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Helmet use in BIXI cyclists in Toronto, Canada: An observational study

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ARTICLE SUMMARY

Article Focus

1. We investigated the use of helmets for cyclists choosing to use BIXI bikes in comparison to personal bike riders in the City of Toronto.
2. We hypothesized that the proportion of helmet users using BIXI bikes would be significantly lower than those on personal bikes.

Key Messages

1. Cyclists using BIXI bikes in Toronto are less likely to wear a helmet than cyclists riding their own bike; only 20.9% of all BIXI cyclists wear helmets compared to 51.7% of cyclists riding a personal bike.
2. More males than females are using the BIXI bikesharing program.
3. Females in Toronto were more likely to wear a helmet while cycling.

Strengths: This is the first study (to our knowledge) investigating helmet use in a bikesharing system. Additional strengths include the prospective study design, number of observations, randomly selected observation sites and stratified analyses by sex.

Limitations: The data was collected by one observer not blinded to the study hypothesis, observations were limited to presumed commuter hours in the downtown core of Toronto and we were unable to account for variables previously associated with helmet use, including income, education and age.

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ABSTRACT

Objective: To investigate the use of helmets for cyclists choosing to use BIXI bikes in comparison to personal bike riders in the City of Toronto.

Design: Prospective cohort study design

Setting: Cyclists were observed in Toronto, Canada

Participants: Of the 6732 sample size, 306 cyclists on BIXI bikes and 6426 personal bike riders were observed.

Outcome measure: The outcome of interest was helmet use.

Results: Overall, 50.3% of cyclists wore helmets. The proportion of BIXI bike riders using helmets was significantly lower than the proportion of helmet users on personal bikes (20.9% versus 51.7%, respectively, $p < 0.0001$).

Conclusions: Although the BIXI bike program has provided an alternate means for Torontonians to use a bicycle, cyclists using BIXI bikes are much less likely to wear a helmet. Since the prevalence of helmet use in cyclists in general is already low, helmet use should be especially promoted in BIXI bike riders in order to promote a safe and healthy environment for cyclists.

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INTRODUCTION

Urban cycling promotes healthy living and also minimizes environmental pollutants from vehicle emissions. Bikesharing initiatives, therefore, provide communities with a means to an active, healthy lifestyle via a sustainable means of transportation.[1]

Multiple variations of bikesharing programs have evolved across the world in the last 46 years, yet the core design amongst all programs remains the same – a finite number of bikes are placed throughout a community for citizens and visitors to 'borrow' at their leisure for shorter commutes within designated community zones.[1] The target population for these programs is within-city commuters who can benefit from the use of a temporary bicycle and avoid the worry of parking and locking a bike while at their destination.

The most prominent bikesharing program in North America is BIXI (named according to a combination of the elements of the program: 'BIcycle' and 'taXI'). BIXI was also the first bikesharing company in Canada, initially in Montreal in 2009, and to the Toronto downtown core on May 3, 2011.[2] Eighty solar-paneled stations were placed throughout the city (Figure 1). Each station consists of a pay station and bike docks (Figure 2), distributed according to population density, frequent travel paths, and frequent bicyclist locations.[2]

[insert Figure 1: BIXI bike docking station locations, Toronto, 2011]

Note: Each station is denoted by the BIXI symbol "  ". Source: Toronto Life[3]

[insert Figure 2: BIXI bike kiosk, with pay station and bike dock, Toronto, 2011]

Users of BIXI bikes can subscribe for a 1-year or 30-day access pass, or they can rent a bike by purchasing a 24-hour or 72-hour access pass. Requirements stated for usage of the BIXI bikes are that cyclists are 18 years of age or older and at least 1.24 meters tall; however, after a credit card has been registered or an account has been created, there is no actual method of

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monitoring who rides the bicycle. Furthermore, there is no requirement for helmets to be worn while on the bicycle, though BIXI encourages riders to wear a helmet while cycling.[2]

Cyclists over 18 years of age in Toronto, make the choice of whether or not to wear a bicycle helmet because helmet legislation in Ontario only applies to children. It has been estimated that bicycle helmets decrease the risk of head injury by 85%.[4] The 2001-2007 Canadian Community Health Surveys showed that 41% of youth and adults in Ontario regularly use helmets while cycling.[5] Recent observational data revealed that only 50% of cyclists use helmets in the Greater Toronto Area.[6]

In the City of Toronto, 13,475 collisions were reported between cyclists and motor vehicles between 1986 and 1996, resulting in 38 cyclist fatalities.[7] In the US as high as 500,000 emergency care visits are attributable to injuries sustained while riding a bicycle in the US, resulting in 900 deaths annually. Head injuries and facial traumas represent one-third of these emergencies, with three quarters of all bicycle-related deaths being attributable to head injuries.[8]

With the advent of the BIXI bikesharing system throughout downtown Toronto and the promotion of bicycle use for commuters, we were interested in examining the prevalence of helmet use by BIXI bike users. To our knowledge, no study has examined the prevalence of helmet use in bikesharing programs. The current study compared the use of helmets by cyclists choosing to use BIXI bikes to personal bike riders in the City of Toronto. We hypothesized that the proportion of helmet users using BIXI bikes would be significantly lower than those on personal bikes.

METHODS

We used a prospective cohort study design to determine the proportion of helmet users in downtown Toronto, Canada, for cyclists on personal bikes versus those on BIXI bikes. During an

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observational period of one hour, a researcher observed how many cyclists on personal bikes and how many cyclists on BIXI bikes wore or did not wear helmets. Observations were made between July and September 2011, and took place during weekday 'commuter hours' (i.e. between 0700–1000 or between 1500–1800). As the BIXI bike main use is to facilitate transportation along short distances,[2] and most of the cyclist commuter traffic occurs during these 'rush hour' time periods, this time period was chosen to maximize the number of both BIXI bike and personal bike cyclists observed.

The main exposure variable was type of bicycle. For the purposes of this study, a "bicycle" or "bike" was defined by the researchers to constitute a 2- wheeled, non-fuel-consuming, foot pedal-based method of transportation, where the rider is seated and can hold handlebars in front of them. The "BIXI bike" was identified by its characteristic BIXI shape and/or colours (Figure 2), whether being removed or returned from the docking station or being ridden past the point of observation. A "personal bicycle" was defined as any bicycle of a brand other than BIXI. The outcome of interest was helmet use. A "helmet" was defined for the purposes of this project to constitute a solid protection device worn on the head, with a chinstrap, as a means of promoting personal safety to protect the head from impact in the event of a fall or collision. Observed sex of the bicycle riders was also recorded as a covariate to understand differences in helmet use by sex.

Using the map of the BIXI bike docking (Figure 1), operational docking stations were assigned numbers from 1-79 sequentially from North-East to South-West. Twenty-five operational stations were randomly selected to designate observation points for the study. During each observation period, a researcher sat in a location with the BIXI bicycle docking station in clear view and noted all cyclists within view (approximately 20m radius from the BIXI bicycle

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docking station), no matter which direction they were traveling. Cyclists of all ages were included in the study. No contact was made with the cyclists. Ethical approval was obtained from the research ethics review board at the Hospital for Sick Children in Toronto, Ontario.

A tally was collected for one of four categories: (1) BIXI bike riders with a helmet, (2) BIXI bike riders without a helmet, (3) personal bike riders with a helmet, or (4) personal bike riders without a helmet. Each category was subdivided by observed sex (male, female, unsure).

The required sample size for each of the two groups (BIXI bike cyclists and personal bike cyclists) was based on calculations using the formula for sample size calculations for two independent sample tests for proportions with an estimated effect size of 10%, and an estimated proportion of 50% of helmet use in personal bike users[6] for a two-sided test with a 5% level of significance, 80% power. The sample size calculation revealed that 407 subjects were needed per group.

Proportions of helmet users in BIXI bike cyclists and personal bike cyclists were calculated and compared between groups by Chi Square analysis using Epi Info (v.3.5.3) StatCalc. Each group was stratified by sex (male, female or "unsure") and the proportion of helmet users within groups by sex was calculated.

RESULTS

A total of 6732 cyclists were observed, including 306 BIXI bike cyclists and 6426 personal bike cyclists. When stratified by sex, a total of 4307 male cyclists and 2399 female cyclists were observed. Within groups, there were 234 male BIXI cyclists and 72 female BIXI cyclists, and 4073 male and 2327 female cyclists on personal bikes. For 24 helmet users and 2 non-helmet wearing cyclists on personal bikes, male or female designation could not be assigned; however, this represented a very small number of cyclists observed (0.4%) and thus

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these observations were not included in the analysis by sex. The remaining 6706 observations were included in the analysis.

Twenty-one percent of bike riders wore helmets while on BIXI bikes. This was significantly lower than the prevalence of helmet use by personal bike riders (51.7%; uncorrected $X^2 = 110.48$, $p<0.0001$). Both male and female personal bike riders were statistically significantly more likely to wear helmets compared to male and female BIXI bike riders (males: 47.9% versus 20.1%, respectively; uncorrected $X^2 = 68.84$, $p<0.0001$, females: 57.8% versus 23.6%, respectively; uncorrected $X^2 = 33.26$, $p<0.0001$). The results for across group comparisons of helmet use in BIXI bike users and personal bike users are summarized in Table 1.

Compared to male bike riders, female bike riders were more likely to wear helmets. On personal bikes, females wore helmets more often than males (57.8% versus 47.9%, respectively; $X^2 = 58.10$, $p<0.0001$). On BIXI bikes, females also wore helmets more often than did males, though this differences was not statistically significant (23.6% versus 20.1%, respectively; $X^2 = 0.41$, $p<0.5201$).

Overall, whether riding a BIXI bike or a personal bike, 3384 of 6732 cyclists observed (50.3%) wore helmets. The observed prevalence of BIXI bike usage in Toronto was 4.5%.

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Table 1: Observed helmet use by bicycle type, Toronto, 2011

	BIXI BIKE			PERSONAL BIKE			X^2	P-value
	Riders (N)	**Helmet (N)**	**Helmet (%)**	**Riders (N)**	**Helmet (N)**	**Helmet (%)**		
Total observed	306	64	**20.9%**	6426	3320	**51.7%**	110.48	**<0.0001**
Females	72	17	**23.6%**	2327	1345	**57.8%**	33.26	**<0.0001**
Males	234	47	**20.1%**	4073	1951	**47.9%**	68.84	**<0.0001**
Could not determine sex	0	0	-	26	24	92.3%	(not analyzed)	

DISCUSSION

The proportion of BIXI bike users (64, 20.9%) who were wearing a helmet, regardless of sex, was significantly lower than the proportion of personal bike users (3320, 51.7%) wearing a helmet. This means that, although BIXI was introduced with the purpose to promote the use of cycling for short commutes within the city, the BIXI bike program appears to decrease the already-low proportion of helmet users. Since the use of helmets while cycling has been recognized as a means of reducing significant head injuries,[4 9] severe facial trauma and even death,[8 10] the advent of a bikesharing program that decreases helmet use may increase the risk of severe injury and/or fatalities in the event of a collision while cycling. This is especially dangerous in an urban center such as Toronto, where cyclists often are found alongside motor vehicles on busy streets in peak commuting hours.

As has been replicated in previous studies,[6 11] a large sex difference was observed both with respect to total cyclists and helmet users. Although females were less likely to ride a bicycle overall, females who did use a bicycle were more likely to wear a helmet. This same pattern translated to BIXI bike users as well, with females less likely to use the BIXI bikes.

This study represents the first investigation (to our knowledge) of helmet use in a bikesharing system. A similar pattern may extend to bikesharing systems worldwide. As of 2008, there have been fatalities reported while using bikesharing systems internationally: 3 fatalities in

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Paris's Velib program, 3 collisions in New Zealand's NextBike, 1 collision in Hangzhou's bikesharing system, and 1 in the North American BIXI system.[1] Given the nature of collision data, these statistics may be underreported. Since helmet use has been shown to protect against severe injuries and fatalities amongst collisions while cycling,[8 10] this suggests that bikesharing systems, such as BIXI, should be accompanied by actions to promote helmet use. However, as bikesharing programs cater to cyclists on-the-go within urban centers,[1] it is imperative that solutions to promote helmet use be amenable to the commuter population and available at the point of bike rental.

One difficulty noted internationally is that helmet use may be legislated (or not) by a municipal, state/province, or nationally country. In cities where helmet use is mandatory, bikesharing systems have already begun to address the problem of low-helmet use, providing a model through which other bikesharing systems may approach this dilemma in injury prevention.[12] As helmets are mandatory for cyclists in Australia, a bikesharing system in Melbourne piloted a project where helmets could be purchased or rented through vending machines at the point of bike rental or at local convenience stores around the city.[13] Pending helmet uptake data through this pilot, other bikesharing companies like BIXI could model this project in order to promote helmet use within their consumers. BIXI bike could also work towards providing machines near BIXI stations for helmet dispensing at the point of BIXI bike rental.

There are several limitations associated with the current study. This was the first study of its kind to observe and count BIXI bike riders and personal bike riders. The fact that only one observer who was not blinded to the hypothesis collected the data for the study could have introduced a data collection bias. However, since the observer was measuring an objective

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outcome through the tallying of bicyclists in the area at each station, it is unlikely that any significant personal or subjective bias was introduced. Furthermore, this study only observed cyclists within the presumed 'commuter' hours within the downtown core, such that the main population targeted for the study was cyclists commuting to work or to school. Previous studies have found that statistics of helmet use vary with income and education,[11] though in this study, all riders, regardless of attire or presumed reason for riding the bicycle, were counted towards the study population. Furthermore, although all observations were made during commuter hours, the locations of the randomly selected BIXI bike stations spanned many areas of downtown Toronto, including financial districts, local parks, intercity areas, and school campuses.[2] This layout in BIXI bike stations allows the program to cater to a wide array of Torontonians, and helped to increase the diversity of our study population to be representative of the natural Toronto population. Finally, this study did not classify cyclists by age; as a result, all analyses were conducted regardless of the age of the cyclists. Patterns of helmet use have been reported to vary with age, with youth and adolescents in Ontario most likely to wear a helmet.[11] Since the majority of the population observed consisted mainly of older youth and adults, it is unlikely that the presence of children under the helmet legislation would have significantly impacted the study's results.

With an increasing focus on Toronto to be a healthy, environmentally-friendly city, cycling continues to be a promising sustainable means of transportation. Although the BIXI bike program has provided an alternate means for Torontonians to use a bicycle that is publically available for short-term, within-city routes,[2] its indirect negative effect on helmet use for cyclists poses a threat to cyclists' safety. Efforts to promote cycling while protecting cyclists from severe injury should be made a priority in the promotion of a healthy and safe Toronto.

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AUTHOR CONTRIBUTIONS

Marissa Bonyun: Study design, data collection, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

Andi Camden: Study design, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

Colin Macarthur: Consultation on design, data interpretation, writing and editing of the manuscript, final approval of the manuscript.

Andrew Howard: Conceptual framework and study design, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

DATA SHARING

No additional data available.

COMPETING INTERESTS

None to declare.

SOURCE OF FUNDING

This research received no specific funding.

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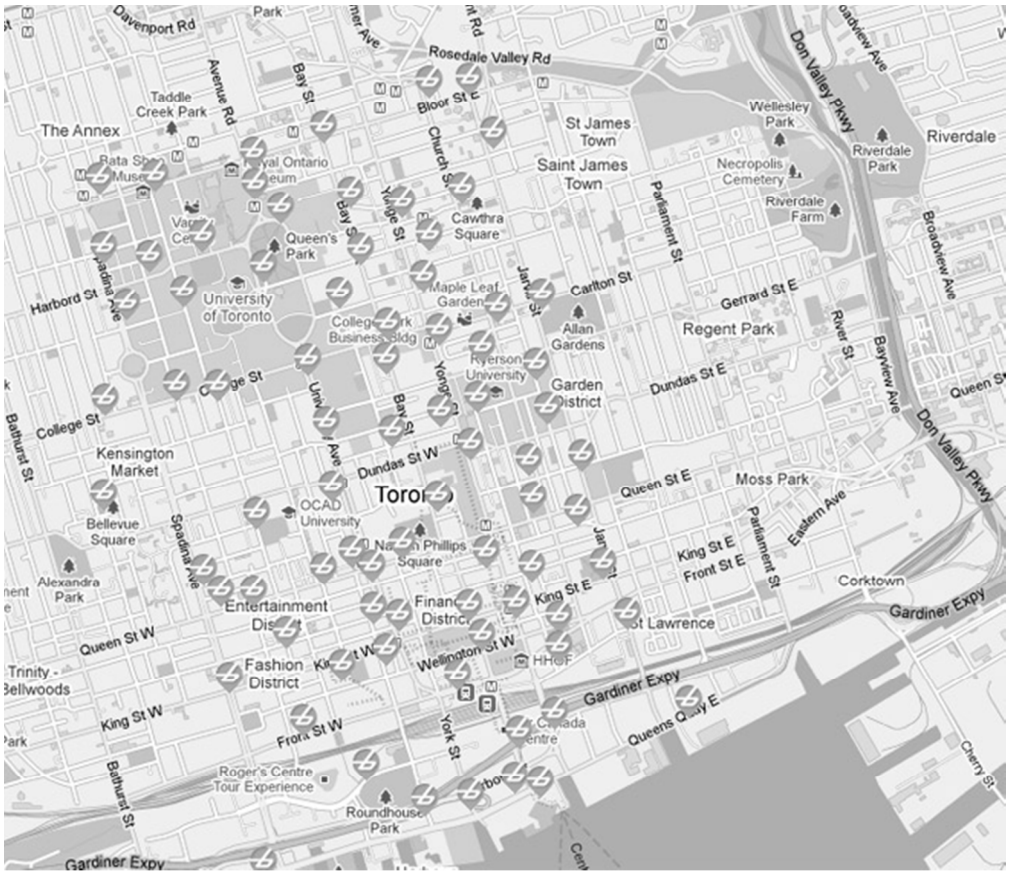

Figure 1: BIXI bike docking station locations, Toronto, 2011
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Figure 2: BIXI bike kiosk, with pay station and bike dock, Toronto, 2011
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1. We investigated the use of helmets for cyclists choosing to use BIXI bikes in comparison to personal bike riders in the City of Toronto.
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1. Cyclists using BIXI bikes in Toronto are less likely to wear a helmet than cyclists riding their own bike; only 20.9% of all BIXI cyclists wear helmets compared to 51.7% of cyclists riding a personal bike.
2. More males than females ~~are~~ ride bicycles in Toronto.~~using the BIXI bikesharing program~~.
3. Females in Toronto were more likely to wear a helmet while cycling.

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Limitations: The data was collected by one observer not blinded to the study hypothesis, observations were limited to presumed commuter hours in the downtown core of Toronto and we were unable to account for variables previously associated with helmet use, including income, education and age.

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ABSTRACT

Objective: To investigate the use of helmets for cyclists choosing to use BIXI bikes in comparison to personal bike riders in the City of Toronto.

Design: ~~Prospective cohort~~Cross sectional study design

Setting: Cyclists were observed in Toronto, Canada

Participants: Of the 6732 sample size, 306 cyclists on BIXI bikes and 6426 personal bike riders were observed.

Outcome measure: The outcome of interest was helmet use.

Results: Overall, 50.3% of cyclists wore helmets. The proportion of BIXI bike riders using helmets was significantly lower than the proportion of helmet users on personal bikes (20.9% versus 51.7%, respectively, $p < 0.0001$).

Conclusions: Although the BIXI bike program has provided an alternate means for Torontonians to use a bicycle, cyclists using BIXI bikes are much less likely to wear a helmet. Since the prevalence of helmet use in cyclists in general is already low, helmet use should be especially promoted in BIXI bike riders in order to promote a safe and healthy environment for cyclists.

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INTRODUCTION

Urban cycling promotes healthy living and also minimizes environmental pollutants from vehicle emissions. Bikesharing initiatives, therefore, provide communities with a means to an active, healthy lifestyle via a sustainable means of transportation.[1]

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METHODS

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We used a cross sectional~~prospective cohort study~~ design to determine the proportion of helmet users in downtown Toronto, Canada, for cyclists on personal bikes versus those on BIXI bikes. During an observational period of one hour, a researcher observed how many cyclists on personal bikes and how many cyclists on BIXI bikes wore or did not wear helmets. Observations were made between July and September 2011, and took place during weekday 'commuter hours' (i.e. between 0700–1000 or between 1500–1800). As the BIXI bike main use is to facilitate transportation along short distances,[2] and most of the cyclist commuter traffic occurs during these 'rush hour' time periods, this time period was chosen to maximize the number of both BIXI bike and personal bike cyclists observed.

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A total of 6732 cyclists were observed, including 306 BIXI bike cyclists and 6426 personal bike cyclists. When stratified by sex, a total of 4307 male cyclists and 2399 female cyclists were observed. Within groups, there were 234 male BIXI cyclists and 72 female BIXI cyclists, and 4073 male and 2327 female cyclists on personal bikes. For 24 helmet users and 2

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non-helmet wearing cyclists on personal bikes, male or female designation could not be assigned; however, this represented a very small number of cyclists observed (0.4%) and thus these observations were not included in the analysis by sex. The remaining 6706 observations were included in the analysis.

Twenty-one percent of bike riders wore helmets while on BIXI bikes. This was significantly lower than the prevalence of helmet use by personal bike riders (51.7%; uncorrected $X^2 = 110.48$, $p<0.0001$). Both male and female personal bike riders were statistically significantly more likely to wear helmets compared to male and female BIXI bike riders (males: 47.9% versus 20.1%, respectively; uncorrected $X^2 = 68.84$, $p<0.0001$, females: 57.8% versus 23.6%, respectively; uncorrected $X^2 = 33.26$, $p<0.0001$). The results for across group comparisons of helmet use in BIXI bike users and personal bike users are summarized in Table 1.

Compared to male bike riders, female bike riders were more likely to wear helmets. On personal bikes, females wore helmets more often than males (57.8% versus 47.9%, respectively; $X^2 = 58.10$, $p<0.0001$). On BIXI bikes, ~~females also wore helmets more often than did males, though this~~gender differences ~~was~~ in helmet use were not statistically significant (23.6% of females versus 20.1% of males, respectively; $X^2 = 0.41$, $p<0.5201$).

Overall, whether riding a BIXI bike or a personal bike, 3384 of 6732 cyclists observed (50.3%) wore helmets. The observed prevalence of BIXI bike usage in Toronto was 4.5%.

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Table 1: Observed helmet use by bicycle type, Toronto, 2011

	BIXI BIKE			PERSONAL BIKE			X^2	P-value
	Riders (N)	**Helmet (N)**	**Helmet (%)**	**Riders (N)**	**Helmet (N)**	**Helmet (%)**		
Total observed	306	64	**20.9%**	6426	3320	**51.7%**	110.48	**<0.0001**
Females	72	17	**23.6%**	2327	1345	**57.8%**	33.26	**<0.0001**
Males	234	47	**20.1%**	4073	1951	**47.9%**	68.84	**<0.0001**
Could not determine sex	0	0	-	26	24	92.3%	(not analyzed)	

DISCUSSION

The proportion of BIXI bike users (64, 20.9%) who were wearing a helmet, regardless of sex, was significantly lower than the proportion of personal bike users (3320, 51.7%) wearing a helmet. This means that, although BIXI was introduced with the purpose to promote the use of cycling for short commutes within the city, the BIXI bike program appears to decrease the already-low proportion of helmet users. Since the use of helmets while cycling has been recognized as a means of reducing significant head injuries,[4 11] severe facial trauma and even death,[9 12] the advent of a bikesharing program that decreases helmet use may increase the risk of severe injury and/or fatalities in the event of a collision while cycling. This is especially dangerous in an urban center such as Toronto, where cyclists often are found alongside motor vehicles on busy streets in peak commuting hours.

As has been replicated in previous studies,[6 13] a large sex difference was observed both with respect to total cyclists and helmet users. Although females were less likely to ride a bicycle overall, females who did use a bicycle were more likely to wear a helmet. This same pattern translated to BIXI bike users as well, with females less likely to use the BIXI bikes.

This study represents the first investigation (to our knowledge) of helmet use in a bikesharing system. A similar pattern may extend to bikesharing systems worldwide. As of 2008, there have been fatalities reported while using bikesharing systems internationally: 3 fatalities in

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Paris's Velib program, 3 collisions in New Zealand's NextBike, 1 collision in Hangzhou's bikesharing system, and 1 in the North American BIXI system.[1] Given the nature of collision data, these statistics may be underreported. Since helmet use has been shown to protect against severe injuries and fatalities amongst collisions while cycling, [9 12] this suggests that bikesharing systems, such as BIXI, should be accompanied by actions to promote helmet use. However, as bikesharing programs cater to cyclists on-the-go within urban centers,[1] it is imperative that solutions to promote helmet use be amenable to the commuter population and available at the point of bike rental.

One difficulty noted internationally is that helmet use may be legislated (or not) by a municipal, state/province, or nationally country. In cities where helmet use is mandatory, bikesharing systems have already begun to address the problem of low-helmet use, providing a model through which other bikesharing systems may approach this dilemma in injury prevention.[14] As helmets are mandatory for cyclists in Australia, a bikesharing system in Melbourne piloted a project where helmets could be purchased or rented through vending machines at the point of bike rental or at local convenience stores around the city.[15] Pending helmet uptake data through this pilot, other bikesharing companies like BIXI could model this project in order to promote helmet use within their consumers. BIXI bike could also work towards providing machines near BIXI stations for helmet dispensing at the point of BIXI bike rental.

There are several limitations associated with the current study. This was the first study of its kind to observe and count BIXI bike riders and personal bike riders. The fact that only one observer who was not blinded to the hypothesis collected the data for the study could have introduced a data collection bias. However, since the observer was measuring an objective

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outcome through the tallying of bicyclists in the area at each station, it is unlikely that any significant personal or subjective bias was introduced. Furthermore, this study only observed cyclists within the presumed 'commuter' hours within the downtown core, such that the main population targeted for the study was cyclists commuting to work or to school. Previous studies have found that statistics of helmet use vary with income and education,[13] though in this study, all riders, regardless of attire or presumed reason for riding the bicycle, were counted towards the study population. Furthermore, although all observations were made during commuter hours, the locations of the randomly selected BIXI bike stations spanned many areas of downtown Toronto, including financial districts, local parks, intercity areas, and school campuses.[2] This layout in BIXI bike stations allows the program to cater to a wide array of Torontonians, and helped to increase the diversity of our study population to be representative of the natural Toronto population. This study did not classify cyclists by age; as a result, all analyses were conducted regardless of the age of the cyclists. Patterns of helmet use have been reported to vary with age, with youth and adolescents in Ontario most likely to wear a helmet.[13] ~~Since the majority of the population observed consisted mainly of older youth and adults,~~ BIXI bicycles are only available for those 18 and over, so it is unlikely that the presence of children under the helmet legislation would have significantly impacted the study's results. Finally, individual cyclists were not identified so may have been observed more than once.

With an increasing focus on Toronto to be a healthy, environmentally friendly city, cycling continues to be a promising sustainable means of transportation. Although the BIXI bike program has provided an alternate means for Torontonians to use a bicycle that is publically available for short-term, within-city routes,[2] its indirect negative effect on helmet use for cyclists

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poses a threat to cyclists' safety. Efforts to promote cycling while protecting cyclists from severe injury should be made a priority in the promotion of a healthy and safe Toronto.

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AUTHOR CONTRIBUTIONS

Marissa Bonyun: Study design, data collection, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

Andi Camden: Study design, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

Colin Macarthur: Consultation on design, data interpretation, writing and editing of the manuscript, final approval of the manuscript.

Andrew Howard: Conceptual framework and study design, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

DATA SHARING

No additional data available.

COMPETING INTERESTS

None to declare.

SOURCE OF FUNDING

This research received no specific funding.

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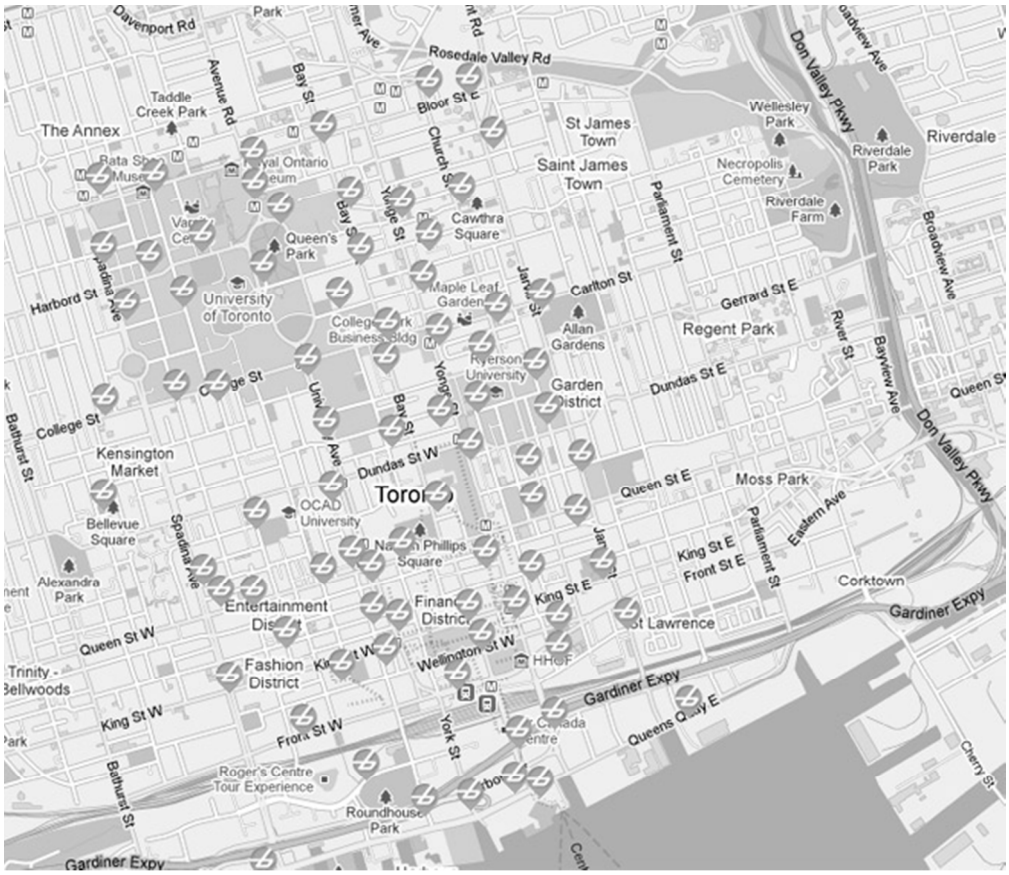

Figure 1: BIXI bike docking station locations, Toronto, 2011
55x48mm (300 x 300 DPI)

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Figure 2: BIXI bike kiosk, with pay station and bike dock, Toronto, 2011
81x60mm (300 x 300 DPI)

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Helmet use in BIXI cyclists in Toronto, Canada: An observational study

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ARTICLE SUMMARY

Article Focus

1. We investigated the use of helmets for cyclists choosing to use BIXI bikes in comparison to personal bike riders in the City of Toronto.
2. We hypothesized that the proportion of helmet users using BIXI bikes would be significantly lower than those on personal bikes.

Key Messages

1. Cyclists using BIXI bikes in Toronto are less likely to wear a helmet than cyclists riding their own bike; only 20.9% of all BIXI cyclists wear helmets compared to 51.7% of cyclists riding a personal bike.
2. More males than females are using the BIXI bikesharing program.
3. Females in Toronto were more likely to wear a helmet while cycling.

Strengths: This is the first study (to our knowledge) investigating helmet use in a bikesharing system. Additional strengths include the prospective study design, number of observations, randomly selected observation sites and stratified analyses by sex.

Limitations: The data was collected by one observer not blinded to the study hypothesis, observations were limited to presumed commuter hours in the downtown core of Toronto and we were unable to account for variables previously associated with helmet use, including income, education and age.

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ABSTRACT

Objective: To investigate the use of helmets for cyclists choosing to use BIXI bikes in comparison to personal bike riders in the City of Toronto.

Design: Prospective cohort study design

Setting: Cyclists were observed in Toronto, Canada

Participants: Of the 6732 sample size, 306 cyclists on BIXI bikes and 6426 personal bike riders were observed.

Outcome measure: The outcome of interest was helmet use.

Results: Overall, 50.3% of cyclists wore helmets. The proportion of BIXI bike riders using helmets was significantly lower than the proportion of helmet users on personal bikes (20.9% versus 51.7%, respectively, $p < 0.0001$).

Conclusions: Although the BIXI bike program has provided an alternate means for Torontonians to use a bicycle, cyclists using BIXI bikes are much less likely to wear a helmet. Since the prevalence of helmet use in cyclists in general is already low, helmet use should be especially promoted in BIXI bike riders in order to promote a safe and healthy environment for cyclists.

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INTRODUCTION

Urban cycling promotes healthy living and also minimizes environmental pollutants from vehicle emissions. Bikesharing initiatives, therefore, provide communities with a means to an active, healthy lifestyle via a sustainable means of transportation.[1]

Multiple variations of bikesharing programs have evolved across the world in the last 46 years, yet the core design amongst all programs remains the same – a finite number of bikes are placed throughout a community for citizens and visitors to 'borrow' at their leisure for shorter commutes within designated community zones.[1] The target population for these programs is within-city commuters who can benefit from the use of a temporary bicycle and avoid the worry of parking and locking a bike while at their destination.

The most prominent bikesharing program in North America is BIXI (named according to a combination of the elements of the program: 'BIcycle' and 'taXI'). BIXI was also the first bikesharing company in Canada, initially in Montreal in 2009, and to the Toronto downtown core on May 3, 2011.[2] Eighty solar-paneled stations were placed throughout the city (Figure 1). Each station consists of a pay station and bike docks (Figure 2), distributed according to population density, frequent travel paths, and frequent bicyclist locations.[2]

[insert Figure 1: BIXI bike docking station locations, Toronto, 2011]

Note: Each station is denoted by the BIXI symbol "". Source: Toronto Life[3]

[insert Figure 2: BIXI bike kiosk, with pay station and bike dock, Toronto, 2011]

Users of BIXI bikes can subscribe for a 1-year or 30-day access pass, or they can rent a bike by purchasing a 24-hour or 72-hour access pass. Requirements stated for usage of the BIXI bikes are that cyclists are 18 years of age or older and at least 1.24 meters tall; however, after a credit card has been registered or an account has been created, there is no actual method of

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monitoring who rides the bicycle. Furthermore, there is no requirement for helmets to be worn while on the bicycle, though BIXI encourages riders to wear a helmet while cycling.[2]

Cyclists over 18 years of age in Toronto, make the choice of whether or not to wear a bicycle helmet because helmet legislation in Ontario only applies to children. It has been estimated that bicycle helmets decrease the risk of head injury by 85%.[4] The 2001-2007 Canadian Community Health Surveys showed that 41% of youth and adults in Ontario regularly use helmets while cycling.[5] Recent observational data revealed that only 50% of cyclists use helmets in the Greater Toronto Area.[6]

In the City of Toronto, 13,475 collisions were reported between cyclists and motor vehicles between 1986 and 1996, resulting in 38 cyclist fatalities.[7] In the US as high as 500,000 emergency care visits are attributable to injuries sustained while riding a bicycle in the US, resulting in 900 deaths annually. Head injuries and facial traumas represent one-third of these emergencies, with three quarters of all bicycle-related deaths being attributable to head injuries.[8]

With the advent of the BIXI bikesharing system throughout downtown Toronto and the promotion of bicycle use for commuters, we were interested in examining the prevalence of helmet use by BIXI bike users. To our knowledge, no study has examined the prevalence of helmet use in bikesharing programs. The current study compared the use of helmets by cyclists choosing to use BIXI bikes to personal bike riders in the City of Toronto. We hypothesized that the proportion of helmet users using BIXI bikes would be significantly lower than those on personal bikes.

METHODS

We used a prospective cohort study design to determine the proportion of helmet users in downtown Toronto, Canada, for cyclists on personal bikes versus those on BIXI bikes. During an

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observational period of one hour, a researcher observed how many cyclists on personal bikes and how many cyclists on BIXI bikes wore or did not wear helmets. Observations were made between July and September 2011, and took place during weekday 'commuter hours' (i.e. between 0700–1000 or between 1500–1800). As the BIXI bike main use is to facilitate transportation along short distances,[2] and most of the cyclist commuter traffic occurs during these 'rush hour' time periods, this time period was chosen to maximize the number of both BIXI bike and personal bike cyclists observed.

The main exposure variable was type of bicycle. For the purposes of this study, a "bicycle" or "bike" was defined by the researchers to constitute a 2- wheeled, non-fuel-consuming, foot pedal-based method of transportation, where the rider is seated and can hold handlebars in front of them. The "BIXI bike" was identified by its characteristic BIXI shape and/or colours (Figure 2), whether being removed or returned from the docking station or being ridden past the point of observation. A "personal bicycle" was defined as any bicycle of a brand other than BIXI. The outcome of interest was helmet use. A "helmet" was defined for the purposes of this project to constitute a solid protection device worn on the head, with a chinstrap, as a means of promoting personal safety to protect the head from impact in the event of a fall or collision. Observed sex of the bicycle riders was also recorded as a covariate to understand differences in helmet use by sex.

Using the map of the BIXI bike docking (Figure 1), operational docking stations were assigned numbers from 1-79 sequentially from North-East to South-West. Twenty-five operational stations were randomly selected to designate observation points for the study. During each observation period, a researcher sat in a location with the BIXI bicycle docking station in clear view and noted all cyclists within view (approximately 20m radius from the BIXI bicycle

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docking station), no matter which direction they were traveling. Cyclists of all ages were included in the study. No contact was made with the cyclists. Ethical approval was obtained from the research ethics review board at the Hospital for Sick Children in Toronto, Ontario.

A tally was collected for one of four categories: (1) BIXI bike riders with a helmet, (2) BIXI bike riders without a helmet, (3) personal bike riders with a helmet, or (4) personal bike riders without a helmet. Each category was subdivided by observed sex (male, female, unsure).

The required sample size for each of the two groups (BIXI bike cyclists and personal bike cyclists) was based on calculations using the formula for sample size calculations for two independent sample tests for proportions with an estimated effect size of 10%, and an estimated proportion of 50% of helmet use in personal bike users[6] for a two-sided test with a 5% level of significance, 80% power. The sample size calculation revealed that 407 subjects were needed per group.

Proportions of helmet users in BIXI bike cyclists and personal bike cyclists were calculated and compared between groups by Chi Square analysis using Epi Info (v.3.5.3) StatCalc. Each group was stratified by sex (male, female or "unsure") and the proportion of helmet users within groups by sex was calculated.

RESULTS

A total of 6732 cyclists were observed, including 306 BIXI bike cyclists and 6426 personal bike cyclists. When stratified by sex, a total of 4307 male cyclists and 2399 female cyclists were observed. Within groups, there were 234 male BIXI cyclists and 72 female BIXI cyclists, and 4073 male and 2327 female cyclists on personal bikes. For 24 helmet users and 2 non-helmet wearing cyclists on personal bikes, male or female designation could not be assigned; however, this represented a very small number of cyclists observed (0.4%) and thus

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these observations were not included in the analysis by sex. The remaining 6706 observations were included in the analysis.

Twenty-one percent of bike riders wore helmets while on BIXI bikes. This was significantly lower than the prevalence of helmet use by personal bike riders (51.7%; uncorrected $X^2 = 110.48$, $p<0.0001$). Both male and female personal bike riders were statistically significantly more likely to wear helmets compared to male and female BIXI bike riders (males: 47.9% versus 20.1%, respectively; uncorrected $X^2 = 68.84$, $p<0.0001$, females: 57.8% versus 23.6%, respectively; uncorrected $X^2 = 33.26$, $p<0.0001$). The results for across group comparisons of helmet use in BIXI bike users and personal bike users are summarized in Table 1.

Compared to male bike riders, female bike riders were more likely to wear helmets. On personal bikes, females wore helmets more often than males (57.8% versus 47.9%, respectively; $X^2 = 58.10$, $p<0.0001$). On BIXI bikes, females also wore helmets more often than did males, though this differences was not statistically significant (23.6% versus 20.1%, respectively; $X^2 = 0.41$, $p<0.5201$).

Overall, whether riding a BIXI bike or a personal bike, 3384 of 6732 cyclists observed (50.3%) wore helmets. The observed prevalence of BIXI bike usage in Toronto was 4.5%.

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Table 1: Observed helmet use by bicycle type, Toronto, 2011

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The proportion of BIXI bike users (64, 20.9%) who were wearing a helmet, regardless of sex, was significantly lower than the proportion of personal bike users (3320, 51.7%) wearing a helmet. This means that, although BIXI was introduced with the purpose to promote the use of cycling for short commutes within the city, the BIXI bike program appears to decrease the already-low proportion of helmet users. Since the use of helmets while cycling has been recognized as a means of reducing significant head injuries,[4 9] severe facial trauma and even death,[8 10] the advent of a bikesharing program that decreases helmet use may increase the risk of severe injury and/or fatalities in the event of a collision while cycling. This is especially dangerous in an urban center such as Toronto, where cyclists often are found alongside motor vehicles on busy streets in peak commuting hours.

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With an increasing focus on Toronto to be a healthy, environmentally-friendly city, cycling continues to be a promising sustainable means of transportation. Although the BIXI bike program has provided an alternate means for Torontonians to use a bicycle that is publically available for short-term, within-city routes,[2] its indirect negative effect on helmet use for cyclists poses a threat to cyclists' safety. Efforts to promote cycling while protecting cyclists from severe injury should be made a priority in the promotion of a healthy and safe Toronto.

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AUTHOR CONTRIBUTIONS

Marissa Bonyun: Study design, data collection, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

Andi Camden: Study design, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

Colin Macarthur: Consultation on design, data interpretation, writing and editing of the manuscript, final approval of the manuscript.

Andrew Howard: Conceptual framework and study design, data analysis and interpretation, writing and editing of the manuscript, final approval of the manuscript.

DATA SHARING

No additional data available.

COMPETING INTERESTS

None to declare.

SOURCE OF FUNDING

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13. VicRoads. Melbourne bike share (the blue bikes). 2006.

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Editor, BMJ Open

Dear Sir/Madam,

Thank you for your interest in our observational study comparing bicycle helmet use between users of a bike sharing system and users of personal bicycles.

We have considered each comment made by the reviewers and have modified the manuscript accordingly. An updated manuscript with track changes in word is submitted.

Details of changes made in response to each reviewers comment are found below.

We look forward to your consideration of this revision.

Sincerely,

Andrew Howard

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Response to Reviewers is in *italics* below the corresponding items.

Reviewer: Aymery Constant, Phd, Mpsych
Senior Lecturer
EHESP School of Public Health
France

I have no competing interest to declare

Strengths: This paper addresses an important issue, i.e. Helmet use in a bikesharing system. Data collection relies upon observed rather than self-reported helmet use. Many cyclists were observed (N=6732). Cyclists were observed in their environment at different locations, in a major city in North America.

Thank you.

Some points however need to be discussed:

My main concern is related to independence of statistical units (observations). It is not stated whether or not observations are independent. In others words, was it possible for the same cyclist to be observed more than once? Did authors take measures to ensure that each observation corresponds to one individual? It seems that observed cyclists were identified by no means. Repeated observations are thus possible. This would constitute a bias. Maybe observations sites were distant enough to ensure a relative independence between observations? This point needs to be clarified, or at least mentioned.

Observations were made at physically separate sites on different days by the same observer. A small fraction of the total number of cyclists in Toronto was sampled, but there was no systematic way to identify individuals. We mention this in the limitations. "Finally, individual cyclists were not identified so may have been observed more than once."

My others concerns are:

1) Page 3 line 10, Design: it seems to me that the term "prospective cohort" is not relevant, since participants were not recruited in the study before being observed. "Ecological" or "observational" study might be better terms.

Agree. We have changed the term to 'cross sectional study per Don Voaklander's review below also.

2) Authors hypothesize that the proportion of helmet users using BIXI bikes would be significantly lower than those on personal bikes (page 2 line 13). Why? This hypothesis needs to be supported by data or previous observations. What are the (supposed) differences between cyclists using personal bikes and those using BIXI bikes? In my opinion, exposure, cycling habits and familiarity with road hazard might discriminate these two groups, as well as others variables potentially influencing helmet use. This point need to be further developed in the introduction.

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Agree. We have substantiated our hypothesis and added a reference to Constant.

3) Authors state that "this is the first study investigating helmet use in a bikesharing system (page 2 line 34; page 5 line 39 and so on). This is no longer true since Februray 15th 2012 (http://www.plosone.org/article/info:doi/10.1371/journal.pone.0031651). But this is the first study, to my knowledge, investigating behavioral differences between cyclists using personal bikes and those using bike sharing system.

Agree. We have cited the Constant paper and thank the reviewer for bringing it to our attention.

4) Authors present the 79 BIXI Bike docking stations locations in Figure 1. Observation points (25 out of 79) should be also indicated, preferably on the same map, or in a separate file.

We did not map the observation locations. I have omitted the figures for the second revision.

5) Selection of observation periods: It is started that "a researcher observed cyclists during one hour during commuters' hours" (7-10; 15-18) (pages 5-6) . Authors should indicate why observation period lasted only one hour (and not two, or three) during each time-slot (fatigue, lack of vigilance after one hour of observation?). Also, authors seem to think that the different time-slots are similar as far as traffic or observed cyclists' profiles are concerned. May be its not true. For instance, cyclists observed at 9 am might be going to work, while those observed at 15pm might just go for a stroll. In fact, authors should present the number of observation by time-slots, and discuss whether or not they are equally distributed (they should be)

Response: we calculated a sample size based on observing sufficient bikes to determine whether a difference in helmet wearing rate was present. While we understand that cycle use differs at different hours of the day, we did not have the resources to study this aspect in detail.

6) The Table 1 is rather confusing. Results are difficult to read. They should follow a logical sequence. First, give the proportion of helmet users in the whole study sample (and indicate whether or not this estimate is similar to helmet wearing rate in Toronto, if available. Computing 95% confidence intervals might be useful). Then, investigate helmet use according to gender, and BIXI use, separately. And then, investigate interaction effects (Helmet use = Gender X BIXI use). The "undetermined sex" cyclists should be excluded from the analyses.

Response: The undetermined sex cyclists are excluded from the analyses. They are small in number and are listed in the table. With respect to the reviewer, we prefer to present a number and proportion of helmet users comparing BIXI to personal bikes as that conforms to the specific research question.

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7) Authors state in a key message that "more males than females are using the BIXI program". This might reflect the fact that more male than female cyclists were observed. The main result should be "more males than females ride a bicycle in Toronto " and consequently, "more males than females are using the BIXI program". The latter statement can be confirmed with a simple crosstab (Gender X BIXI use) and a chi square test. However, this is not the aim of the study. It is rather an ancillary result.

Agree. We have changed the key message to more males than females ride bicycles in Toronto.

8) Page 8 line 32: Authors state that "in bixi bikes, females wore helmets more often than did males, thought this difference was not significant". This statement is not true. In the absence of a significant effect, there is no difference in helmet wearing rate between males and females using bixi bikes. Please correct.

*Agree. We have changed the statement to "*On BIXI bikes, gender differences in helmet use were not statistically significant (23.6% of females versus 20.1% of males, respectively; $X^2 = 0.41$, $p<0.5201$)."

9) Age is not assessed in the study (as stated in the "limitations"). An estimated age (e.g. youth, adult, senior) would have been a very interesting variable, though. In Toronto, helmet law applies to children only. The law was passed on October 1, 1995. Accordingly, young adults (aged 18-30 years, for instance) might be more likely to wear helmet than older people. Since they have been required to do it for years. Habit is a significant predictor of actual behavior. This should be mentioned in the discussion section. Moreover, authors state "the majority of population observed consisted mainly of older youth and adults" (page 11 line 34). In the absence of an estimated age in collected data, such statement is not relevant.

Agree. We have removed the statement about our impression of the ages. We have replaced it with a statement that BIXI bikes are available only to adults.

10) Overall, most legislative and non-legislative interventions to promote helmet use in Canada were oriented towards children only. This study suggests that prevention initiatives are required towards adult cyclists also. Especially those using bikesharing programs, who might be less familiar with road hazard than others cyclists.

Agree. We hope to publish the observations to contribute to this necessary dialogue.

Reviewer: Emmanuel LAGARDE
INSERM U897 Bordeaux, France

General comment

This is a very-well conducted study on the prevalence of helmet use among BIXI bicycle users showing a 21% rate of use, lower than the 52% rate for personal bike riders. These estimates are based on the observations of a total of 6706. While these

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results are of interest and are worth to be mentioned in a journal like BMJ, my opinion is that it does not deserve a short report and should be published as a research letter.

Thank You.

Specific comments

Introduction: cautions should be exercise when citing a 85% protection of helmet from Thompson 1989 study. Since that time, this has been criticized and more recent studies seemed to provide lower protection rate estimates. Please see Elvik' 2011 paper (Acc Anal Prev 2011;43:1245-1251).

Agree. We have cited Elvik also and modified the statement in the introduction.

Addition information would be of interest to understand why some users are using BIXI with and without a helmet. My guess would be that those with a helmet are those who are also personnel bike riders and who, for some reason, were using BIXI this time. Incidentally, I must say that I am very much impressed by these overall rates of use. In Bordeaux, we just conducted a similar study (but with automatic video observation) and found a rate of 0.8% (N=1455) for our BIXI-like system users and 3.2% (N=3162) for other bike riders. The main reason for non-users is the helmet inconvenience.

Agree. We cannot provide additional information on users decisions from this type of study, though.

Finally, given the very simple study design, I see no particular methodological problem. In particular, I am not concerned with the non-blind nature of the observer which unlikely to have biased the results.

Agree

Reviewer: Don Voaklander
Professor, University of Alberta
Canada

This is not a prospective cohort study. It is a cross-sectional study.

Agree. We have changed the abstract and methods.

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