Motorcycle Lane-splitting and Safety in California

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Abstract

This document summarizes an analysis of data from the California Enhanced Motorcycle Collision Data Project. We report the prevalence of lane-splitting among 5,969 motorcyclists who were involved in traffic collisions from June 2012 through August 2013 and examine how other characteristics varied by whether the motorcyclist was lane-splitting at the time of their collision. For lane-splitting riders, we also examined how the likelihood of head, torso, and extremity injury varied by the manner in which they were lane-splitting.

Of the 5,969 collision-involved motorcyclists we studied, 997 were lane-splitting at the time of their collision (17%). Motorcyclists who were lane-splitting were notably different from those that were not lane-splitting. Compared with other motorcyclists, lane-splitting motorcyclists were more often riding on weekdays and during commute hours, were using better helmets, and were traveling at lower speeds. Lane-splitting riders were also less likely to have been using alcohol and less likely to have been carrying a passenger.

Lane-splitting motorcyclists were also injured much less frequently during their collisions. Lane-splitting riders were less likely to suffer head injury (9% vs 17%), torso injury (19% vs 29%), extremity injury (60% vs 66%), and fatal injury (1.2% vs 3.0%). Lane-splitting motorcyclists were equally likely to suffer neck injury, compared with non-lane-splitting motorcyclists.

We also examined how the manner in which riders were lane-splitting affected their likelihood of being injured for each of the three injury types using multivariate regression methods. We found that both traffic speed and motorcycle speed differential (the difference between motorcycle speed and traffic speed) were important in predicting the occurrence of injury. There was no meaningful increase in injury incidence until traffic speed exceeded roughly 50 MPH. Motorcycle speed differential was a stronger predictor of injury outcomes. Speed differentials of up to 15 MPH were not associated with changes in injury occurrence; above that

point, increases in speed differential were associated with increases in the likelihood of injury of each type.

Lane-splitting appears to be a relatively safe motorcycle riding strategy if done in traffic moving at 50 MPH or less and if motorcyclists do not exceed the speed of other vehicles by more than 15 MPH. A significant number of motorcyclists lane-split in fast-moving traffic or at excessive speed differentials. These riders could lower their risk of injury by restricting the environments in which they lane-split and by reducing their speed differential when they do choose to lane-split.

Introduction

Lane-splitting is the practice of riding between lanes of traffic or sharing a lane with another motor vehicle. It is legal in California, but it is controversial and has not been studied. It is known that lane-splitting is widely practiced among motorcyclists in the state. Motorcyclists will report that they achieve safety benefits by the increased mobility on roadways with respect to traffic. They cite the ability to strategically place themselves in pockets of lower congestion during commute traffic to improve safety. They report that they distance themselves from safety hazards from larger vehicles beside or behind them, or from hazards presented by highly congested clusters of traffic. They also claim they can improve their ability to see traffic ahead of them as well as their conspicuity -- the ability to be seen by others -- by placing themselves in open sections of roadways and also by having the freedom to place themselves strategically within a traffic lane or between traffic lanes. Other benefits of lane-splitting that are often discussed in the motorcycling community include the reduction of congestion and the reduction of fuel consumption and tailpipe emissions from spending less time sitting in stopped or slow-moving traffic.

There appear to be some risks to lane-splitting. The most basic is that lane-splitting riders often put themselves closer to other vehicles than they otherwise would. This proximity reduces the time riders have to identify and react to changes in the behaviors of other motorists. Anecdotal evidence suggests that the primary risk while lane-splitting is the lane-changing of other vehicles. Other drivers often initiate lane changes without first checking for lane-splitting motorcycles. It is in these situations where the motorcycle speed differential may play a strong role in collision causation.

Other potential hazards that may exist for lane-splitting motorcyclists include uneven pavement and markings (e.g., striping or Bott's dots) between roadway lanes on which lane-splitting riders must traverse, and, in the case of motorcycle filtering between a lane of traffic and parked vehicles, door openings.

A 2014 UC Berkeley survey of 951 motor vehicle drivers and 709 motorcyclists in California found that 80% of motorcyclists reported that they lane-split at least some of the time when traveling on freeways, and 37% of riders reported that they lane-split "always" when on freeways. (Source material is available from the authors.)

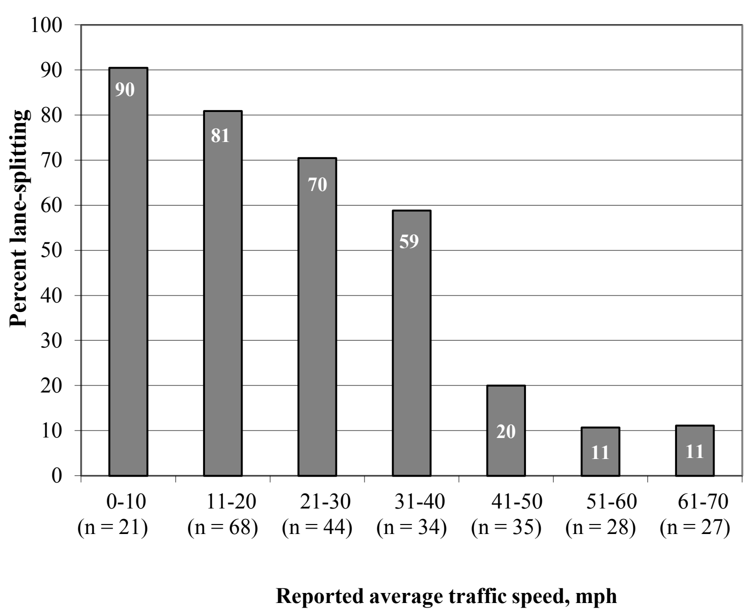
The survey confirmed that the non-motorcycling public often disapproves of lane-splitting. Among passenger vehicle drivers, 61% "somewhat" or "strongly" disapproved of the practice of lane-splitting. There is also considerable confusion about the legality of lane-splitting among non-motorcycling motorists; 36% of motorists believed incorrectly that motorcycle lane-splitting on multi-lane roadways is illegal, and an additional 12% were unsure about its legality.

The proportion of motorcyclists who lane-split generally decreased as traffic speed increased. Four-fifths of the surveyed motorcyclists stated that they split lanes when riding on freeways. Of these riders, 38% reported that they only split lanes in stopped or "stop-and-go" traffic. An additional 27% reported lane-splitting when traffic is moving at 20 MPH or less, and 15% reported lane-splitting when traffic was moving at 30 MPH or less. Increasingly small numbers of riders reported lane-splitting as traffic speed increased; 7%, 2%, and 3% engaged in lane-splitting in traffic moving at 40, 50, and 60 MPH or less, respectively.

The survey also found that a large majority of motorcyclists exceeded the speed of the surrounding traffic by 15 MPH or less while lane-splitting. When asked "How much faster than the rest of traffic do you go when lane-splitting?," 30%, 47%, and 14% responded traveling 5 MPH, 10 MPH, and 15 MPH faster than traffic, respectively.

Another attempt to understand the prevalence of lane-splitting was made by Ouellet. He estimated the occurrence of lane-splitting by observing rush hour traffic in Los Angeles. He found that 55% of motorcyclists (n=257) were lane-splitting at the time of observation. The graphic below illustrates the inverse relationship between traffic speed and motorcyclist lane-splitting. When traffic was moving at 0-10 MPH, 90% of riders were lane-splitting. As speed increased, the proportion of riders lane-splitting decreased steadily to 59% when traffic was moving at 31-40 MPH. At traffic speeds of 50 MPH or greater, the proportion of riders who were lane-splitting dropped markedly. (Source material is available from the authors.)

Figure 1. Percentage of motorcycles splitting lanes as a function of average traffic speed, Los Angeles, 2011.



Reproduced with permission from: Ouellet JV, Motorcycle lane splitting on California freeways (unpublished manuscript). 2012. Motorcycle Accident Analysis, Playa del Rey, CA.

There is considerable support for lane-splitting outside of California in the motorcycling community and motorcycle-related industries. The Motorcycle Industry Council, a trade group representing manufacturers and dealers of motorcycles and motorcycling equipment endorses lane-splitting. A 2011 release reads “In full consideration of the risks and benefits of lane splitting, the Motorcycle Industry Council supports state laws that allow lane splitting under reasonable restrictions.” (Source material is available from the authors.)

The American Motorcyclist Association issued a cautiously-worded endorsement of lane-splitting in December 2014. (Source material is available from the authors.)

> “Given the ongoing success of lane splitting in California and the recent enthusiasm for lane splitting and/or filtering in other states, the AMA endorses these practices and will assist groups and individuals working to bring legal lane splitting and/or filtering to their states.”

Their position is that lane-splitting is a safe and beneficial strategy for motorcyclists if done in a reasonable manner, and that the success of legalized lane-splitting in any US state will be dependent upon high levels of knowledge among non-motorcycling road users.

There is currently considerable interest in potentially legalizing lane-splitting in several US states. Unsuccessful legislative attempts have been made in Oregon, Nevada, and Texas. A bill was passed in Arizona but was vetoed by their Governor. In California, three legislative bills have been written that would define the conditions under which lane-splitting could be legally practiced by motorcyclists. The first bill was withdrawn and the second one was “tabled” to await the findings of the current research. A third bill, Assembly Bill 51, was introduced in December 2014 and is currently under legislative committee review.

Jurisdictions outside the US have also considered legalizing lane-splitting. In 2014, the state of New South Wales in Australia changed existing laws governing lane splitting, following an eight-week trial period. The trial, conducted by Transport for New South Wales, analyzed the nature and prevalence of lane filtering at five urban sites. The study included data collection on the activity and behavior of motorcyclists, pedestrians, and cyclists. Using a combination of traffic congestion data, behavioral data, and video data, the trial concluded that lane-splitting “was a relatively low risk riding activity for motorcyclists under the conditions of the trial.” As a result of these findings, New South Wales changed existing laws from disallowing lane-splitting entirely, to permitting lane-splitting at a speed less than 30 km/h (19 m/h). (Source material is available from the authors.)

To increase our understanding of the relative safety of lane-splitting in California and identify lane-splitting practices that may put riders at risk, we analyzed data from a recent UC Berkeley motorcycle research project.

Methods

Data

The primary data source for this analysis was the California Enhanced Motorcycle Collision Data Project -- a collaboration between the UC Berkeley and the California Highway Patrol (CHP). The CHP is the law enforcement agency with jurisdiction over California’s state highway system. The agency is staffed by 7,773 uniformed personnel, who are responsible for patrolling more than 106,000 miles of roadway (87% county roads and 13% state highways). The agency is organized into eight divisions and 109 area offices across the state. In 2012, CHP investigated 62,309 injury-producing traffic collisions, 38% of collisions in California. Of the 11,617 collisions that involved a motorcycle in the state that year, CHP investigated 52%. (Source material is available from the authors.)

The goal of the project was to acquire information not usually collected during law enforcement investigations of motorcycle traffic collisions in California. Between June 2012 and

August 2013, a one-page supplemental data form was used during collision investigations by CHP officers and by officers at more than 80 local law enforcement agencies in the state. CHP officers completed the forms using an encrypted web site linked to the software used to complete other traffic collision forms. Supplemental forms from local agencies were mailed to CHP and were forwarded to UC Berkeley for key entry. CHP officers used the supplemental form from August 1, 2012 through July 31, 2013 and participating local agencies used the form from June 1, 2012 through May 31, 2013. A small number of supplemental forms were submitted in August 2013 and are included in this analysis.

The data collected included driver license status, whether the motorcyclist was lane-spitting, speed of the motorcycle, speed of surrounding traffic, and for each motorcycle rider -- helmet type, helmet standard labeling (DOT, Snell, etc), whether the office thought that the helmet met the DOT standard, helmet damage, helmet retention, body region injured, injury severity, whether rider was transported by EMS, alcohol BAC, and the use of high visibility or reflective gear.

Copies of the corresponding police collision reports were also obtained. Personal identifiers were redacted and copies were transported to Berkeley for data abstraction. The information obtained from the reports included rider and motorcycle characteristics, collision descriptors, alcohol use, extent of injury, and information on lane-splitting or helmet characteristics found in the report narrative. Police collision report data were linked to the supplemental form data using the collision date, time, and officer badge number. Inconclusive matches were then hand matched using CHP area office identifier, local agency identifier, motorcyclist age, or motorcyclist gender.

The project resulted in the creation of a new database of information from 7,836 motorcycle collisions in California and the operators and passengers involved. Of these supplemental forms, 6,333 were submitted by CHP (81%) and 1,503 were submitted by local agencies (19%).

These collisions involved a total of 8,262 motorcycle riders (7,836 operators and 426 passengers).

For the current analysis, we used 5,969 of the 6,318 (94.5%) motorcyclist supplemental forms submitted by CHP for which we were able to identify and link data from the corresponding hard copy police collision report. Detailed information on roadway characteristics was not available in our database. To reduce the heterogeneity of roadway types and reporting practices of local law enforcement agencies, we restricted our sample to collisions that occurred on roadways in CHP jurisdiction. Data from local law enforcement agencies are being included in analyses of motorcycle helmet effectiveness.

Goals & Objectives

The goal of the analysis was to increase our understanding of collisions involving lane-splitting motorcyclists and of how lane-splitting impacts collision injuries. Specific objectives were (1) to compare personal, motorcycle, and collision characteristics of lane-splitting collisions with those of other collision types and (2) to compare the occurrence of head, torso, and extremity injury among lane-splitting riders by the manner in which they were lane-splitting.

Data Analysis

Tabular and graphical methods were used to examine the data and explore associations between various characteristics and lane-splitting status. Among lane-splitting motorcyclists, speed differential was calculated as the motorcycle speed minus the speed of the surrounding traffic as reported by the investigating officer. Motorcycle speed and speed differential was examined graphically for lane-splitting motorcyclists.

The probability of injury among collision-involved, lane-splitting motorcyclists was compared across different combinations of traffic speed and speed differential by comparing the proportion of riders injured either directly or with a log-binomial regression model that controlled for potential confounding by rider age, rider sex, and motorcycle helmet type. The regression models estimate the probability of a binary outcome as a log-linear function of a set of predictors. Three models were used with head injury, torso injury, and extremity injury as outcomes. Predictors included categories of traffic speed, categories of motorcycle speed differential, age, and gender. The speed differential risk ratios were allowed to vary across levels of traffic speed by including all two-way product terms between traffic speed and speed differential categories.

Results

We identified 5,969 collision-involved motorcyclists on whom we had data from both the supplemental form and the police collision report. The motorcycle collisions in this study occurred in CHP jurisdiction. The CHP divisions with the largest number of collisions were Border, Southern, and Golden Gate, accounting for 61% of the collisions investigated (Table 1).

Riders aged 15-34 comprised 47% of the total, and those aged 25-54 years comprised 24% of the total. Small numbers of older riders were involved in collisions - 13% were aged 55-64 and 4% were aged 65 or older. Women were a small minority of the motorcyclists - 5,577 were male (93%), 315 were female (5%), and 77 had an undetermined gender (1.3%)

Of the 5,969 motorcyclists, 171 were fatally injured (2.9%), 1,025 were severely injured (17%), 2,388 receive some other visible injury (40%), and 2,329 had either no injury or a complaint of pain (39%).

The brand of motorcycle ridden at the time of collision is also shown in Table 1. The most common brands were Harley-Davidson (26%), Honda (17%), and Yamaha (16%). Additionally, almost 20% of the riders were not properly licensed at the time of collision.

Of the 5,969 motorcyclists, 997 were lane-splitting at the time of their collisions (17%) (Table 1). Lane-splitting motorcyclists (LSM) were more likely to have been riding on weekdays than other motorcyclists. For example, only 14% of LSM were traveling on a Saturday or Sunday, compared with 37% of non-lane-splitting riders (Tables 2 and 3). LSM were more likely to have been riding during commute hours (6:00-8:59 am or 3:00-5:59 pm) - 62% compared with 38% of non-lane-splitting motorcyclists (Table 4).

Lane-splitting was strongly associated with state highway use - 94% of LSM were traveling on a state highway compared with only 66% of non-lane-splitting motorcyclists (Table 5). LSM were also notably younger than non-lane-splitting riders (Table 6). For example, 58% of LSM were aged 34 or younger and 6% were aged 55 or older, compared with 45% and 19%, respectively, for other motorcyclists. Minor differences in gender were observed between LSM and other riders. The differences approached statistical significance at p=0.065 (Table 7).

We observed minor, non-significant differences in the proportion of riders who were properly licensed (81.0% vs 79.6%, p=0.094) (Table 8). LSM were much less likely to have been carrying a passenger (2.1%) than other motorcyclists (6.6%) (Table 9). Alcohol use (Table 10) was low among all the motorcyclists in our sample (3.0%). The prevalence of alcohol use was lower among LSM (1.2%) than among other motorcyclists (3.4%).

The type of motorcycle helmet used at the time of collision also differed by lane-splitting status (Table 11). Non-lane-splitting riders were more likely to be wearing a 1/2-helmet (15% vs 9%), a 3/4-helmet (9% vs 5%), or a novelty helmet (4.2% vs 1.8%) than LSM, and LSM were more likely to be wearing a full-face helmet than other motorcyclists (81% vs 67%).

The observed injuries among the motorcyclists were significantly different between LSM and other motorcyclists (Table 12). LSM were markedly less likely to suffer head injury (9% vs 17%), torso injury (19% vs 29%), or fatal injury (1.2% vs 3.0%) than non-lane-splitting motorcyclists.

The occurrence of neck injury and extremity injury did not differ meaningfully by lane-splitting status.

Overall, these motorcyclists were very infrequently rear-ended by other motorists, 254 out of 5,914 (4.3%). Lane-splitting riders were significantly less likely to be rear-ended than other non-lane-splitting riders (2.6% vs 4.6%). LSM were, on the other hand, more likely to rear-end another vehicle than other riders (38% vs 16%) (Tables 13 and 14).

Of the 5,969 riders, 164 were fatally injured due to their traffic collision (2.8%) (Table 15). Compared with non-fatally injured riders, those who did not survive their injuries were significantly more likely to have suffered head injury (47% vs 15%), neck injury (18% vs 8%), and torso injury (43% vs 27%). The fatally injured riders were much less likely to have suffered an extremity injury (26% vs 66%).

Figure 2 shows the motorcycle speed differential at the time of collision. The data have been categorized by the speed of the surrounding traffic. For example, the first graphic shows the speed differential when traffic was not moving. The height of each bar represents the number of motorcyclists (y-axis) within a given range of speed differentials (x-axis). The mean speed differential and standard deviation (SD) are provided within each graphic. It can be seen that the variability of speed differential is generally higher for slower traffic speeds. Variability is greatest for stopped traffic and for traffic flowing at 60-69 MPH. For stopped traffic, the high SD is driven by a large number of riders traveling at most differential values within the total range. For 60-69 MPH traffic, the high SD results from a small number of riders traveling at very small or very large speed differentials. For each level of traffic speed, a small number of riders were traveling at a speed less than the surrounding traffic (with the exception of riders in stopped traffic).

Table 16 shows the proportion of lane-splitting motorcyclists who suffered head, torso, and extremity injury by the manner in which they were lane-splitting. Each super-row (of four rows) in the table contains a classification of all lane-splitting riders by whether they were lane-splitting consistent with one combination of traffic speed and speed differential. We looked at all twelve combinations of traffic speeds of 25, 35, 45, and 55 MPH and speed differentials of 5, 10, and 15 MPH. For example, lines 1-4 consider the lane-splitting parameters of 25 MPH or less and 5 MPH or less for traffic speed and speed differential, respectively. The percent with each injury type by whether the motorcyclist was lane-splitting consistent with one, the other, both, or neither lane-splitting parameter is presented in the four rows. Line 4 shows that, of riders lane-splitting in traffic flowing at 25 MPH or less and splitting at 5 MPH or less above the traffic speed, 13% suffered head injury, 10% suffered torso injury, and 52% suffered extremity injury. In general, lane-splitting riders who were riding consistent with neither parameter (across all combinations of considered parameters) had the greatest proportion with injury, followed by those riding consistent with the traffic speed parameter, those riding consistent with the differential parameter, and those riding consistent with both parameters. In all 12 super-rows, riders who were lane-splitting consistent with both parameters had, by far, the lowest likelihood of injury. This was true for each injury type, but differences in injury proportions were greatest for head injury.

To estimate the differences in injury proportions while controlling for potential confounders, we fitted a regression model to data from the lane-splitting riders. Table 17 presents the estimated risk ratios (RR) from the first model using head injury as the outcome. The risk ratios reflect the average risk (or probability) of having suffered a head injury for lane-splitting riders in each level divided by the average risk in the referent category, given involvement in a traffic collision. Each risk ratio estimate is statistically adjusted for the other variables in the table and for age, gender, and helmet type. We estimated minor and non-statistically significant differences in the probability of head injury for riders when traffic was moving at speeds between 0 and 49 MPH. Riders in traffic moving at 50-59 MPH (RR 2.38, p 0.004) or 60+ MPH (RR 2.58, p 0.007) were significantly more likely to suffer head than those traveling in lower speed traffic. Motorcycle speed differential of 15 MPH or greater was also significantly associated with head injury probability. Estimated risk ratios were 1.98 (p 0.022) and 2.66 (p

0.001) for speed differentials of 15-24.9 MPH and 25 MPH or greater, respectively. Interaction product terms for traffic speed and speed differential were not significant (p 0.770) and were dropped from the model.

Risk ratios for torso injury are presented in Table 18. Risk ratios for each traffic speed category at 20-29 MPH or greater were significantly greater than 1. A comparison of each risk ratio to that of the 20-29 MPH category showed that only the 60+ MPH risk ratio was significantly different (p 0.036). The speed differential risk ratios displayed a monotonic trend. The risk ratio for 15-24.9 MPH differential approached significance (p 0.117) and the risk ratios for 25+ MPH differential was significant at p = 0.010. Overall, the association between speed differential and torso injury was marginally significant (p 0.072). The interaction between traffic speed and speed differential was not significant and was excluded from the model (p 0.726).

Using extremity injury as the outcome, traffic speed risk ratios were all significant when compared with the probability of injury for traffic moving at 0-19 MPH (Table 19). When compared to traffic moving at 20-29 MPH, the probability of extremity injury was also significantly different. The risk ratios for traffic speeds of 30-39 MPH, 40-49 MPH, and 60+ MPH were significant at p equal to 0.011, 0.051, and 0.024, respectively. The estimated risk ratio for traffic speeds of 50-59 MPH was not significant (p 0.635). The estimated risk ratios for motorcycle speed differential were 1.14 when comparing the 15-24.9 MPH differential with the 0-9.9 MPH differential (p 0.090) and 1.26 comparing the 25+ MPH differential with the 0-9.9 MPH differential (p 0.003). The interaction product terms were not significant and were excluded from the model (p 0.343).

Discussion

Lane-splitting is legal and is widely practiced by motorcyclists in California. Of the almost 6,000 collision-involved motorcyclists we studied, nearly 1,000 were lane-splitting at the time of their collision. When we compared motorcyclists who were lane-splitting with those who were not, we could see that the lane-splitting riders were notably different. Compared with other motorcyclists, lane-splitting motorcyclists were more often riding on weekdays and during commute hours, were using better helmets, and were traveling at lower speeds. Lane-splitting riders were also less likely to have been using alcohol and less likely to have been carrying a passenger. Lane-splitting motorcyclists were much less often injured during their collisions. They were considerably less likely to suffer head injury, torso injury, extremity injury, and fatal injury than riders who were not lane-splitting.

We also found that the manner in which motorcyclists split lanes varied greatly. Most riders exceeded the speed of the surrounding traffic by a small or moderate amount. For example, 69% of riders were exceeding the traffic speed by 15 MPH or less. A significant number were traveling at excessive speed: 14% had a speed differential of 25 MPH or greater, and 3% had a speed differential of 40 MPH or greater. Lane-splitting in such a manner is likely to increase the risk of being involved in a traffic collision.

In this analysis, we found that the manner in which motorcyclists were lane-splitting when involved in traffic collisions was highly predictive of the occurrence of bodily injury. Both traffic speed and motorcycle speed differential were significantly associated with the occurrence of head, torso, and extremity injury. (The number of fatally injured lane-splitting motorcyclists was insufficient for analysis [n=12]). Traffic speed is, of course, a known predictor of injury occurrence and injury severity in all types of motorcycle collisions. In non-lane-splitting collisions in our data set, the occurrence of injury is low at motorcycle speeds below 20 MPH. Starting at 20 MPH, a steady increase in the injury occurrence can be seen as motorcycle speed increases. The trend is similar for head, torso, and extremity injury. In lane-splitting collisions, the same trend can be seen for torso and extremity injury. For head injury occurrence, the trend is different from what is observed in non-lane-splitting collisions. During lane-splitting collisions, head injury occurrence is low at all motorcycle speeds up to 50 MPH (6.6% on average) and increases markedly above 50 MPH (16.7% on average).

We found that motorcycle speed differential is a stronger predictor of injury than was the overall traffic speed. Speed differentials of up to 15 MPH were not associated with changes in injury occurrence; above that point, increases in speed differential were associated with increases in the likelihood of injury of each type.

The findings from this analysis suggest that countermeasures to alter the way motorcyclists lane-split are likely to result in reductions in injury. Many motorcyclists may not understand how lane-splitting at excessive traffic speed creates unnecessary risk. It is in high-speed environments where lane-splitting has the lowest benefit to the motorcyclist, and high-speed lane-splitting could be reduced or eliminated from California roadways without significant loss of the overall potential benefits of lane-splitting, which include reductions in fuel consumption, emissions, and traffic congestion. Riders may also be unaware that the speed differential at which they lane-split is highly predictive of injury occurrence. There has been considerable discussion in the motorcycling community that lane-splitting should be done only at lower speed differentials. Many riders advocate for speed differentials of 10, 15, or 20 MPH. Our findings suggest that riders who adopt a 10 or 15 MPH speed differential practice may reduce their exposure to injury risk. While our study data cannot be used to estimate the risk of actually being involved in a collision, an informal examination of a few dozen lane-splitting collisions revealed an overwhelming trend of lane-splitting collisions resulting from a motorcyclist lane-splitting at a high speed differential. (A planned 2016 study will determine the exact causes of lane-splitting collisions.)

The primary strength of this analysis was the study design which allowed for data collection for motorcycle traffic collisions regardless of injury outcome. We believe we came close to achieving our goal of including every traffic collision involving a motorcycle that was investigated by CHP. CHP officers were trained at the initiation of the study, were regularly briefed during the study period, and were prompted to complete the supplemental data collection form by the software system used to generate the police collision report. In addition, all collision investigation forms were reviewed for completeness by a supervising officer and were not finalized until that officer approved it. Other strengths of this analysis are the large sample size and the use of multivariate methods to control for confounding by age, gender, and motorcycle helmet type.

This study is not without limitations. The primary limitation is our lack of exposure data. To estimate how the risk of being involved in a collision changes when motorcyclists chose to lane-split, we would require information on both the lane-splitting and non-lane-splitting riding that is done by some identifiable sample of motorcyclists. The collection of these data is fraught with problems, and the current study did not attempt to collect such data. The current data set cannot be used to compare the collision risks for lane-splitting or non-lane-splitting riders. The data that we do have enables us only to examine the collision, personal, and injury characteristics of the riders who were involved in traffic collisions and whose collisions occurred in the study jurisdictions.

We are also not currently able to examine how collision and injury characteristics vary across roadway types because access to data on roadway characteristic is pending. One particular analysis that we plan to conduct using roadway data is a comparison of injury outcomes by whether the motorcyclist was rear-ended. There is considerable concern in the motorcycling community about the relative dangers of being rear-ended. A good approach to conducting an analysis of this topic would be to compare injury types and injury severities by whether the rider was rear-ended for given roadway types. Making comparisons within given roadway types will control for the influence (confounding) of collision severity (energy) and other collision characteristics. The importance of controlling for this confounding necessitates our delay of examining the impact of lane-splitting on rear-end collisions until we have roadway data.

Finally, our injury data in this analysis consisted of a yes/no indicator, which results in minor injuries being grouped together with severe or even critical injuries. It is known that injury severity is related to motorcycle speed, but we were only able to examine the occurrence of some level of observable injury. In an ongoing project, we will acquire hospital-based injury data, including the specific nature and severity of each injury. These data will allow for a more detailed analysis of the role that a variety of characteristics, including lane-splitting and helmet type, play in the incidence of specific injuries.

Research is also needed to increase our understanding of how motorcycle collisions come about, for both lane-splitting and non-lane-splitting riders. A planned study will focus on collision causation among our 997 lane-splitting motorcyclists. The study will still lack information on the motorcycling done when a collision did not occur, but it is still likely to identify causal factors that would have a high likelihood of preventing collisions if they are modifiable (e.g., specific practices among riders).

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Tables and Figures

Table 1. Injury severity, collision-involved motorcyclists

Characteristic	#	%
CHP Division		
Northern	238	4.0
Valley	635	10.6
Golden Gate	1,040	17.4
Central	452	7.6
Southern	1,283	21.5
Border	1,314	22.0
Coastal	386	6.5
Inland	608	10.2
Unknown	13	0.2
Age		
<15	16	0.3
15-24	1,212	20.3
25-34	1,606	26.9
35-44	988	16.6
45-54	1,031	17.3
55-64	753	12.6
65+	246	4.1
Unknown	117	2.0
Gender		
Female	315	5.3
Male	5,577	93.4
Unknown	77	1.3
Injury Severity		
None	930	15.6
Complaint of Pain	1,399	23.4
Other Visible	2,388	40.0
Severe	1,025	17.2
Fatal	171	2.9
Injured, severity unknown	53	0.9
Unknown	3	0.1
Motorcycle Make		
BMW	218	3.7
Ducati	151	2.5
Harley-Davidson	1,545	25.9
Honda	1,026	17.2
Kawasaki	700	11.7
Suzuki	882	14.8

Yamaha	958	16.0
Triumph	107	1.8
Other	293	4.9
Unknown	89	1.5
Properly Licensed		
No	1,167	19.6
Yes	4,763	79.8
Unknown	39	0.7
Helmet Type		
Full-face	4,116	69.0
1/2 Helmet	820	13.7
3/4 Helmet	493	8.3
Modular	180	3.0
Novelty	227	3.8
None	89	1.5
Unknown	44	0.7
Lane-Splitting		
No	4,917	82.4
Yes	997	16.7
Unknown	55	0.9
Total	5,969	100

Table 2. Day of week by lane-splitting status, collision-involved motorcyclists

	Lane-Splitting					
	No		Yes		Total*	
Day of Week	#	%	#	%	#	%
Sunday	835	17.0	58	5.8	893	15.1
Monday	525	10.7	124	12.4	649	11.0
Tuesday	549	11.2	181	18.2	730	12.3
Wednesday	636	12.9	205	20.6	841	14.2
Thursday	636	12.9	172	17.3	808	13.7
Friday	755	15.4	172	17.3	927	15.7
Saturday	970	19.7	84	8.4	1,054	17.8
Unknown	11	0.2	1	0.1	12	0.2
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 3. Weekend status by lane-splitting status, collision-involved motorcyclists

	Lane-Splitting					
	No		Yes		Total*	
Weekend	#	%	#	%	#	%
No	3,101	63.1	854	85.7	3,955	66.9
Yes	1,805	36.7	142	14.2	1,947	32.9
Unknown	11	0.2	1	0.1	12	0.2
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 4. Time of day by lane-splitting status, collision-involved motorcyclists

	Lane-Splitting					
	No		Yes		Total*	
Time of Day	#	%	#	%	#	%
Mid-3:00	124	2.5	4	0.4	128	2.2
3:00-5:59	135	2.7	21	2.1	156	2.6
6:00-8:59	541	11.0	276	27.7	817	13.8
9:00-11:59	749	15.2	80	8.0	829	14.0
12:00-14:59	1,077	21.9	110	11.0	1,187	20.1
15:00-17:59	1,335	27.2	345	34.6	1,680	28.4
18:00-20:59	679	13.8	144	14.4	823	13.9
21:00-23:59	273	5.6	17	1.7	290	4.9
Unknown	4	0.1	0	0.0	4	0.1
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 5. State highway by lane-splitting status, collision-involved motorcyclists

	Lane-Splitting					
	No		Yes		Total*	
State Highway	#	%	#	%	#	%
No	1,682	34.2	53	5.3	1,735	29.3
Yes	3,219	65.5	941	94.4	4,160	70.3
Unknown	16	0.3	3	0.3	19	0.3
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 6. Age category by lane-splitting status, collision-involved motorcyclists

Age Category	Lane-Splitting					
	No		Yes		Total*	
	#	%	#	%	#	%
<15	16	0.3	0	0.0	16	0.3
15-24	983	20.0	220	22.1	1,203	20.3
25-34	1,231	25.0	358	35.9	1,589	26.9
35-44	794	16.1	182	18.3	976	16.5
45-54	897	18.2	126	12.6	1,023	17.3
55-64	694	14.1	51	5.1	745	12.6
65+	238	4.8	8	0.8	246	4.2
Unknown	64	1.3	52	5.2	116	2.0
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 7. Sex by lane-splitting status, collision-involved motorcyclists

Sex	Lane-Splitting					
	No		Yes		Total*	
	#	%	#	%	#	%
Female	274	5.6	40	4.0	314	5.3
Male	4,600	93.6	923	92.6	5,523	93.4
Unknown	43	0.9	34	3.4	77	1.3
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 8. Licensure by lane-splitting status, collision-involved motorcyclists

Properly Licensed	Lane-Splitting					
	No		Yes		Total*	
	#	%	#	%	#	%
No	981	20.0	174	17.5	1,155	19.5
Yes	3,913	79.6	808	81.0	4,721	79.8
Unknown	23	0.5	15	1.5	38	0.6
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 9. Passenger presence by lane-splitting status, collision-involved motorcyclists

Passenger Present	Lane-Splitting					
	No		Yes		Total*	
	#	%	#	%	#	%
No	4,591	93.4	976	97.9	5,567	94.1
Yes	326	6.6	21	2.1	347	5.9
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 10. Alcohol involvement by lane-splitting status, collision-involved motorcyclists

Alcohol Involved	Lane-Splitting					
	No		Yes		Total*	
	#	%	#	%	#	%
No	4,751	96.6	985	98.8	5,736	97.0
Yes	166	3.4	12	1.2	178	3.0
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 11. Helmet type by lane-splitting status, collision-involved motorcyclists

Helmet Type	Lane-Splitting					
	No		Yes		Total*	
	#	%	#	%	#	%
Full-face	3,273	66.6	804	80.6	4,077	68.9
1/2 Helmet	729	14.8	86	8.6	815	13.8
3/4 Helmet	442	9.0	47	4.7	489	8.3
Modular	146	3.0	32	3.2	178	3.0
Novelty	205	4.2	18	1.8	223	3.8
None	86	1.7	3	0.3	89	1.5
Unknown	36	0.7	7	0.7	43	0.7
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 12. Injury type by lane-splitting status, collision-involved motorcyclists

	Lane-Splitting					
	No		Yes		Total*	
Injury Type	#	%	#	%	#	%
Head Injury						
No	4,089	83.2	907	91.0	4,996	84.5
Yes	828	16.8	90	9.0	918	15.5
Neck Injury						
No	4,478	91.1	923	92.6	5,401	91.3
Yes	439	8.9	74	7.4	513	8.7
Torso Injury						
No	3,510	71.4	808	81.0	4,318	73.0
Yes	1,407	28.6	189	19.0	1,596	27.0
Extremity Injury						
No	1,675	34.1	404	40.5	2,079	35.2
Yes	3,242	65.9	593	59.5	3,835	64.8
Fatal Injury						
No	4,768	97.0	985	98.8	5,753	97.3
Yes	149	3.0	12	1.2	161	2.7
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 13. Rear-ended status by lane-splitting status, collision-involved motorcyclists

	Lane-Splitting					
	No		Yes		Total*	
Rear-ended by Other	#	%	#	%	#	%
No	4,655	94.7	968	97.1	5,623	95.1
Yes	228	4.6	26	2.6	254	4.3
Unknown	34	0.7	3	0.3	37	0.6
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 14. Rear-ended other vehicle status by lane-splitting status, collision-involved motorcyclists

Rear-ended Other Vehicle	Lane-Splitting					
	No		Yes		Total*	
	#	%	#	%	#	%
No	4,120	83.8	611	61.3	4,731	80.0
Yes	774	15.7	383	38.4	1,157	19.6
Unknown	23	0.5	3	0.3	26	0.4
Total	4,917	100	997	100	5,914	100

* 55 motorcyclists with unknown lane-splitting status excluded

Table 15. Injury type by fatality status, collision-involved motorcyclists

Injury Type	Fatally Injured					
	No		Yes		Total	
	#	%	#	%	#	%
Head Injury						
No	4,952	85.3	87	53.0	5,039	84.4
Yes	853	14.7	77	47.0	930	15.6
Neck Injury						
No	5,318	91.6	134	81.7	5,452	91.3
Yes	487	8.4	30	18.3	517	8.7
Torso Injury						
No	4,266	73.5	93	56.7	4,359	73.0
Yes	1,539	26.5	71	43.3	1,610	27.0
Extremity Injury						
No	1,982	34.1	121	73.8	2,103	35.2
Yes	3,823	65.9	43	26.2	3,866	64.8
Total	5,805	100	164	100	5,969	100

Table 16. Injury by selected traffic speed thresholds and motorcycle speed differential thresholds among lane-splitting motorcyclists involved in collisions

	Traffic Speed (MPH)	Speed Differential (MPH)	Lane-splitting Manner**	% Head Injury	% Torso Injury	% Extremity Injury
1*	25 or less	5 or less	Neither	13.0	26.0	70.4
2			Traffic speed only	7.9	20.7	67.5
3			Speed differential only	8.7	17.8	56.0
4			Both	6.7	10.0	52.0
5	25 or less	10 or less	Neither	17.0	30.7	75.0
6			Traffic speed only	8.1	20.8	66.9
7			Speed differential only	10.7	19.8	59.4
8			Both	5.2	11.1	49.8
9	25 or less	15 or less	Neither	21.3	27.9	68.9
10			Traffic speed only	8.0	22.2	68.8
11			Speed differential only	11.6	19.8	61.6
12			Both	5.8	13.0	50.4
13	35 or less	5 or less	Neither	16.7	30.0	68.9
14			Traffic speed only	9.8	23.6	68.3
15			Speed differential only	8.7	18.3	58.5
16			Both	6.1	12.2	57.0
17	35 or less	10 or less	Neither	20.5	34.1	70.5
18			Traffic speed only	10.7	24.3	68.0
19			Speed differential only	11.0	20.7	61.9
20			Both	4.9	12.4	54.4
21	35 or less	15 or less	Neither	25.8	25.8	64.5
22			Traffic speed only	10.4	26.4	69.2
23			Speed differential only	12.1	21.0	62.9
24			Both	5.5	13.9	55.3
25	45 or less	5 or less	Neither	18.6	33.9	69.5
26			Traffic speed only	13.3	25.3	72.0
27			Speed differential only	8.9	18.6	59.0
28			Both	5.8	13.7	57.9
29	45 or less	10 or less	Neither	21.9	31.3	75.0
30			Traffic speed only	13.7	28.4	69.6
31			Speed differential only	11.2	21.4	61.8
32			Both	5.1	13.2	56.1
33	45 or less	15 or less	Neither	30.0	20.0	70.0
34			Traffic speed only	13.2	30.7	71.1
35			Speed differential only	12.4	21.6	62.5
36			Both	5.5	14.5	56.6
37	55 or less	5 or less	Neither	17.2	37.9	69.0
38			Traffic speed only	13.3	28.9	73.3

39			Speed differential only	9.5	19.2	59.6
40			Both	6.5	14.3	59.1
41	55 or less	10 or less	Neither	21.4	42.9	78.6
42			Traffic speed only	13.3	30.0	70.0
43			Speed differential only	11.7	21.4	62.2
44			Both	5.9	14.3	57.2
45	55 or less	15 or less	Neither	33.3	33.3	66.7
46			Traffic speed only	12.3	32.3	72.3
47			Speed differential only	12.9	21.1	62.9
48			Both	6.2	15.7	57.7

* Line numbers

** Neither: Traffic was exceeding selected speed and motorcyclist was exceeding selected speed differential

Traffic speed only: Traffic was within selected speed and motorcyclist was exceeding selected speed differential

Speed differential only: Traffic was exceeding selected speed and motorcyclist was within selected speed differential

Both: Traffic was within selected speed and motorcyclist was within selected speed differential

Table 17. Head injury risk ratios for traffic speed and motorcycle speed differential categories, lane-splitting motorcyclists involved in collisions

Characteristic	Head Injury RR*	95% CI	p	Overall p
Traffic Speed				
0-19 MPH	ref.**	-	-	
20-29 MPH	1.53	0.87-2.68	0.138	
30-39 MPH	0.95	0.42-2.13	0.898	
40-49 MPH	1.81	0.81-4.08	0.149	
50-59 MPH	2.38	1.32-4.30	0.004	
60+ MPH	2.58	1.30-5.14	0.007	0.017
Speed Differential				
0-9.9 MPH	ref.	-	-	
10-14.9 mph faster	0.80	0.41-1.56	0.508	
15-24.9 mph faster	1.98	1.10-3.55	0.022	
25+ mph faster	2.66	1.50-4.72	0.001	<0.001

* Risk ratio comparing the probability of head injury, controlling for age, gender, helmet type, and variables in table

** Referent category to which others were compared

Table 18. Torso injury risk ratios for traffic speed and motorcycle speed differential categories, lane-splitting motorcyclists involved in collisions

Characteristic	Torso Injury RR*	95% CI	p	Overall p
Traffic Speed				
0-19 MPH	ref.**	-	-	
20-29 MPH	1.50	1.01-2.21	0.042	
30-39 MPH	1.48	0.96-2.28	0.074	
40-49 MPH	1.82	1.08-3.09	0.025	
50-59 MPH	1.99	1.15-3.47	0.014	
60+ MPH	2.49	1.58-3.91	<0.001	0.002
Speed Differential				
0-9.9 MPH	ref.	-	-	
10-14.9 mph faster	1.21	0.82-1.78	0.329	
15-24.9 mph faster	1.37	0.92-2.04	0.117	
25+ mph faster	1.68	1.13-2.50	0.010	0.072

* Risk ratio comparing the probability of head injury, controlling for age, gender, helmet type, and variables in table

** Referent category to which others were compared

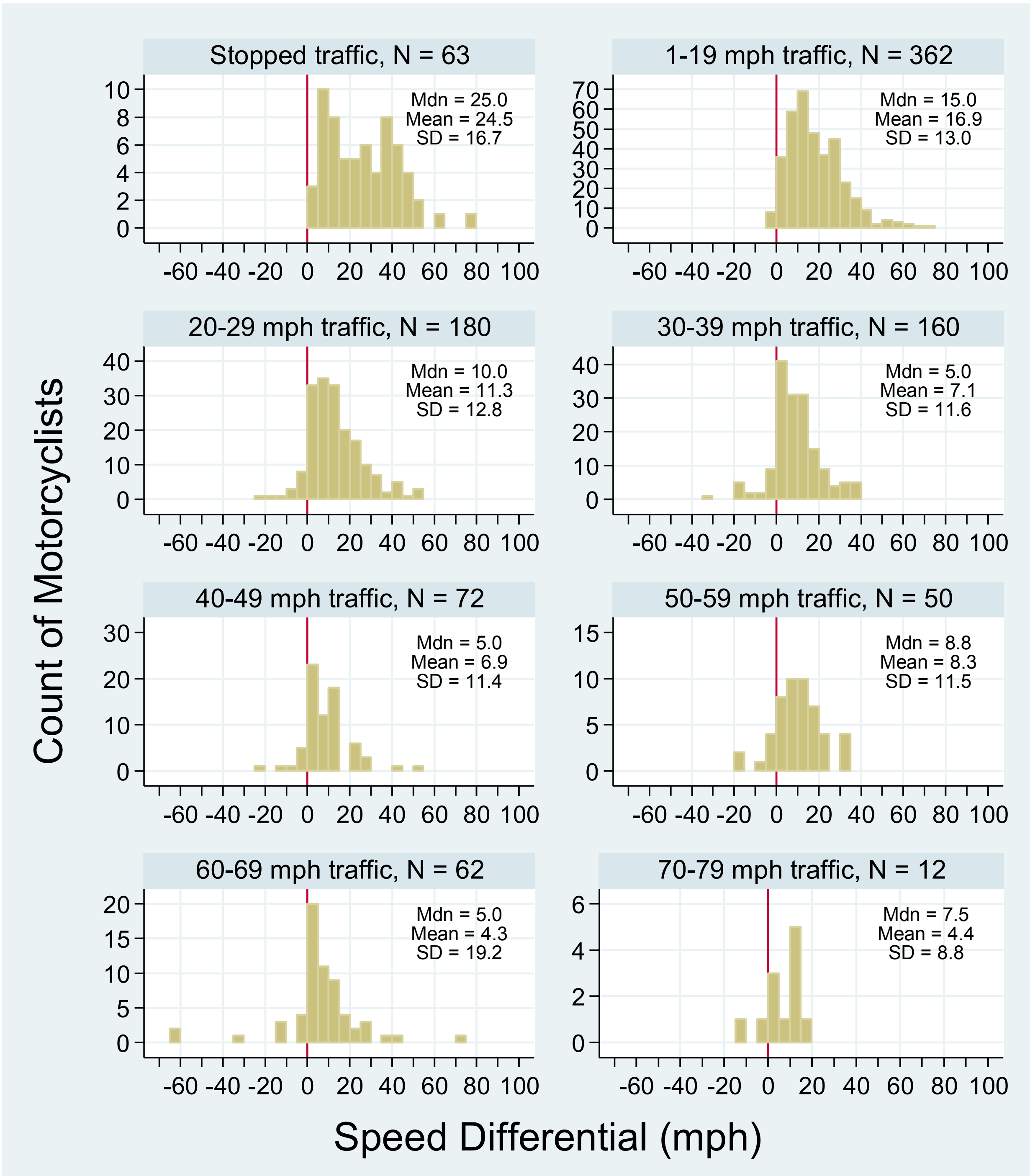
Table 19. Extremity injury risk ratios for traffic speed and motorcycle speed differential categories, lane-splitting motorcyclists involved in collisions

Characteristic	Extremity Injury RR*	95% CI	p	Overall p
Traffic Speed				
0-19 MPH	ref.**	-	-	
20-29 MPH	1.18	1.00-1.37	0.045	
30-39 MPH	1.46	1.25-1.69	<0.001	
40-49 MPH	1.45	1.19-1.77	<0.001	
50-59 MPH	1.25	0.98-1.59	0.070	
60+ MPH	1.48	1.23-1.78	<0.001	<0.001
Speed Differential				
0-9.9 MPH	ref.	-	-	
10-14.9 mph faster	0.99	0.85-1.16	0.945	
15-24.9 mph faster	1.14	0.98-1.33	0.091	
25+ mph faster	1.26	1.08-1.47	0.003	0.011

* Risk ratio comparing the probability of head injury, controlling for age, gender, helmet type, and variables in table

** Referent category to which others were compared

Figure 2. Motorcycle speed differential* by traffic speed category among lane-splitting motorcyclists involved in collisions



* Motorcycle speed minus speed of surrounding traffic