The Role of Probability and Statistics in Bicycle Helmet Research

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Abstract

Bicycle helmets have been consistently shown to be efficacious in biomechanical studies and effective in epidemiological studies of crash data to mitigate the risk of head injury. However, there is still an ongoing debate regarding the appropriateness of case-control studies of crash data, the possibility of a mediating factor such as risk compensation, and whether bicycle helmet legislation leads to fewer people cycling. In this paper, it will be demonstrated that better understanding of statistics and probability can help us differentiate which of these questions already have reasonable answers and which ones require further research.

Background

There is an ongoing debate regarding the effectiveness of bicycle helmets and bicycle helmet legislation to mitigate the risk of head injury (Olivier, Wang, Walter & Grzebieta, 2014). This topic has been thoroughly discussed in the literature with a recent systematic review identifying over 1,000 relevant articles (Olivier & Creighton, *in press*). However, there has been very little discussion regarding the information that can be discerned from current study designs such as case-control designs of crash data or counts of cyclists from helmet use surveys.

This discussion requires an understanding of basic probability. We will therefore begin with a brief revision of the fundamental concepts of probability including notation. In the remainder of the paper, we will derive probabilities with regards to bicycle helmet effectiveness, risk compensation and helmet wearing, and probabilities of measuring changes in cycling exposure.

Bicycle helmet effectiveness

With the exception of possible confounding, crash data can directly estimate helmet effectiveness if helmet use and crash occurrence are independent. There have been many discussions for and against this assumption, although there is a paucity of original research on this topic.

Bicycle helmet effectiveness can be represented in terms of probability. If we let H indicate helmet wearing, I a head injury and C a crash, the relative risk for bicycle helmet effectiveness is

$$RR = \frac{P(I|H)}{P(I|\overline{H})}$$

This can be interpreted as the probability of a head injury for those wearing helmets versus those that do not. Helmets are effective when $RR < 1$. Unfortunately, crash data cannot estimate this RR.

Suppose we partition crashes into those that have been reported and those that have not, i.e., $C = C_R \cup C_{\overline{R}}$ where R denotes that a crash has been reported. It can be shown the relative risk is approximately

$$RR \approx \frac{P(C_R|H)}{P\left(C_R|\overline{H}\right)} RR_C$$

where RR_C is the relative risk from crash data. This result demonstrates the relative risk using crash data is a good estimate of the *true* relative risk when helmet use is independent of having a crash.

Risk compensation and bicycle helmets

The risk compensation hypothesis posits cyclists wearing helmets increase risk which offsets any benefit afforded by the helmet. Risk can be thought of as the probability of a binary event such as a crash, injury or fatality. However, no articles in the existing literature estimates risk and instead focuses on cycling speed (Phillips, Fyhri & Sagberg, 2011) or motor vehicle passing distance (Olivier & Walter, 2013).

Bicycle helmet legislation and measures of cycling exposure

It is often argued bicycle helmet legislation deters cycling. This hypothesis appears to have originated from counts of cyclists taken from helmet use surveys (Olivier, Boufous & Grzebieta, 2016). We will demonstrate that estimating changes in cycling using cyclist counts at various locations requires (1) the random selection of sites and (2) a total count of travelers at each site.

Discussion

In this paper, we will demonstrate estimates of helmet effectiveness using crash data are likely accurate; however, a definitive answer requires other study designs such as a large cohort study. Such a study design could also provide evidence for or against risk compensation. Further, the use of cycling counts from helmet use surveys are inappropriate for estimating cycling exposure and we encourage others to provide more appropriate measures in the future.

References

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