North Carolina Linkage Study for Motor Vehicle Crashes Involving Pedestrians and Bicyclists

UNC Highway Safety Research Center Crash & NC Healthcare Association Hospital Encounter Data

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List of Abbreviations

CCHI	Carolina Center for Health Informatics
DMV	Division of Motor Vehicles
DOT	Department of Transportation
GHSP	Governor's Highway Safety Program
HSRC	Highway Safety Research Center
MVC	Motor vehicle crash
NC	North Carolina
NHTSA	National Highway Traffic Safety Administration.
PBCAT	Pedestrian & Bicycle Information Center
UNC	University of North Carolina
UNC-CH	University of North Carolina at Chapel Hill

Background

The North Carolina (NC) Governor's Highway Safety Program (GHSP), a program within the NC Department of Transportation (NC DOT), has the stated mission of "zero deaths on North Carolina roadways." As part of this mission, the GHSP funded the Carolina Center for Health Informatics (CCHI) at the University of North Carolina at Chapel Hill (UNC-CH) to link health outcome data with police crash report data to improve MVC (motor vehicle crash) injury surveillance in the state. While the ultimate objective of the MVC Injury Data Linkage Project is to improve injury surveillance for all MVCs, our initial project focus is on pedestrian and bicycle crashes only. We selected these types of MVC injuries primarily because of the increased incidence of pedestrian/bicycle crash fatalities in NC.

Purpose

In this report, we describe a demonstration project in which we linked police crash report and health outcome data. In Aim 1, we describe injuries among pedestrians and bicyclists involved in NC MVCs during the 2017 calendar year using two separate data sources: police crash reports and hospital encounter data (combined emergency department visit and hospital inpatient data). In Aim 2, we describe the results of a data linkage between these two data sources. The aims for this project are listed below.

Aims

Aim 1: Describe the characteristics of motor vehicle crashes involving pedestrians and bicyclists

Aim 2: Link UNC HSRC Crash and NCHA Hospital Encounter Data Using Deterministic Linkage Methods

Methods

Data Sources

We received 2017 pedestrian/bicyclist injury data from two separate data sources: NC police crash reports and NC hospital encounter data. Table 1 describes the sources used in the data linkage study. We received the 2017 police crash report data file from the UNC Highway Safety Research Center (HSRC). The UNC HSRC pulled all records in which the crash report indicated that a pedestrian or bicyclist was involved in the crash. We intentionally used a broad case definition to capture as many pedestrian and bicycle crashes as possible. Typically, the Pedestrian & Bicycle Information Center (PBCAT), a center located within the UNC HSRC, codes all pedestrian/bicycle crashes; however, this process is labor intensive and the 2017 PBCAT data file is not yet available. Therefore, the pedestrian/bicycle crash data file used in our data linkage analyses may contain misclassified cases. Upon release, please refer to the PBCAT data for the

"official" 2017 total of pedestrian/bicycle crashes in NC (http://www.pedbikeinfo.org/pbcat_nc/). For several records, the crash report coded the crash as both pedestrian and bicycle-related. For these crashes, we coded the crash as involving a bicyclist, rather than a pedestrian. Data were provided in HTML (UNC HSRC) and Microsoft Excel (NCHA) format and were imported into SAS (Cary, NC, Version 9.4) for cleaning and analysis.

Table 1. Sources and descriptions of 2017 pedestrian/bicycle crash data linkage study

Data	Description	Source
Police Crash Reports[1,2]	All 2017 NC crash reports for MVCs involving pedestrians/bicyclists.	UNC Highway Safety Research Center
Hospital Encounter Data[3]	All 2017 hospital encounters (ED and inpatient) related to MVCs involving pedestrians /bicyclists.	NC Healthcare Association

Abbreviations: NC, North Carolina; UNC, University of North Carolina; MVC, motor vehicle crash
[1]Pedestrian/bicyclist involved MVCs were identified using the variables "Person Type" (Field 22 on the NC DMV 349 form), "Vehicle Type" (Field 41 on the NC DMV 349 form), "First Harmful Event (Field 52 on the NC DMV 349 form), and "Most Harmful Event" (Field 56 on the NC DMV 349 form). For crash reports that characterized the collision as involving a pedestrian and a bicyclist, the record was classified as involving a bicyclist.
[2]In NC, police are only required to complete a crash report if the crash occurred on a publicly maintained road or public vehicle access road (e.g. "traffic-related"); however, for pedestrian/bicycle crashes, police sometimes complete reports that do not meet these criteria. We included all records regardless of whether the crash met the criteria of being "traffic-related".
[3]An "hospital encounter" can refer to an emergency department visit and/or an inpatient encounter. Nearly all inpatient records had a corresponding ED visit record; however, most patients were discharged directly home from the ED, and so these patients did not have a corresponding inpatient record.

Data Linkage Analysis

Since the NCHA hospital encounter data contain several sensitive data elements that are not available for research, our partners at NCHA performed all data linkage activities, with input from the MVC Injury Project Team and a group of experts convened by the National Highway Traffic Safety Administration (NHTSA) as part of a GO Team. NHTSA's Traffic Records GO Team program assists states in improving their traffic records systems. For more information about NHTSA GO Teams, please visit the following website: https://one.nhtsa.gov/Data/Traffic-Records. While the NCHA took all input under consideration, the data analysts ultimately made their own data linkage decisions based on internal factors.

Linkage Algorithm

For the data linkage, NCHA data analysts used deterministic methods. Deterministic linkage matches data according to a list of predefined variables. For a match to occur, the two data sources must have had the exact same values for the linkage variables. The matching variables used for the pedestrian/bicycle crash data linkage were: sex, age (years), five-digit ZIP code of residence, and first five characters of patient street address. In addition, the hospital encounter had to take place after the crash date with an admission date within 14 days of the crash.

Linkage Variables (Exact Match)

1. Sex
2. Age (years)
3. 5-Digit ZIP code of residence
4. Street address (first five characters)

Other Criteria

1. Hospital encounter date/time occurred after crash date/time
2. Emergency department visit date/hospital admission date less than or equal to 14 days after crash.

[1]Emergency department visit date/hospital admission date refers to the date of the initial emergency department visit (for patients discharged directly from the emergency department without admission to the hospital) or the date of hospital admission (for patients admitted to the hospital).

Aim 1: Describe the characteristics of motor vehicle crashes involving pedestrians and bicyclists

According to the NC Division of Motor Vehicles (DMV) (2018), all motor vehicle traffic crashes meeting one or more of the following criteria, must be reported:

1. The crash resulted in a fatality, or
2. The crash resulted in a non-fatal person injury, or
3. The crash resulted in total property damage amounting to $1,000 or more, or
4. The crash resulted in property damage of any amount to a vehicle seized, or
5. The vehicle has been seized and is subject to forfeiture under G. S. § 20-28.3.

In addition, according to the NC DMV (2018):

> "A reportable MVC must occur on trafficway (any land way open to the public as a matter of right or custom for moving persons or property from one place to another) or occur after the motor vehicle runs off the roadway but before events are stabilized."

Occasionally, police officers complete crash reports for pedestrian/bicycle involved crashes that do not meet these criteria. We have included all pedestrian/bicycle crash reports, even if the reports did not meet the criteria of a "traffic-related" motor vehicle crash.

UNC Highway Safety Research Center Crash Report Data

The NC DMV shares a copy of their crash report data (excluding the names of all individuals involved in the crash) with the UNC HSRC each year. Out of 275,067 total MVCs, we identified 4,452 pedestrians (N=3,336) and bicyclists (N=1,206) involved in MVCs.

Description of Pedestrians/Bicyclists Involved in Crashes

In Tables 2 and 3, we display pedestrian/bicyclist characteristics stratified by KABCO, Police officers use KABCO to indicate injury severity. According to the NC DMV (2018), police officers assign a KABCO score using the following criteria:

1. Killed (K) – Deaths (which must occur within 12 months after the crash) resulting from injuries sustained in a specific road vehicle crash.
2. Suspected serious injury (A) – A suspected serious injury is any injury other than fatal which results in one or more of the following:
    - Severe laceration resulting in exposure of underlying tissues/ muscle/ organs or resulting in significant loss of blood.
    - Broken or distorted extremity (arm or leg)
    - Crush injuries
    - Suspected skull, chest or abdominal injury other than bruises or minor lacerations
    - Significant burns (second and third degree burns over 10% or more of the body)
    - Unconsciousness when taken from the crash scene
    - Paralysis
3. Suspected minor injury (B) - A minor injury is any injury that is evident at the scene of the crash, other than fatal or serious injuries. Examples include lump on the head, abrasions, bruises, minor lacerations (cuts on the skin surface with minimal bleeding and no exposure of deeper tissue/muscle).
4. Possible injury (C) - A possible injury is any injury reported or claimed which is not a fatal, suspected serious or suspected minor injury. Examples include momentary loss of consciousness, claim of injury, limping, or complaint of pain or nausea. Possible injuries are those which are reported by the person or indicated by his/her behavior, but no wounds or injuries are readily evident.
5. No injury (O)

<u>Pedestrians</u>

Table 2 describes the characteristics of pedestrians involved in 2017 NC MVCs. According to the reporting police officer, nearly all pedestrians involved in a crash had a suspected injury (92%). Among the 2,948 pedestrians who sustained injuries, over 80% were classified as having possible injuries (injury=C, N=1,260, 43%) or minor injuries (injury=B, N=1,177, 40%). Slightly less than one-fifth of pedestrians were classified as having a serious (injury=A, N =311, 10.5%) or fatal injury (injury= K, N=200, 7%). Injury severity status was missing for 134 pedestrians (5%).

The mean age of pedestrians involved in MVCs was 39 years (standard deviation: 19.3, range: 1-98 years). Most of the pedestrians involved in crashes were male (61%). Regarding race and Hispanic/Latino ethnicity, 47% were white, non-Hispanic/Latino and 42% were black, non-Hispanic/Latino. Alcohol or drug use was suspected in 9% of pedestrian-involved MVCs. For fatal crashes, alcohol/drug involvement was suspected in 27%% of pedestrian deaths.

Bicyclists

Table 3 describes the characteristics of bicyclists involved in 2017 MVCs. Similar to pedestrians, the overwhelming majority of bicyclists were injured in crashes (90%). Among bicyclists injured in MVCs, 44% %had a possible injury (injury=C, N=471), 45% %had a minor injury (injury=B, N=492), seven % had a serious injury (injury=A, N=71), and four % had a fatal injury (injury=K, N=39). Injury severity status was missing for 29 bicyclists (2%).

The mean age of bicyclists involved in MVCs was 36 years (standard deviation: 18.7, range: 0-82 years). Over three-quarters of the bicyclists were male (76%) and over one-half were white, non-Hispanic/Latino (54%). A lower proportion of bicyclists, as compared to pedestrians, were suspected of being impaired at the time of the crash (5%).

Table 2. Description of pedestrians involved in motor vehicle crashes: UNC HSRC, 2017

Pedestrian Characteristic	Injury Severity (KABCO)[1]											
	Fatal Injury (K)		Serious Injury (A)		Minor Injury (B)		Possible Injury (C)		No Injury (O)		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Gender												
Male	145	73.6%	209	67.9%	692	60.0%	715	57.8%	156	64.2%	1,917	61.1%
Female	52	26.4%	99	32.1%	462	40.0%	523	42.2%	87	35.8%	1,223	38.9%
Age Group												
0-9	4	2.0%	18	5.8%	55	4.7%	50	4.0%	20	7.9%	147	4.6%
10-19	16	8.0%	35	11.3%	179	15.2%	173	13.7%	40	15.8%	443	13.9%
20-29	23	11.6%	66	21.3%	231	19.6%	264	21.0%	47	18.6%	631	19.7%
30-39	28	14.1%	49	15.8%	170	14.5%	187	14.8%	49	19.4%	483	15.1%
40-49	33	16.6%	49	15.8%	163	13.9%	199	15.8%	31	12.3%	475	14.9%
50-59	47	23.6%	54	17.4%	185	15.7%	199	15.8%	35	13.8%	520	16.3%
60+	48	24.1%	39	12.6%	193	16.4%	188	14.9%	31	12.3%	499	15.6%
Race/Hispanic Ethnicity												
White, Not Hispanic	102	51.8%	155	50.2%	533	46.4%	553	45.2%	120	50.2%	1,463	47.0%
Black, Not Hispanic	72	36.5%	108	35.0%	490	42.7%	559	45.7%	92	38.5%	1,321	42.4%
Hispanic/Latino	15	7.6%	26	8.4%	78	6.8%	76	6.2%	12	5.0%	207	6.6%
Other Race	8	4.1%	20	6.5%	47	4.1%	35	2.9%	15	6.3%	125	4.0%
Alcohol or Drugs Suspected												
Yes	53	26.5%	60	19.3%	111	9.4%	61	4.8%	16	6.3%	301	9.4%
No	147	73.5%	251	80.7%	1,066	90.6%	1,199	95.2%	238	93.7%	2,901	90.6%
TOTAL	**200**	**100.0%**	**311**	**100.0%**	**1,177**	**100.0%**	**1,260**	**100.0%**	**254**	**100.0%**	**3,202**	**100.0%**

Missing: Injury severity missing for 134 records, gender missing 62 records, age group missing four records, and race/Hispanic ethnicity missing for 86 records.
[1]Missing values are excluded from column totals; column totals sum to 100%.

Table 3. Description of bicyclists involved in motor vehicle crashes: UNC HSRC, 2017

Bicyclist Characteristic	Injury Severity (KABCO)[1]											
	Fatal Injury (K)		Serious Injury (A)		Minor Injury (B)		Possible Injury (C)		No Injury (O)		Total	
	N	%	N	%	N	%	N	%	N	%	N	%
Gender												
Male	33	84.6%	57	80.3%	392	81.7%	319	68.3%	91	82.7%	892	76.4%
Female	6	15.4%	14	19.7%	88	18.3%	148	31.7%	19	17.3%	275	23.6%
Age Group												
0-9	0	0.0%	4	5.6%	23	4.8%	24	5.1%	8	7.1%	59	5.0%
10-19	5	12.8%	19	26.8%	82	17.1%	79	16.9%	19	16.8%	204	17.4%
20-29	5	12.8%	11	15.5%	117	24.4%	109	23.3%	33	29.2%	275	23.4%
30-39	3	7.7%	11	15.5%	53	11.0%	82	17.6%	15	13.3%	164	14.0%
40-49	7	17.9%	6	8.5%	52	10.8%	46	9.9%	8	7.1%	119	10.1%
50-59	9	23.1%	10	14.1%	77	16.0%	78	16.7%	22	19.5%	196	16.7%
60+	10	25.6%	10	14.1%	76	15.8%	52	11.1%	8	7.1%	156	13.3%
Race/Hispanic Ethnicity												
White, Not Hispanic	22	56.4%	39	55.7%	270	56.6%	232	50.1%	65	57.0%	628	54.2%
Black, Not Hispanic	9	23.1%	16	22.9%	168	35.2%	184	39.7%	34	29.8%	411	35.5%
Hispanic/Latino	7	17.9%	10	14.3%	26	5.5%	29	6.3%	5	4.4%	77	6.6%
Other Race	1	2.6%	5	7.1%	13	2.7%	18	3.9%	5	4.4%	42	3.6%
Alcohol or Drugs Suspected												
Yes	9	23.1%	6	8.5%	22	4.6%	18	3.8%	7	6.1%	62	5.3%
No	30	76.9%	65	91.5%	460	95.4%	453	96.2%	107	93.9%	1,115	94.7%
TOTAL	**39**	**100.0%**	**71**	**100.0%**	**482**	**100.0%**	**471**	**100.0%**	**114**	**100.0%**	**1,177**	**100.0%**

Missing: Injury severity missing for 29 records, gender missing for 10 records, age group missing for four records, and race/Hispanic ethnicity missing for 19 records.
[1]Missing values are excluded from column totals; column totals sum to 100%.

Characteristics of Motor Vehicle Crashes Involving Pedestrians/Bicyclists

Pedestrians

Most pedestrian crashes occurred during the week (77%) and during daylight hours (56%). Nearly half of the reported crashes occurred on local roads (48%). The season with the most pedestrian involved MVCs was autumn (29%). Less than 5% of crashes were related to the weather or involved a work zone.

Factors associated with a greater likelihood of severe (K or A injury) according to 2017 crash reports (data are not shown):

- Male sex
- Age greater than or equal to 40 years of age
- Alcohol/drug involvement
- Crash occurred on a Saturday or Sunday (i.e. "weekend")
- Crash occurred during the evening (6:00-11:59 PM) or early morning hours (12:00-5:59 AM)
- Crash occurred during low light conditions
- Crash occurred in a work zone
- Crash occurred on an interstate or highway

Bicyclists

Most bicycle crashes occurred during the week (75%) and during daylight hours (69%). As compared to pedestrian crashes, bicycle crashes were more likely to occur during the afternoon and early evening (12:00-5:59 PM, 42% of bicycle crashes versus 35% of pedestrian crashes) and less likely to occur during the early morning hours (12:00-5:59 AM, 4% of bicycle crashes versus 9% of pedestrian crashes). Over half of the reported crashes occurred on local roads (61%). The seasons with the most bicyclist involved MVCs were summer (30%) and autumn (30%). Less than 5% of crashes were related to the weather or involved a work zone.

Factors associated with a greater likelihood of severe (K or A injury) according to 2017 crash reports (data are not shown):

- Alcohol/drug involvement
- Crash occurred during the evening (6:00-11:59 PM) or early morning hours (12:00-5:59 AM)

- Crash occurred during low light conditions
- Crash was weather-related
- Crash occurred on an interstate or highway

Table 4. Characteristics of crashes involving pedestrians: UNC HSRC, 2017

Crash Characteristic	Pedestrian-Related MVCs[1]	
	N	%
Weekday/Weekend		
Weekday	2,568	77.0%
Weekend	768	23.0%
Time of day		
12:00-5:59 AM	302	9.1%
6:00-11:59 AM	738	22.1%
12:00-5:59 PM	1,175	35.2%
6:00-11:59 PM	1,121	33.6%
Season[2]		
Winter	867	26.0%
Spring	744	22.3%
Summer	759	22.8%
Autumn	966	29.0%
Light Condition		
Daylight	1,866	56.1%
Dawn	54	1.6%
Dusk	115	3.5%
Dark	1,292	38.8%
Other	2	0.1%
Weather-Related Crash		
Yes	74	2.3%
No	3,170	97.7%
Work Zone-Related Crash		
Yes	64	1.9%
No	3,272	98.1%
Roadway Class		
Local Street	1,575	47.9%
Public Vehicular Area	786	23.9%
State Secondary Route	350	10.7%
NC Route	202	6.1%
US Route	187	5.7%
Private Road/Driveway	101	3.1%
Interstate	77	2.3%

Crash Characteristic	Pedestrian-Related MVCs[1]	
	N	%
Other Roadway	8	0.2%
Safety Equipment[3]		
Yes	262	8.1%
No	2,957	91.9%
TOTAL	**3,336**	**100.0%**

Missing: Light condition missing for seven records, weather-relatedness missing for 92 records, roadway class missing for 50 records, and safety equipment missing for 117 records.
Abbreviations: MVCs, motor vehicle crashes; NC, North Carolina; US, United States.
[1]Missing values are excluded from column totals; column totals sum to 100%.
[2]Winter: January, February, December; Spring: March, April, May; Summer: June, July, August; Autumn: September, October, December.
[3]Safety equipment consists of reflective clothing, safety pads, and other safety equipment.

Table 5. Characteristics of crashes involving bicyclists: UNC HSRC, 2017

Crash Characteristic	Bicycle-Related MVCs[1]	
	N	%
Weekday/Weekend		
Weekday	901	74.7%
Weekend	305	25.3%
Time of day		
12:00-5:59 AM	53	4.4%
6:00-11:59 AM	260	21.6%
12:00-5:59 PM	506	42.0%
6:00-11:59 PM	387	32.1%
Season[2]		
Winter	208	17.2%
Spring	274	22.7%
Summer	360	29.9%
Autumn	364	30.2%
Light Condition		
Daylight	828	68.9%
Dawn	9	0.7%
Dusk	33	2.7%
Dark	331	27.5%
Other	1	0.1%
Weather-Related Crash		
Yes	15	1.3%
No	1,159	98.7%
Work Zone-Related Crash		
Yes	64	1.9%
No	3,272	98.1%
Roadway Class		

Crash Characteristic	Bicycle-Related MVCs[1]	
	N	%
Local Street	728	61.4%
Public Vehicular Area	138	11.6%
State Secondary Route	126	10.6%
NC Route	90	7.6%
US Route	83	7.0%
Private Road/Driveway	12	1.0%
Interstate	7	0.6%
Other Roadway	2	0.2%
Safety Equipment[3]		
Yes	245	20.9%
No	928	79.1%
TOTAL	**1,206**	**100.0%**

Missing: Light condition missing for four records, weather-relatedness missing for 32 records, roadway class missing for 20 records, and safety equipment missing for 33 records.
Abbreviations: MVCs, motor vehicle crashes; NC, North Carolina; US, United States.
[1]Missing values are excluded from column totals; column totals sum to 100%.
[2]Winter: January, February, December; Spring: March, April, May; Summer: June, July, August; Autumn: September, October, December.
[3]Safety equipment consists of helmets, reflective clothing, safety pads, and other safety equipment.

North Carolina Healthcare Association Hospital Encounter Data

We provided the NCHA with a copy of the 2017 police crash report data. NCHA linked the data according to the algorithm discussed in the Methods section. NCHA did not provide any information about the hospital encounters that did not link to the crash report data. Tables 6 and 7 display patient characteristics for pedestrians and bicyclists, respectively. In total, there were 1,344 hospital encounters involving pedestrians and bicyclists (1,001 pedestrian encounters and 343 bicyclist encounters).

Health Outcomes of Pedestrians/Bicyclists Involved in Crashes

Pedestrians

Table 6 displays patient characteristics of pedestrians whose patient records ***linked*** to police crash reports, stratified according to inpatient status. Out of 1,001 hospital encounters involving pedestrians, there were seven direct admits to hospital inpatient care; the remaining 994 pedestrians entered through the emergency department (ED). According to the NCHA data, the average age of the pedestrians involved in MVCs was 40 years (standard deviation: 20.0, range 2-92 years). Most pedestrian ED and hospital inpatient encounters had a discharge disposition of home/self-care (ED: 93% and hospital inpatient: 62%). Among pedestrians, the most common source of payment was commercial insurance (38%) and self-pay (19%). The average length of

stay was 1.6 days (standard deviation: 2.0, range: 1-18 days). The average length of stay was much shorter for patients discharged directly from the ED (average: 1.1 days, standard deviation: 0.5) than from hospital inpatient care (5.1 days, standard deviation: 3.7).

Bicyclists

Table 7 displays patient characteristics of bicyclists whose patient records ***linked*** to police crash reports, stratified according to inpatient status. Out of 343 bicyclist hospital encounters, there were five direct admits to hospital inpatient care; the remaining 338 bicyclists entered through the ED. According to the NCHA data, the average age of bicyclists involved in MVCs was 37 years (standard deviation: 19.6, range 0-77 years). Most bicyclist ED and hospital inpatient encounters had a discharge disposition of home/self-care (ED: 94% and hospital inpatient: 82%). Among bicyclists, the most common source of payment was commercial insurance (45%) and self-pay (15%). The average length of stay was 1.3 days (standard deviation: 1.2, range: 1-11 days). The average length of stay was much shorter for patients discharged directly from the ED (average: 1.0 days, standard deviation: 0.2) than from hospital inpatient care (3.6 days, standard deviation: 2.6).

Table 6. Characteristics of hospital encounters involving pedestrians, stratified by hospital admission status: NCHA, 2017

Pedestrian Characteristic	Flagged as an Inpatient Encounter (e.g. Hospital Admission)[1,2]					
	Hospital Inpatient		Discharged from ED		Total	
	N	%	N	%	N	%
Age Group						
0-9	6	4.2%	42	4.9%	48	4.8%
10-19	6	4.2%	137	15.9%	143	14.3%
20-29	23	16.2%	143	16.6%	166	16.6%
30-39	17	12.0%	121	14.1%	138	13.8%
40-49	17	12.0%	144	16.8%	161	16.1%
50-59	26	18.3%	141	16.4%	167	16.7%
60+	47	33.1%	131	15.3%	178	17.8%
Discharge Disposition						
Home/Self-Care	49	62.0%	506	92.7%	555	88.8%
Transferred to a Different Hospital	1	1.3%	15	2.7%	16	2.6%
Died	4	5.1%	8	1.5%	12	1.9%
Home Health Service	11	13.9%	1	0.2%	12	1.9%
Left Against Medical Advice	1	1.3%	9	1.6%	10	1.6%
Inpatient Rehabilitation	7	8.9%	1	0.2%	8	1.3%
Transferred to a SNF	5	6.3%	2	0.4%	7	1.1%
Still a Patient	0	0.0%	3	0.5%	3	0.5%
Hospice	1	1.3%	0	0.0%	1	0.2%
Transferred to a Facility that Provides Supportive Care	0	0.0%	1	0.2%	1	0.2%
Payment						
Other Commercial Insurance	39	27.7%	241	28.1%	280	28.0%
Self-Pay	16	11.3%	178	20.7%	194	19.4%
Medicaid	19	13.5%	115	13.4%	134	13.4%
BCBS	13	9.2%	89	10.4%	102	10.2%
Medicare	27	19.1%	73	8.5%	100	10.0%
Other Govt Insurance	11	7.8%	64	7.5%	75	7.5%
Liability	11	7.8%	61	7.1%	72	7.2%
WC	5	3.5%	36	4.2%	41	4.1%
Automobile Medical	0	0.0%	2	0.2%	2	0.2%
Length of Stay						
≤1 Day	23	16.2%	836	97.3%	859	85.8%

Pedestrian Characteristic	Flagged as an Inpatient Encounter (e.g. Hospital Admission)[1,2]					
	Hospital Inpatient		Discharged from ED		Total	
	N	%	N	%	N	%
2 Days	18	12.7%	9	1.0%	27	2.7%
3 Days	20	14.1%	10	1.2%	30	3.0%
4 Days	18	12.7%	2	0.2%	20	2.0%
≥5 Days	63	44.4%	2	0.2%	65	6.5%
TOTAL	**142**	**100.0%**	**859**	**100.0%**	**1,001**	**100.0%**

Missing: Discharge disposition missing for 376 records and payment missing for one record.
Abbreviations: ED, emergency department; SNF, skilled nursing facility; BCBS, Blue Cross Blue Shield; govt, government; WC, workers' compensation.
[1]Missing values are excluded from column totals; column totals sum to 100%.
[2]Denominator is the number of linked crash-hospital encounter records.

Table 7. Characteristics of hospital encounters involving pedestrians, stratified by hospital admission status: NCHA, 2017

Bicyclist Characteristic	Flagged as an Inpatient Encounter (e.g. Hospital Admission)[1,2]					
	Hospital Inpatient		Discharged from ED		Total	
	N	%	N	%	N	%
Age Group						
0-9	2	5.0%	23	7.6%	25	7.3%
10-19	6	15.0%	46	15.2%	52	15.2%
20-29	8	20.0%	61	20.1%	69	20.1%
30-39	7	17.5%	48	15.8%	55	16.0%
40-49	4	10.0%	27	8.9%	31	9.0%
50-59	4	10.0%	54	17.8%	58	16.9%
60+	9	22.5%	44	14.5%	53	15.5%
Discharge Disposition						
Home/Self-Care	27	81.8%	202	93.5%	229	92.0%
Transferred to a Different Hospital	2	6.1%	6	2.8%	8	3.2%
Died	3	9.1%	1	0.5%	4	1.6%
Left Against Medical Advice	0	0.0%	3	1.4%	3	1.2%
Home Health Service	1	3.0%	1	0.5%	2	0.8%
Still a Patient	0	0.0%	2	0.9%	2	0.8%
Psychiatry Patient	0	0.0%	1	0.5%	1	0.4%
Payment						
Other Commercial Insurance	15	37.5%	98	32.7%	113	33.2%
Medicaid	9	22.5%	42	14.0%	51	15.0%
Self-Pay	3	7.5%	47	15.7%	50	14.7%
Other Govt Insurance	6	15.0%	41	13.7%	47	13.8%
BCBS	2	5.0%	38	12.7%	40	11.8%
Medicare	3	7.5%	17	5.7%	20	5.9%
Liability	2	5.0%	16	5.3%	18	5.3%
WC	0	0.0%	1	0.3%	1	0.3%
Length of Stay						
≤1 Day	11	27.5%	296	97.7%	307	89.5%
2 Days	8	20.0%	6	2.0%	14	4.1%
3 Days	5	12.5%	1	0.3%	6	1.7%
4 Days	3	7.5%	0	0.0%	3	0.9%
≥5 Days	13	32.5%	0	0.0%	13	3.8%
TOTAL	**40**	**100.0%**	**303**	**100.0%**	**343**	**100.0%**

Missing: Discharge disposition missing for 94 records and payment missing for three records.

Abbreviations: ED, emergency department; SNF, skilled nursing facility; BCBS, Blue Cross Blue Shield; Govt, government; WC, workers' compensation.
[1]Missing values are excluded from column totals; column totals sum to 100%.
[2]Denominator is the number of linked crash-hospital encounter records.

Summary of Aim 1

Overall, we found that each data source provides a different picture of pedestrian and bicyclist injuries. For instance, crash reports provide details about the crash itself, but limited information regarding patient outcome (other than death) and clinical care. If patient injury, treatment, or outcome is the primary research interest, then one should use NCHA hospital encounter data to study pedestrian and/or bicyclist injuries. On the other hand, the crash report data provide considerably more information about the circumstances of the crash. Table 8 displays the strengths and limitation of each data source.

Table 8. Comparison of the strengths and limitations of each data source

Source	Strengths	Limitations
UNC Highway Safety Research Center	**1.** Capture detailed information about the crash **2.** Collect demographics for all persons involved in crash **3.** Examine possible alcohol and drug involvement of the individuals involved in the crash	**1.** No descriptions of the nature/location of injury **2.** Limited information about patient outcome (e.g. admitted to the hospital, entered rehabilitative care, etc.) **3.** Police are not clinicians and may overestimate/underestimate the severity of injury **4.** Data missingness is a problem for some variables of interest (e.g. safety equipment) **5.** Can be difficult to determine if MVC was pedestrian/bicyclist-related
NC Healthcare Association	**1.** Capture patient outcome (e.g. discharge disposition) **2.** Capture information about the ED and inpatient encounter (if applicable) **3.** Collect patient demographics **4.** Collect information about the nature/location of injury using ICD-10-CM diagnosis codes **5.** Capture the amount time the patient stayed in the ED/hospital (i.e. "length of stay")	**1.** Data missingness is a problem for some variables of interest (e.g. discharge disposition) **2.** In order to protect patient anonymity, NCHA only released for research a small proportion of the total number of variables captured in the NCHA hospital encounter data

Abbreviations: UNC, University of North Carolina; NC, North Carolina; MVC, motor vehicle crash; ED, emergency department; NCHA, NC Healthcare Association

Aim 2: Link UNC HSRC Crash and NCHA Hospital Encounter Data Using Deterministic Linkage Methods

Figure 1 displays the process for the linkage between police crash reports and NCHA hospital encounter data for pedestrian and bicycle involved MVCs.

Inclusion Criteria for Data Sources

Crash reports: Sex and age were not missing from the crash reports (N=4,349 reports).

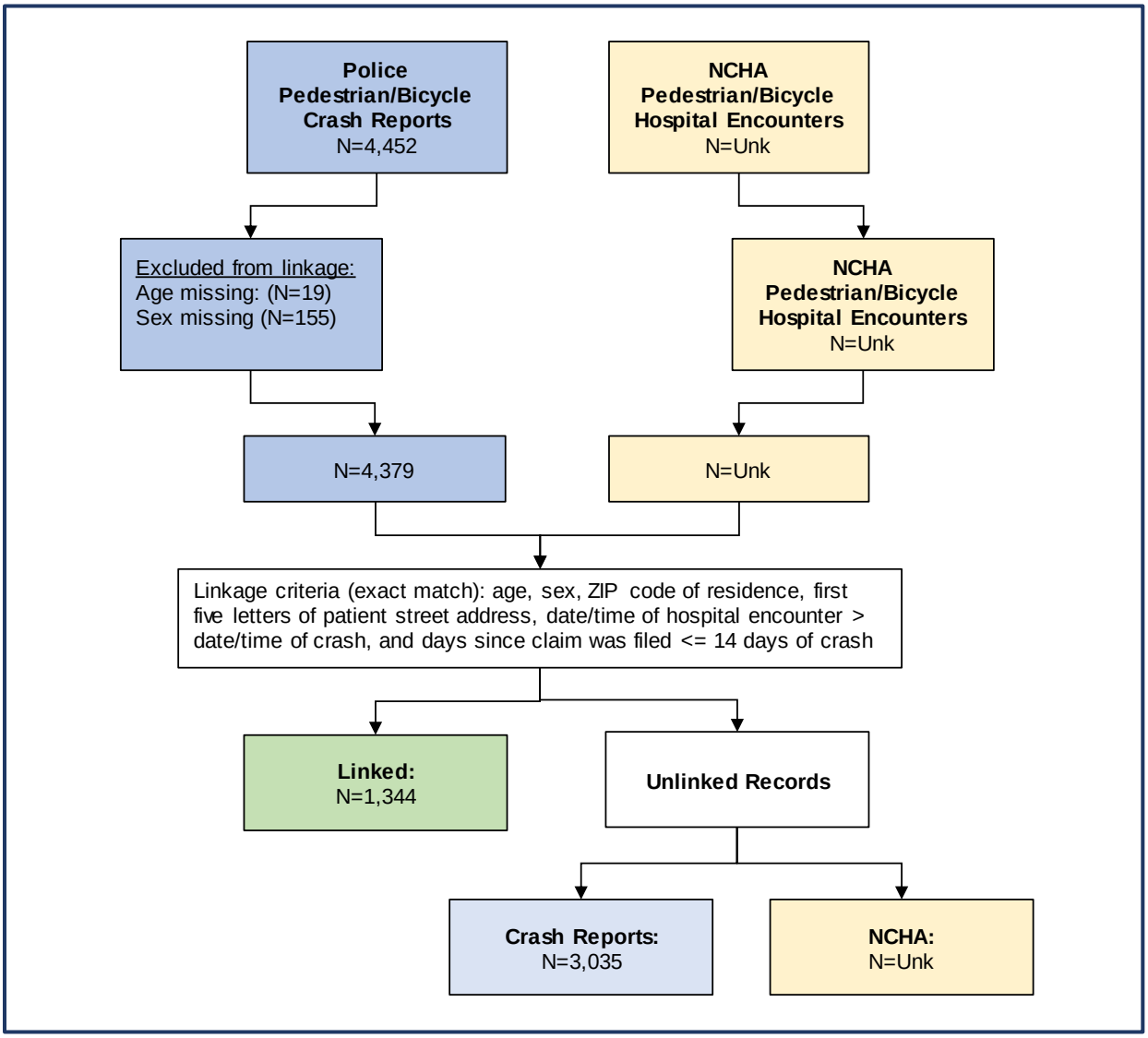
Hospital encounter: Sex and age were not missing from the hospital encounter record. Since NCHA performed the linkage, we do not know how many records were excluded.

Results: NCHA was able to successfully link 1,344 crash reports and hospital encounters. Overall, 30% of the crash reports linked to health outcome data.

Comparison of Linked Vs. Unlinked Crash Report Data

Tables 9 and 10 display pedestrian and bicyclist characteristics stratified by crash report linkage status. The major difference between linked and unlinked crash reports is related to injury severity (e.g. KABCO). For both pedestrians and bicyclists, individuals with police officer-reported fatal injuries and no injuries were less likely to link to hospital encounter data than individuals with other injury severities. This pattern was expected, since patients who die at the scene are not admitted to the ED or hospital, and patients without injuries are unlikely to seek emergency care.

Figure 1. Process chart of results linking crash reports and hospital encounter data: UNC HSRC & NCHA, 2017



Abbreviations: NCHA, NC Healthcare Association; Unk, unknown

Table 9. Comparison of linked crash-hospital encounter data vs unlinked crash report data for motor vehicle crashes involving pedestrians: UNC HSRC & NCHA, 2017

Pedestrian Characteristics	Linkage Status of Crash Report Data[1,2]			
	Linked to Hospital Encounter Data		Did Not Link to Hospital Encounter Data	
	N	%	N	%
Sex				
Male	606	60.5%	1,351	61.4%
Female	395	39.5%	851	38.6%
Age Group				
0-9	48	4.8%	107	4.6%
10-19	143	14.3%	314	13.5%
20-29	166	16.6%	492	21.2%
30-39	138	13.8%	370	15.9%
40-49	161	16.1%	330	14.2%
50-59	167	16.7%	373	16.0%
60+	178	17.8%	338	14.5%
Race/Hispanic Ethnicity				
White, Not Hispanic	429	43.2%	1,062	48.7%
Black, Not Hispanic	429	43.2%	917	42.0%
Hispanic/Latino	89	9.0%	119	5.5%
Other Race	46	4.6%	84	3.8%
Alcohol or Drugs Suspected				
Yes	78	7.8%	233	10.0%
No	923	92.2%	2,102	90.0%
KABCO				
Fatal Injury (K)	30	3.0%	170	7.7%
Serious Injury (A)	96	9.7%	215	9.7%
Minor Injury (B)	447	45.2%	730	33.0%
Possible Injury (C)	388	39.2%	872	39.4%
No Injury (O)	29	2.9%	225	10.2%
TOTAL	**1,001**	**100.0%**	**2,335**	**100.0%**

Missing: Sex missing for 133 records (unlinked crash reports, only), age group missing for 11 records (unlinked crash reports, only), race/ethnicity missing for 161 records, and KABCO missing for 134 records.
[1]Missing values are excluded from column totals; column totals sum to 100%.
[2]Examination of linked/unlinked data pertains only to the crash report data; NCHA did not provide unlinked bicycle/pedestrian hospital encounter records.

Table 10. Comparison of linked crash-hospital encounter data vs unlinked crash report data for motor vehicle crashes involving bicyclists: UNC HSRC & NCHA, 2017

Bicyclist Characteristics	Linkage Status of Crash Report Data[1,2]			
	Linked to Hospital Encounter Data		Did Not Link to Hospital Encounter Data	
	N	%	N	%
Sex				
Male	261	76.1%	645	76.7%
Female	82	23.9%	196	23.3%
Age Group				
0-9	25	7.3%	36	4.2%
10-19	52	15.2%	154	18.0%
20-29	69	20.1%	217	25.4%
30-39	55	16.0%	113	13.2%
40-49	31	9.0%	89	10.4%
50-59	58	16.9%	141	16.5%
60+	53	15.5%	105	12.3%
Race/Hispanic Ethnicity				
White, Not Hispanic	181	52.9%	455	54.7%
Black, Not Hispanic	121	35.4%	298	35.8%
Hispanic/Latino	30	8.8%	47	5.6%
Other Race	10	2.9%	32	3.8%
Alcohol or Drugs Suspected				
Yes	24	7.0%	41	4.8%
No	319	93.0%	822	95.2%
KABCO				
Fatal Injury (K)	10	2.9%	29	3.5%
Serious Injury (A)	30	8.8%	41	4.9%
Minor Injury (B)	163	47.9%	319	38.1%
Possible Injury (C)	124	36.5%	347	41.5%
No Injury (O)	13	3.8%	101	12.1%
TOTAL	**343**	**100.0%**	**863**	**100.0%**

Missing: Sex missing for 22 records (unlinked crash reports, only), age group missing for eight records (unlinked crash reports, only), race/ethnicity missing for 32 records, and KABCO missing for 29 records.
[1]Missing values are excluded from column totals; column totals sum to 100%.
[2]Examination of linked/unlinked data pertains only to the crash report data; NCHA did not provide unlinked bicycle/pedestrian hospital encounter records.

Summary of Aim 2

This is the first study to link NC police crash report data and NCHA hospital encounter data. We feel that the linked data set provides a more complete picture of MVCs involving pedestrians and bicyclists. We hope that these linked data will be useful for researchers and will help inform pedestrian/bicycle crash prevention programs and policies.

This study has several limitations. First, the proportion of crash reports that linked to hospital encounter data was lower than expected, especially given the high proportion of crashes that resulted in injuries. Second, since NCHA performed the linkage, we had limited control over the linkage process. For example, NCHA used the first five characters of street address as part of their linkage algorithm. Due to the number of variations one could expect with street address, we wonder if the inclusion of this linkage variable may have hindered the linkage process. However, we cannot assess this assumption, because NCHA provided minimal information about the hospital encounter data that did not link to the crash report data.

Table 11. Strengths and limitations of the linked crash and health outcome data: UNC HSRC & NCHA, 2017

Strengths	Limitations
1. Able to compare injury severity/nature of injury across two different data sources **2.** The linkage of the two data sources presents a more complete picture of injury among pedestrians/bicyclists involved in MVCs than the individual data sources	**1.** Unable to examine the hospital encounter records that did not link to crash report data **2.** Key linkage variables have missing data (e.g. "sex"), limiting the ability of the data to link **3.** The version of the police crash data owned by UNC HSRC is missing patient name (a key linkage variable) **4.** Due to the sensitivity of the hospital encounter data, linkage must be performed in-house at NCHA and so MVC Project Team members have little control over linkage methodology

Final Recommendations for Future Data Linkages in NC

Based on the results of the demonstration project, we have the following recommendations to help improve future MVC data linkage efforts in the state of NC.

1. Improve the collection of information for the variable "Destination of the injured person". The NC DMV 349 form contains a free text field for "Destination of the injured person". This variable identifies the hospital at which the injured pedestrian or bicyclist sought clinical care. This variable could be of use for future data linkages; however, at the present, this variable is often left blank. In addition, when police officers provide a destination hospital, there is considerable variation in hospital designation. For example, "CFVM", "CAPE FEAR VALLEY MEDICAL", and "CAPE FEAR VALLEY FAYETTEVILLE" all refer to the same hospital. For police departments with electronic crash report forms, including a "pick list" of local hospitals could improve the data quality of this variable.
2. Include a unique personal identifier on all MVC injury data sources. Currently, there is no common unique personal identifier on police crash report and hospital encounter data. Therefore, we are unable to verify the accuracy of the linkage results. In addition, the inclusion of a unique patient identifier would help simplify the linkage process.
3. Perform the linkage in-house or in close consultation with members of the MVC Injury Project Team. Due to the sensitivity of the NCHA data, we were unable to be directly involved with the data linkage process. Although we are willing to work with other organizations to improve MVC injury data linkage in the state of NC, we feel that greater input, and a more thorough understanding of the linkage process, would lead to linkage results that are more successful.

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