vs.* 12.50% male). These results remained after controlling for rider characteristics and environmental factors. Female riders were much more likely to use a headlight when riding at night (OR=2.83, 95% CI [1.40, 5.76]) (Table 4).

Environmental conditions and bicycle safety behaviors

Environment-traffic volume: There were significant dependencies between environmental traffic volume and bicycle commuter safety behaviors. Average traffic volume, which was measured as count of vehicles during the first five minutes and last five minutes of collection time, was categorized as high (>30 vehicles/minute), medium (12-30 vehicles/minute) or low (<12 vehicles/minute) based on natural breaks on the data.

Variables	Headlight use during night riding					
	Model (1)		Model (2)		Model (3)	
	OR	95% CI	OR	95% CI	OR	95% CI
Female	2.07*	1.18-3.60	2.50**	1.28-4.88	2.83**	1.40-5.76
Rider						
Exercise	-	-	0.26	0.01-3.25	0.46	0.01-13.29
Bike	-	-				
Hybrid	-	-	0.41	0.06-2.37	1.89	0.58-6.60
Mountain	-	-	1.29	0.35-5.94	1.27	0.33-4.59
Road	-	-	2.26	0.46-12.11	1.74	0.34-8.92
Age						
20s	-	-	0.07**	0.01-0.41	0.04**	0.01-0.29
Environmental Factors						
Location						
800 N	-	-	-	-	1.29	0.42-4.46
Heritage	-	-	-	-	0.68	0.05-6.96
Univ. Ave.	-	-	-	-	0.09^	0.01-0.95
Canyon Rd.	-	-	-	-	0.43	0.11-1.74
Likelihood Ratio Test	(*vs.* Null) χ^2(1, N=201)=6.33, p=0.012		(*vs.* Model 1) χ^2(7, N=194)=15.97, p=0.025		(*vs.* Model 2) χ^2(12, N=194)=8.65, p=0.732	
^p<0.10, *p<0.05, **p<0.01, ***p<0.001						

Table 4: Odds ratio (OR and 95% confidence intervals (CI) for predictors of headlight use during night riding.

Traffic volume and helmet use: Traffic volume was statistically dependent with helmet use (χ^2(2, N=530)=14.32, p=0.001). Proportion of helmet users increased with increased traffic volume: commuters wore helmets most often in high traffic (31.33% helmet use), followed by medium traffic (20.78% helmet use) and low traffic with the lowest helmet use (13.42% helmet use).

Traffic volume and riding position: Bicyclist position on the road was dependent with traffic volume. Specifically, crosswalk use (χ^2(2, N=490)=114.18, p<0.001) and sidewalk use (χ^2(2, N=530)=89.00, p<0.001) were statistically dependent on traffic volume. Both crosswalk and sidewalk use increased as traffic volume increased. Crosswalk use increased from low traffic volume (11.29%) to medium traffic volume (20.64%) to high traffic volume (65.54%). Similarly, sidewalk use increased from low traffic volume (17.45%) to medium traffic (25.11%) to high traffic volume (64.67%). Wrong-way riding was likewise dependent on traffic volume (χ^2(2, N=530)=7.55, p=0.023) in that wrong-way riding increased as traffic increased (from low (16.78%) to medium (22.08%) to high (30.00%)).

Traffic volume and riding behaviors: Riding behaviors were dependent with traffic volume. The use of hand signals by bicyclists depended on the volume of traffic (χ^2(2, N=451)=5.34, p=0.069). Hand signaling was most often used during medium traffic (5.61%), followed by low traffic (3.13%), with the fewest hand signals being used during high traffic (0.79%). Likewise, stopping behavior (χ^2(4, N=380)=144.67, p<0.001) was dependent on traffic volume also. During low traffic, bicyclists either yielded (38.04%) or did not stop (61.96%). However, during medium traffic, stopping behavior was fairly evenly distributed between yielding (34.91%), completely stopping (30.18%) and not stopping (34.91%). The majority of bicyclists stopped during high traffic (77.31%), followed by not stopping (16.68%) and yielding (5.88%). The full presentation of traffic volume by safety behaviors is found in Table 1.

Environment-daylight

Our study was interested in examining bicyclists' commuting behavior during peak traffic times at daylight and non-daylight hours. Peak traffic during daylight hours was 8:00 AM-10:00 AM; and peak non-daylight traffic times were 7:30 PM-9:00 PM.

Daylight and riding position: There were significant dependencies between daylight and bicycle commuter safety behaviors. Position on the road in terms of crosswalk use was significantly dependent on daylight conditions (χ^2(1, N=627)=21.93, p<0.001). A higher proportion of riders used the crosswalk at night (46.77%) than during the day (27.47%). Likewise, sidewalk use was dependent on daylight conditions (χ^2(1, N=671)=17.13, p<0.001) where there were more bicycle commuters using the sidewalk at night (46.77%) than during the day (29.79%).

Daylight and stopping: Bicycle commuting behavior with regard to stopping behavior was dependent on daylight conditions (χ^2(2, N=515)=30.79, p<0.001). The majority of bicycle commuters stopped at night (55.43%) compared to yielding (20.00%) or not stopping (24.57%). Conversely, the distribution during the day was more uniform between completely stopping (30.29%), yielding (30.00%) and not stopping (39.71%). The full results of daylight conditions and bicycle commuter safety behaviors are presented in Table 1.

Discussion

This study sought to determine prevalence of bicycle safety behaviors and they differ by gender and environment. Several differences were observed with respect to gender and environmental conditions. Statistical dependences were observed between gender and position on the road (i.e. crosswalk, sidewalk, direction of travel), and some riding behaviors. Similar observations were made with traffic volume and daylight conditions with respect to position on the road and safety behaviors.

Unlike prior research by Basch et al. [3], we found no statistical difference in helmet use among gender groups. However, several riding behaviors were dependent on gender, including position on the road, stopping behavior, bicycle type ridden, and light use at night. Female riders were more likely to ride with both front and rear lights at night, on the sidewalk and in the crosswalk, ride in the opposite direction of traffic flow and ride cruiser or hybrid bicycles. Our findings support and extend prior research that has described women cyclists' perceived safety. Bicycling in traffic and bicycling with too much traffic is reported as a significant barrier to women cycling [12,34]. Emond et al. [25] report that being hit by a car and crashing while bicycling are the most commonly cited concerns among women. This may explain why we saw more female bicyclists riding on the sidewalk, riding in the crosswalk, and riding in the opposite direction, while being more likely than men to use both front and rear lights at night. Female riders appear to be riding in a manner they feel is protective (i.e. isolated and away from traffic and visible). More research needs to be conducted to further explore the motivations of female bicyclists with respect to these behaviors. It should be noted that research findings have documented no actual increased risk for women cyclists compared to men [22,35]. In fact, one report in the UK demonstrated that men were more likely to be injured and severely injured [32]. Thus, it appears that perceived safety is contributing, to some degree, to women bicyclists' position on the road.

Differences in bicycle type used between genders lend insight to promoting utility cycling. For example, a higher proportion of women bicyclists rode cruiser bicycles. Although cruisers are functional in some locales, they are not ideal for urban riding in Utah for two main reasons. First, cruisers typically have on only one gear, making traveling uphill or changing speeds quickly particularly challenging. Second, cruisers are typically heavier bicycles compared to a road or mountain bicycle. These factors in context of Utah's topography, the likelihood of stops in route, and the long, snowy winters, render this choice in bicycle problematic. It is not well understood why cruiser bicycles are chosen for utility bicycling. However, prior research points to the reality of bicyclists being "on-view" to motorists and that women's concerns about appearance may contribute to using a bicycle that is more aesthetic than functional [12,36].

Perceived safety among all riders seemed to change by traffic and daylight conditions, as represented by bicyclist behaviors. For example, helmet use, sidewalk use, wrong direction of travel, and crosswalk use all increased as traffic volume increased. Likewise, the proportion of crosswalk use, sidewalk use, and complete stopping all increased during night travel (i.e. when it was dark outside). Although the actual risk for injury may have changed somewhat between these environments, bicyclists changed their riding behavior in connection to their perceived safety. In the high-traffic and night-time riding environments, bicyclists exhibited protective riding behaviors as seen in more sidewalk and crosswalk riding.

Use of hand signals was significantly associated with traffic volume, but did not increase in proportion to traffic volume. Hand signals were most often used during medium traffic and were used with equal frequency during high and low traffic times. The use of hand signals may be based on perceived need. At low traffic times, more bicyclists were on the road, but there were fewer cars to alert changes in behavior to (e.g. turning, slowing, etc.). During times of medium-level traffic, there was a marked increase in traffic volume and an increased need for safety and alerting motorist's changes in riding. However, at high traffic volume, the majority of bicyclists was riding on the sidewalk and separated from traffic. This reduced the need for hand signaling, because they were not riding in the flow of traffic. Likewise, stopping behavior changed with traffic volume. Bicyclists were most likely to completely stop during high traffic times and least likely to completely stop during low traffic times. Bicyclists were most likely to either not stop or yield during both low and medium traffic. These observations give support that bicyclists recognize perceived dangers en-route and change their riding behavior accordingly.

Limitations

This study had inherent weaknesses. Data was only collected during morning, daylight and evening, night peak commuting times over a two-week period during fall 2014 at one university campus. Collecting data over a brief, but intensive period allowed a thorough snapshot of bicyclists' behavior. There inherently was the possibility of misclassification because variables were measured via observation and bicyclists were not directly contacted. Likewise, there is the potential for uncontrolled variables.

Implications

Preventing bicycling collision injuries needs to be informed by behaviors bicyclists are performing. This study provides some framework for promoting safe bicycle commuting by illuminating areas of improvement. Likewise, it also points out areas for future research, which should include understanding the gender inequality of bicycle commuters. Further understanding of why this phenomenon exists will help create more holistic bicycling-friendly communities. This study provides important insights for futures studies. For example, our results support previous research about gender differences among commuter bicyclists. Future studies should seek to further understand this difference and promote bicycle safety among female riders [12]. In order to more broadly characterize bicycling behavior, further research needs to examine different age groups and different types of bicyclists (e.g. exercisers).

Conclusions

This study observed the prevalence of bicycle safety behaviors among Utah commuters. We found that bicycling behaviors differ by gender and environmental conditions (i.e. traffic and daylight). Findings from this study will be foundational to creating environments that are conducive to safe bicycling by preventing injuries while riding in-traffic.

References

1. Kim J, Kim S, Ulfarsson GF, Porrello LA (2007) Bicyclist injury severities in bicycle-motor vehicle accidents. Accident Analysis and Prevention 39: 238-251.
2. Basch CH, Ethan D, Rajan S, Samayoa-Kozlowsky S, Basch CE (2014) Helmet use among users of the citi bike bicycle-sharing program: A pilot study in New York City. J Community Health 39: 503-507.
3. Basch CH, Zagnit EA, Rajan S, Ethan D, Basch CE (2014) Helmet use among cyclists in New York City. J Community Health 39: 956-958.
4. Bopp M, Child S, Campbell M (2014) Factors associated with active commuting to work among women. Women Health 54: 212-231.
5. The League of American Bicyclists (2014) Bicycle commuting data. Washington DC, USA.
6. The League of American Bicyclists (2013) Where we ride: Analysis of bicycling in American cities. Annual American Community.
7. The League of American Bicyclists (2012) Facts and figures.
8. National Highway Traffic Safety Administration (2011) Traffic safety facts: 2011 Data-bicyclists and other cyclists.
9. National Highway Traffic Safety Administration (2014) Preventing two-wheeled tragedies: The mistakes we all make. Safety in numbers.
10. World Health Organization (2010) Why urban health matters. Geneva.
11. League of American Bicyclists (2013) Bike friendly America. Provo, USA.
12. World Health Organization (2014) The Top 10 Causes of Death. WHO, Geneva.
13. Chaney RA, Kim C (2014) Characterizing bicycle collisions by neighborhood in a large Midwest City. Health Promot Pract 15: 232-242.
14. Garrard J, Handy S, Dill J (2012) Women and cycling. In City Cycling, MIT Press. pp: 211-234.
15. Centers for Disease Control and Prevention (2011) Physical activity and health.
16. Oja P, Titze S, Bauman A, de Geus B, Krenn P, et al. (2011) Health benefits of cycling: A systematic review. Scand J Med Sci Sports 21: 496-509.
17. Shephard RJ (2008) Is active commuting the answer to population health? Sports Med 38: 751-758.
18. Lindsay G, Macmillan A, Woodward A (2011) Moving urban trips from cars to bicycles: Impact on health and emissions. Aust N Z J Public Health 35: 54-60.
19. De Hartog JJ, Boogaard H, Nijland H, Hoek G (2010) Do the health benefits of cycling outweigh the risks? Environmental Health Perspectives 118: 1109-1116.
20. Woodcock J, Edwards P, Tonne C, Armstrong BG, Ashiru O, et al. (2009) Public health benefits of strategies to reduce greenhouse-gas emissions: Urban land transport. The Lancet 374: 1930-1943.
21. Lohse JL (2003) A bicycle safety education program for parents of young children. J Sch Nurs 19: 100-110.
22. National Highway Traffic Safety Administration (2008) National survey of bicyclist and pedestrian attitudes and behavior.
23. Osberg JS, Stiles SC, Asare OK (1998) Bicycle safety behavior in Paris and Boston. Accid Anal Prev 30: 679-687.
24. Jacobson GA, Blizzard L, Dwyer T (1998) Bicycle injuries: Road trauma is not the only concern. Aust N Z J Public Health 22: 451-455.
25. Emond C, Tang W, Handy S (2009) Explaining gender difference in bicycling behavior. Transportation Research Board 2125: 16-25.
26. Gossen R, Charles LP (2005) Activities, time and travel: Changes in women's travel time expenditures, 1990-2000. Transportation Research Board.
27. Durand CP, Andalib M, Dunton GF, Wolch J, Pentz MA (2011) A systematic review of built environment factors related to physical activity and obesity risk: Implications for smart growth urban planning. Obesity Reviews 12: e173-e182.
28. McCormack GR, Shiell A (2011) In search of causality: A systematic review of the relationship between the built environment and physical activity among adults. Int J Behav Nutr Phys Act 8: 1-11.
29. Osberg JS, Stiles SC (1998) Bicycle use and safety In Paris, Boston and Amsterdam. Transportation Quarterly 52: 61-76.
30. R Development Core Team (2015) The R project for statistical computing.
31. Carter DL, Council FM (2007) Factors contributing to pedestrian and bicycle crashes on rural highways. National Academies of Sciences.
32. Knowles J, Adams S, Cuerden R, Savill T, Reid S, et al. (2009) Collisions involving pedal cyclists on Britain's roads: Establishing the causes. TRL Published Project Report.
33. Faraway JJ (2006) Extending the Linear Model with R. Chapman & Hall/CRC Press, United States of America.
34. Basford L, Reid S, Lester T, Thomson J, Tolmie A (2002) Driver's perceptions of cyclists. Transport Research Laboratory Report 549.
35. Hoffman MR, Lambert WE, Peck EG, Mayberry JC (2010) Bicycle commuter injury prevention: It is time to focus on the environment. J Trauma 69: 1112-1117.
36. Horton D (2012) Fear of cycling. In Cycling and Society, Ashgate Publishing, Ltd. pp: 133-152.