

OPINION

Risk compensation theory should be subject to systematic reviews of the scientific evidence

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BACKGROUND

Many readers of *Injury Prevention* are quite familiar with the debate over bicycle helmet use. The core of this debate is the opinion on one side that helmets are effective and thus should be worn, countered on the other side by the belief that risk compensation negates this protective effect of helmets. A systematic review on helmet effectiveness has been published in the Cochrane Library.¹ The objective of the Cochrane review was to determine whether bicycle helmets reduce head, brain, and facial injury for bicyclists of all ages involved in a crash. The principles required of high quality evidence based reviews were followed: a comprehensive literature search, pre-established study selection criteria, and most importantly a critical review of study methods. A well conducted systematic review identifies and considers all the literature (peer reviewed, government reports, and unpublished papers), and rates the study quality. Appropriately, such reviews only include better designed and conducted studies. The evidence is then summarized across all the studies.

The literature search for the Cochrane review yielded five studies meeting the pre-established criteria for inclusion. The strengths and weaknesses of five case-control studies of bicycle helmet effectiveness were carefully evaluated. The scientific evidence which indicates that bicycle helmets protect against head, brain, severe brain and facial (upper and mid-face) injuries has been well established. Additionally, the evidence indicates that helmets provide injury protection in all type of crashes including those involving motor vehicles.

Based on this review the authors recommended that as a policy bicycle riders of all ages should be encouraged to wear helmets. The purpose of publishing health research, and discourse about it, is to improve the health of the public. We believe that the evidence indicates such a strong protective effect of helmets, that the net effect on the health of the public will be positive.

WHAT ABOUT THE THEORY OF RISK COMPENSATION?

What is risk compensation?

Risk compensation is frequently raised during debates about helmet promotion and legislation. Briefly put, risk compensation theory suggests that individuals provided with a protective device such as a bicycle helmet or an automobile seat belt will act in a riskier manner because of the sense of increased protection from the helmet or seat belt and thereby nullify the protection

afforded by the helmet or seat belt. The theory of risk compensation is not applicable to case-control studies of helmet effectiveness *per se*. Its potential applicability is to the impact of widespread use of helmets, particularly legislation to require helmet use, and its net protective effect.

What are the arguments for risk compensation?

The theories of risk homeostasis and risk compensation are well summarized by Gerald Wilde and John Adams.²⁻⁴ Those who argue that risk compensation must be taken into account before bicycle helmets are adopted as a safety measure have said:

(1) Encouraging helmet use would have serious adverse consequences on the public health, without making any significant difference to the dangers of riding.⁵

(2) Wearing of a helmet influences cyclists' behaviour, thereby affecting the likelihood of them being involved in such an incident in the first place. Cyclists are less likely to ride cautiously when wearing a helmet owing to their feeling of increased security. In this way, they consume some, if not all, of the benefit that would otherwise accrue from wearing a helmet.^{6,7}

There have been no systematic reviews of the evidence for the relevance of risk compensation to bike helmets. Mayer Hillman states the evidence for risk compensation is "overwhelming".⁶

What empirical evidence exists for risk compensation behaviour?

If risk compensation plays a role, one would expect the gains from helmet effectiveness to be erased or strongly mitigated by increasingly risky riding habits of helmet wearers which would neutralize any protective effect provided by helmet wearing. What do the empiric data show?

(A) Bicycle riders

The evidence from time series studies in Australia, New Zealand, Europe, and the United States indicates that increased rates of helmet use resulting from multifaceted educational campaigns and/or legislation are linked to significant decreases in bicycle related head injuries.⁸⁻¹³ Given that helmets are very effective, cyclists would have to increase their risk taking fourfold to overcome the protective effect of helmets. This seems unlikely.

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(B) Motorcycle riders

The closest analogy to bicycle helmet use is mandatory motorcycle helmet use laws in the United States. Although there is general agreement that motorcycle helmets reduce head and brain injury when a crash occurs, many motorcyclists dislike helmets. Risk compensation theory would propose that a motorcyclist might drive more recklessly if legislation requires helmet use. Motorcyclists may also be considered vulnerable road users, since motorcycle crashes usually result in serious injury to the motorcyclists themselves and not to cars and other motor vehicle passengers. In the United States nearly all 50 states passed laws requiring motorcycle helmets in the mid-1960s. In 1976 almost half of the states repealed their laws. This provided an opportunity for a natural experiment. Fewer motorcyclists wore helmets following the repeal of motorcycle helmet laws. This resulted in a 25% to 40% increase in motorcycle deaths.¹⁴⁻¹⁸ These results strongly imply that wearing a helmet does not lead to large increases in risk taking.¹⁸

(C) Motor vehicle drivers and passengers

An extensive systematic review of automobile safety interventions by the non-federal national Community Preventive Services Task Force has been sponsored by the Centers for Disease Control and Prevention since 1996. The task force looks at both the benefits and the risk for any given intervention. Based on results of systematic reviews, the task force makes recommendations on population based interventions to promote health and prevent disease, injury, disability and premature death, and to reduce environmental hazards. The task force found that child safety seats, seat belts, and alcohol laws all contributed to substantial reductions in motor vehicle injuries and deaths. The task force recommended a number of community-wide information and enforcement campaigns to promote these measures.¹⁹

Based on risk composition theory, John Adams has long opposed seat belt legislation.^{3,4} The Adams essay published on the Cato Institute web site discusses risk compensation and seat belt legislation. The essay explains the theory of risk management and uncertainty but it is not a critical systematic review. Information on the United States experience with seat belt legislation is omitted from the discussion. The reason provided in reference number 3, is that "calls by Cato staff to the National Highway Traffic Safety Administration to obtain research results about how many lives have been saved through seat belt use were unsuccessful".⁴ However, this information is available to the public from the National Technical Information Service, Springfield, Virginia. It is also indexed in the Transportation Research Information Service (TRIS) database.^{20,21} Authors of a systematic review would obtain and evaluate all available research before arriving at a conclusion.

SUMMARY AND CONCLUSION ON RISK COMPENSATION THEORY ARGUMENTS

In summary the empirical evidence to support the risk compensation theory is limited if not absent. There are a number of studies in the traffic literature that point out problems or show data at odds with the risk compensation/homeostasis theory. No systematic review of the evidence for risk homeostasis has been conducted.

We recommend that interested readers consult a comprehensive discussion of the risk compensation debate presented by James Hedlund at the Fifth World Conference on Injury Prevention and Control.²² James Hedlund provided his personal view: "I believe the evidence is overwhelming that every safety law or regulation is not counterbalanced by compensating behavior". We suggest risk compensation is an appropriate area for systematic reviews.

CONCLUSIONS ON RECOMMENDING THE USE OF BICYCLE HELMETS

Based on the solid empirical evidence for bicycle safety helmet effectiveness, we are confident in recommending their use, and policies to encourage their use. However, additional criticisms of our Cochrane review have been raised by Bill Curnow and Dorothy Robinson. These criticisms and our replies are published on the Cochrane injuries group web site (<http://www.cochrane-injuries.ich.ucl.ac.uk/HelmetComment.htm>). Criticisms from Richard Keatinge and Mayer Hillman will be published along with author's replies in the next edition of the Cochrane reviews. Please read this series of interesting debates. In our opinion, we have provided well founded answers to the criticisms.

We feel there is strong scientific evidence for recommending or mandating bicycle helmet use. This is a first step in reducing bicycle related head injuries. Encouraging cycling, building a bicycle friendly infrastructure, and promoting safe cycling instruction are also important activities. These activities are not mutually exclusive. Promoting bicycle helmet use does not exclude other road safety approaches. There are many aspects to bicycle injury prevention, helmet use is just one technique, one which has proven effective.

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The risk compensation theory and bicycle helmets

J Adams, M Hillman

The Cochrane review by Rivara and the Thompsons found evidence that if you bang your head the consequences will be less severe if you are wearing a protective helmet.¹ Based on this review they recommend that cyclists should be “encouraged” to wear helmets. The form of encouragement that they favour is compulsion.

We accept the principal finding of their review—that protective helmets protect *in the event of an accident*—but not the policy conclusions that they derive from it. The issue that divides us is *risk compensation*—does the behaviour of cyclists change as a consequence of wearing a helmet in ways that offset the protective benefit of helmets in accidents? After briefly referring to selected references from the safety literature on cycling, motorcycling, and driving, Rivara and the Thompsons assert that “the empirical evidence to support the risk compensation theory is limited if not absent”. Certainly such evidence is limited or absent from the sources they choose to cite—with a notable exception which we discuss below. We find abundant evidence for risk compensation.

It is important to distinguish between evidence for risk compensation in general—which is overwhelming, and evidence relating to cycle helmets—which is limited. Let us consider the general evidence first. Rivara and the Thompsons recommend readers to consult James Hedlund’s article in *Injury Prevention* entitled “Risky business: safety regulations, risk compensation, and individual behaviour”.² We strongly support their recommendation. They quote James Hedlund: “I believe the evidence is overwhelming that *every* (our italics) safety law or regulation is not counterbalanced by compensating behaviour”. But Hedlund also makes clear that the evidence is overwhelming that some laws and regulations, as well as safety measures voluntarily adopted, *are* counterbalanced by compensating behaviour. He states:

“We all change our behaviour in response to changes in our environment. Safety measures change our environment, so we may change our behaviour in response to them. . . . Never assume that behaviour will not change”.

Hedlund helpfully sets out four rules for judging the circumstances in which behaviour might or might not change:

(1) *If I don’t know it’s there I won’t compensate for a safety measure.* Bicycle helmets manifestly fail this test.

(2) *If it doesn’t affect me, I won’t compensate for a safety measure.* He poses the question “Do I feel safer wearing a bicycle helmet?” and suggests that if the answer is yes compensation is likely to occur.

(3) *If I have no reason to change my behaviour, I won’t compensate for a safety measure.* Only if the

behaviour of cyclists is completely unmotivated by concern for safety are they unlikely to compensate for a safety measure such as a helmet.

(4) *If my behaviour is tightly controlled I won’t compensate for a safety measure.* He singles out driving as an activity that offers very considerable freedom to compensate. Cycling offers at least as much.

Hedlund advises “to reduce or eliminate risk compensation, use measures rating low on at least one factor”. Cycling scores high on all four. Of all the cases Hedlund considers perhaps sports offer the closest comparators. He observes:

“Sports provide interesting examples of the interplay between injury prevention, compensation, and control. In many sports, such as ice hockey and American football, players are required to wear protective equipment. Some players have compensated by acting more violently within the confines of the rules. In some instances this has led to rules changes to control player actions more tightly”.

Cyclists, like hockey and football players, are acutely sensitive to the likelihood that a miscalculation can result in serious injury, and govern their behaviour accordingly. We find it highly probable, *in the absence of any change in propensity to take risks*, that cyclists will respond like hockey and football players to measures that reduce the severity of the consequences of miscalculation.

Hedlund offers two further bits of useful advice:

(1) *Consider system effects.* Cycle helmet laws have led to a decrease in cycling; after it became compulsory to wear helmets in Australia, the level of cycling fell by about twice as much as did the number of cyclists admitted to hospital for the treatment of head injury.³ Other studies have found that the health benefits of cycling, measured in years of life gained, far outweigh the injury risks measured in years of life lost⁴—by about 20 to 1.⁵ By concentrating attention on the need to protect cyclists from head injuries Rivara and the Thompsons encourage the view of cycling as an inherently dangerous activity. Other countries, most notably Denmark and the Netherlands, demonstrate that, by making proper provision, cycling by largely helmetless cyclists can be made much safer.

(2) *Don’t over-predict benefits:* “many injury prevention measures promise more benefits than they can deliver”. Promises that deny the existence of risk compensation are almost certainly committing this offence.

Rivara and the Thompsons assert that “there have been no systematic reviews of the evidence for the relevance of risk compensation to bike helmets”. So, ignoring Hedlund’s “rules”, and contrary to Hedlund’s advice, they simply *assume* that there is no behavioural response to the protection afforded by cycle helmets.

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The empirical difficulty with establishing the relevance of risk compensation to cycle helmets is that, compared with other activities such as motoring, there is a shortage of reliable data. Information about exposure is limited and difficult to interpret—the exposed population includes everyone from purposeful adults commuting on bicycles to small children using them for recreation rather than transport. There are few reliable surveys of helmet use. The jurisdictions in which helmet wearing is compulsory are few, and the level of cycle use in these jurisdictions is generally low. What is known is that helmet wearing rates are very low in countries such as Denmark and the Netherlands, where cycle use is high, and that cycling in these countries is much safer.

So Rivara and the Thompsons turn to argument by analogy, asserting that experience of motorcycle helmet laws provides support for their cycle helmet campaign. They say that motorcyclists are also vulnerable road users “since motorcycle crashes usually result in serious injury [only] to the motorcyclists themselves and not to cars and other motor vehicle passengers”. The curious omission of pedestrians (and cyclists) from the list of motorcycle accident victims ignores the significant threat that they pose to the most vulnerable. Plowden and Hillman found that two wheeled motor vehicles, per mile driven, were five times more likely than cars to cause the death or serious injury of a pedestrian.⁶ Nevertheless they proffer in support of their views “the natural experiment” in the United States in which some states passed and repealed motorcycle helmet laws and others did not. Here we find another curious omission. They make no mention of Adams’ review of this experiment that found that motorcyclist fatalities increased by more in states that did not repeal their laws than in those that did.⁷

Their brief review of evidence relating to seat belts is equally selective. They complain that a four page discussion of seat belt legislation in a 49 page paper on the management of risk and uncertainty by Adams⁸ was not a proper systematic review because it did not “evaluate all available research”. This short discussion did not purport to be a comprehensive review of the subject. For a much fuller discussion of seat belts and risk compensation the reader is referred to various publications by Adams^{7–13} and Hillman *et al.*¹⁴

There is now an intractable problem for those studying road safety in separating the wheat from the chaff. It is no longer possible to evaluate “all available research”. Hedlund reports a literature search on nine motor vehicle injury prevention strategies that turned up 54 078 titles or abstracts. Most of these he suggests do not pass minimal standards of scientific rigour or quality. Faced with such an enormous volume of mostly poor quality research one must resort to crude filtering devices. One such filter might be to reject out of hand all studies that reject out of hand the possibility of risk compensation.

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Response

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We are pleased that Mayer Hillman and John Adams accept the central point of our Cochrane systematic review—that bicycle helmets are effective in decreasing head injuries to cyclists. They disagree, however, with our conclusion that the use of helmets should therefore be encouraged based on our differing views of the evidence for risk compensation. They claim there is solid evidence for this hypothesis. We believe there is not and that we will only know this once a systematic review of risk compensation is conducted. Instead of being scientific, their arguments are based mainly on theory, philosophy, or expert opinion. We do not accept their proposition that “it is no longer possible to evaluate all the available research”. We believe a systematic review could sift the empirical evidence. A systematic review is not based on expert opinions, theoretical discussions, narrative literature reviews, or positions taken by professional groups, and neither Adams’ nor Hillman’s publications include systematic reviews. A systematic review does not “resort to crude filtering devices”; it employs explicit inclusion and exclusion criteria and sets forth *the rules of evidence and analytical processes before any of the evidence is examined*.¹⁻⁵ Clearly, it is time for an impartial body to examine the applicability of risk compensation theory to the use of bicycle helmets, and other areas where it has been invoked. A properly conducted systematic review that follows the criteria established by the Community Preventive Services Task Force recommendations can provide solid scientific evidence to support or disprove this

theory.³⁻⁵ If risk compensation is the “real deal” after a recognized group examines the evidence systematically, we will accept that the proven benefits of bicycle safety helmets are outweighed by the negative effects.

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Response

J Adams, M Hillman

We did NOT accept that bicycle helmets are effective in reducing head injuries. We had hoped that by putting it in italics they would have noticed our rider *in the event of an accident*. For evidence of their predisposition also to include inadequate science supportive of their argument see our letter in the *BMJ*.¹

We wish them luck in their systematic review of *all* the tens of thousands of articles that have a bearing on risk compensation. In undertaking this review we suggest that in devising inclusion and exclusion criteria for their more refined filters they be wary of the following¹:

- Studies that deal with small subsets of populations—such as the oft cited study of admissions to 16 hospitals in Sweden after the introduction of a seat belt law, which concluded that the law had reduced injuries and fatalities. The fact that in Sweden as a whole the number of deaths and injuries suffered by car occupants increased after the law suggests that it must have been possible to find other sets of hospitals which found the opposite result.²
- Claims based on statistical significance. One time in 20 researchers who use the conventional 5% test of significance will find “significance” by chance. Given the well known desire of researchers to “prove” their hypotheses, one in 20 is probably a generous estimate of the ratio of tests published to tests done.
- Studies that ignore system effects. Prohibiting motorcycling, for example, would prevent the loss of lives in motorcycle accidents. But to demonstrate that it had saved lives one would have to track the alternative forms of transport and thrill seeking adopted by the banned motorcyclists—everything from sky diving to driving old bangers in a way that pumps as much adrenaline.

- Empirical evidence of risk compensation. In Britain there is one cycling fatality for every 25 million kilometres cycled—not all of them of course due to head injuries. The risk compensating behaviour required to offset the claimed benefits of helmets would require an extra fatal error once in many millions of kilometres—a behavioural change unlikely to be directly observable.

Hedlund, whom they cite respectfully, having surveyed the debate about risk compensation, says “if experiments cannot provide useful evidence, and if evaluations are contaminated by poor data and uncontrolled factors, we are left with theory”. The theory supporting risk compensation is well supported by empirical evidence in cases where the risks are large: trapeze artists will attempt manoeuvres with safety nets that they would not contemplate without them. The contention of those who would introduce measures that would criminalize self risk (for example, riding without a helmet) is that this effect vanishes when the risk is smaller. Given the dismal record of the prohibitionists, we suggest that the burden of proof lies with them.

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