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Bicycle helmets are highly protective against traumatic brain injury within a dense urban setting

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ABSTRACT

Background: New York City (NYC) has made significant roadway infrastructure improvements, initiated a bicycle share program, and enacted Vision Zero, an action plan to reduce traffic deaths and serious injuries. The objective of this study was to examine whether bicycle helmets offer a protective advantage against traumatic brain injury (TBI) within a contemporary dense urban setting with a commitment to road safety.

Methods: A prospective observational study of injured bicyclists presenting to a Level I trauma centre was performed. All bicyclists arriving within 24 h of injury were included. Data were collected between February, 2012 and August, 2014 and included demographics, imaging studies (e.g. computed tomography (CT)), injury patterns, and outcomes including Glasgow Coma Scale (GCS) and Injury Severity Score.

Results: Of 699 patients, 273 (39.1%) were wearing helmets at the time of injury. Helmeted bicyclists were more likely to have a GCS of 15 (96.3% [95% Confidence Interval (CI), 93.3–98.2] vs. 87.6 [95% CI, 84.1–90.6]) at presentation. Helmeted bicyclists underwent fewer head CTs (40.3% [95% CI, 34.4–46.4] vs. 52.8% [95% CI, 48.0–57.6]) and were less likely to sustain intracranial injury (6.3% [95% CI, 2.6–12.5] vs. 19.7% [14.7–25.6]), including skull fracture (0.9% [95% CI, 0.0–4.9] vs. 15.3% [95% CI, 10.8–20.7]) and subdural hematoma (0.0% [95% CI, 0.0–3.2] vs. 8.1% [95% CI, 4.9–12.5]). Helmeted bicyclists were significantly less likely to sustain significant TBI, i.e. Head AIS $\geq$3 (2.6% [95% CI: 0.7–4.5] vs.10.6% [7.6–12.5]). Four patients underwent craniotomy while three died; all were un-helmeted. A multivariable logistic regression model showed that helmeted bicyclists were 72% less likely to sustain TBI compared with un-helmeted bicyclists (Adjusted Odds Ratio 0.28, 95% CI 0.12–0.61).

Conclusions: Despite substantial road safety measures in NYC, the protective impact of simple bicycle helmets in the event of a crash remains significant. A re-assessment of helmet laws for urban bicyclists is advisable to most effectively translate Vision Zero from a political action plan to public safety reality.

Introduction

Bicycling is an increasingly popular mode of transportation and recreation for New Yorkers. Commuter ridership in New York City (NYC) jumped 262% from 2000 to 2010, and this accelerated growth is projected to continue in ensuing years [1]. In May 2013, NYC launched its bicycle share program, which significantly expanded bicycle accessibility and further increased ridership [2].

Bicycling, however, is not without risk. National statistics report that 500,000 people sustain bicycle-related injuries, including approximately 800 deaths, every year in the U.S. [3]. In 2013, there were nearly 4,300 reported bicycle-related injuries in NYC [4]. Head injury is the leading cause of death and permanent disability in bicycle-related crashes, with traumatic brain injury (TBI) accounting for more than one-third of bicycle-related emergency room visits, two-thirds of hospital admissions, and three-fourths of deaths [5].

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With the goal of promoting safe bicycling, the NYC Department of Transportation (DOT) has made substantial improvements in roadway infrastructure, including the addition of over 300 miles of bicycle lanes and vehicle-protected bicycle paths in just the last six years [6]. In January 2014, NYC launched 'Vision Zero,' a multidisciplinary traffic safety action plan with a strong government commitment aimed at eliminating traffic-related deaths and serious injuries [7–9]. Vision Zero was first introduced by the Swedish government in the late 1990's as a sustained road safety campaign and has since been adopted in many cities and states internationally.

Currently, NYC mandates bicycle helmets for delivery cyclists and children under the age of 14 [10]; helmet use remains optional for the broader bicyclist population. Evidence that helmets protect against TBI derives from pivotal epidemiologic and case-controlled studies conducted in the 1980s and 90s [11,] [12]. The scientific literature has also focused on high-speed sporting injury [13], biomechanical laboratory data [14], and paediatric head injury before and after the passage of helmet legislation [15–17]. A major limitation of earlier studies is that they do not delineate collision-related brain injuries in a detailed systematic manner based on radiologic findings. Additionally, the effect of helmets in more contemporary urban traffic conditions within a presumed safer infrastructure requires examination. Despite a correlation between helmet non-use and bicycle share programs [2] [18], there is little data showing how this relationship might impact bicycle-related injuries.

The objective of this study was threefold: 1 – to examine whether bicycle helmet use offers a protective advantage in NYC's hub, a uniquely dense urban centre with significant motor-vehicular traffic congestion, an evolving cycling infrastructure, and a newly-implemented bicycle share program, 2 – to define patient demographics and risk-factors associated with helmet use and non-use, and 3 – to delineate the specific types of brain injuries which may be impacted by helmet use. Our primary hypothesis was that un-helmeted bicyclists sustain more severe TBI in the event of a crash regardless of bicycling infrastructure advances intended to make cycling safer.

Materials and methods

This was a prospective cohort study of injured bicyclists presenting to Bellevue Hospital Center (BHC)–a Level I regional trauma centre. Data collection was performed at BHC between February 1, 2012 and August 31, 2014, excluding a 14-week interruption (between October 29, 2012 and February 7, 2013) when clinical services were disrupted as a result of Superstorm Sandy. BHC's catchment area includes the lower half of Manhattan and western Brooklyn. The BHC emergency department (ED) evaluates over 100,000 patients per year.

Prospective data were collected on all bicyclists who presented to the BHC ED within 24 h of injury. The study included patients requiring hospitalization and those discharged from the ED. Patients with unknown or indeterminate helmet status were excluded. Variables collected included patient demographics, helmet use at the time of injury, bicyclists' behaviours at the time of the incident (e.g., riding with or against flow of traffic, alcohol use, distracting factors), scene-related data (e.g., bicycle path or lane availability, time of day), and outcomes including Glasgow Coma Scale (GCS) score, initial computed tomography (CT) imaging studies, Abbreviated Injury Scale (AIS) score, Injury Severity Score (ISS), admission status, hospital length of stay (LOS), procedures (e.g. surgeries and intubations), disposition, and mortality.

Data collection was performed by a dedicated study coordinator, a trauma coordinator, or attending physicians in trauma or emergency medicine. Verbal informed consent was obtained from all patients. Data were primarily obtained via patient self-report and supplemented with information from scene witnesses or first responders if available. Pre-hospital call reports were used to verify data if accessible.

Injury scores were calculated after radiology evaluations were finalized. To better delineate the effect of helmets on brain injury, 'Head and Neck AIS' was narrowed to a 'Head AIS' category by removing patients with cervical spine injuries. A blood alcohol concentration (BAC) of >0.01 g/dL was used to determine whether patients had consumed alcohol prior to injury. BAC levels were obtained as part of a routine work-up in most cases. History of recent alcohol use as self-reported by the patient was considered next if lab data was unavailable. Electronic device use included texting or speaking on a mobile phone and listening to music on a portable player.

Data were analysed using STATA version 13.0 statistical software. Means and proportions with 95% Confidence Intervals (CIs) were reported for continuous and categorical data and stratified by helmet use. Several outcomes variables were also presented as unadjusted odds ratios (OR) with 95% CI. Any missing data points were specified for the relevant variables as footnotes in the tables. Hospital-based variables (e.g. AIS score, procedures performed, imaging results) had no missing data. We used multivariable logistic regression to model the effect of helmet use on head injury (Head AIS), when controlling for other factors, including mechanism of injury, age, alcohol use, distracting factor, and commercial status. For the multivariable logistic regression model, we employed multiple imputations to account for missing data using the method of chained equations.

Both the New York University School of Medicine and the Bellevue Hospital Center institutional review boards approved this study. Funding was provided by a Highway Safety Grant from the State of New York Governor's Traffic Safety Committee.

Results

Seven hundred and six bicyclists were enrolled. Of these, seven had unknown or indeterminate helmet status and were excluded from analysis. Of the remaining 699 patients, 273 (39.1%) were wearing helmets at the time of injury. Demographic data of the study population is listed in Table 1. The mean age was 34.6 years (range 3–82 years) and 79.9% were men. 36.9% of men wore helmets versus 47.8% of women. The helmeted group had a greater proportion of Caucasian (52.9% [95%CI, 46.6–58.8] vs. 42.9% [95% CI, 38.0–47.6]) and a lower proportion of Latino (24.3% [95% CI, 19.2–29.7] vs. 32.6% [95% CI, 28.0–37.1]) bicyclists.

Riding behaviours and mechanisms of injury

Bicyclists' riding behaviours and mechanisms of injury are detailed in Table 2. Most bicyclists reported riding for leisure at the time of injury. Working bicyclists were more likely to be helmeted (51.8%), while bicyclists riding for leisure were less likely (29.9%). Thirty-three bicyclists were riding as part of the NYC bicycle share program (also known as 'Citibike') at the time of injury, representing 8.5% of study patients from the launch of the program (May 27, 2013) onward; of these, 18.2% were wearing helmets at the time of injury.

Most bicycle-related injuries occurred in collisions with motor vehicles. Helmeted bicyclists were more likely to be riding in a bicycle lane or vehicle-protected bicycle path (56.6% [95% CI, 50.2–62.8] vs. 32.1% [95% CI, 27.3–37.2]) at the time of injury. Most patients (87.3%) self-reported that they were travelling at 15 mph or less, and there were no significant differences in riding speed between the groups.