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Helmet Softness *vs* Injury Severity

The recently completed Harborview study suggests there may be no discernible advantage to softer, less dense bicycle helmets. Furthermore, if this softness is obtained by reducing the ultimate protective capacity of current headgear, the data suggest a corresponding increase in head and brain injury.

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Although there is no direct evidence to support it, some helmet experts and advocates urge that bicycle helmet standards be rewritten to favor softer headgear than those currently available. Some recommend softer headgear for children while others reserve their concern for older adults. Some propose that softer helmets will reduce the instance of concussion. Others speculate that physiological differences imply lower tolerances to impact acceleration for certain population groups when compared to young adult males.

No one argues that softness itself implies risk but softness is linked with thickness in determining a helmet's ultimate protective capacity, that is, the severest impact for which a helmet will provide effective protection. *The softer the helmet, the thicker it must be to withstand a given impact*. In order to obtain softer helmets, cyclists must opt either to wear thicker helmets or they must forego protection from severe impacts.

Some experts have proposed that the average accidental head impact is less severe than a one meter fall, about fifty joules. This conclusion has been based on studies of damaged helmets returned to manufacturers. If it is true, then protection from severe impacts might not be necessary. However, the helmets collected in the recent Harborview study suggest something quite different.

The investigators in the Harborview study collected 527 helmets from 1718 helmeted bicyclists. These were cyclists who went to one of seven Seattle area hospitals as a result of a bicycle accident and who either reported having hit their heads or whose helmets were visibly damaged. The helmets were examined by a team deliberately isolated from the rest of the data collection so that their judgments would not be biased by knowledge of the wearer's injuries.

Of these helmets, fully 40% had no visible damage that could be related to an accident. 20% more were so slightly damaged that no real shock attenuation could have taken place. 18% had moderate damage. 14% had major damage exhausting a substantial amount of the helmet's impact protection capacity. Finally, 7% of the helmets underwent catastrophic damage with a loss of shell integrity.

After the helmets had been examined, the Harborview team compared the helmet analyses to injury data recorded at the hospitals. The correlations between helmet damage and both head and brain injury were striking. Injury increased very slightly with increasing damage score up to the point where the helmet received catastrophic damage. Then the injury rates shot upward dramatically.

The likeliest inference to be drawn is that the catastrophically damaged helmets failed because the impact severity exceeded their ultimate protective capacity. Two percent of helmeted bicyclists who were treated at a hospital after a bicycle accident appear to have suffered a head impact more severe than the design limit of their helmets.

Furthermore, the correlations suggest a very sharp increase in the risk of injury when a head impact exceeds the design limit of the protective headgear. The brain injury rate for the minimal helmet damage score through major damage is almost flat. The helmets appear to work equally well for all impacts less severe than their ultimate protective capacity. However, when the impact is so severe that it destroys the helmet, the risk of brain injury jumps by a factor of four.

The number of helmets receiving major damage was twice that of those receiving catastrophic damage. A reduction in ultimate protective capacity would surely result in helmets being shifted from the category of major damage to that of catastrophic damage. Therefore, a reduction in ultimate protective capacity would result in more brain and head injuries.

The chain of reasoning is as follows:

1. There is a level of impact severity beyond which a helmet's effectiveness decreases sharply. This level of severity, called the ultimate protective capacity, is determined by the helmet's design and construction.
2. There is a small but distinct probability that a bicycle accident will result in a head impact exceeding the ultimate protective capacity of current bicycle helmets.
3. Any reduction in the ultimate protective capacity of current helmets will result in more accidental head impacts exceeding this limit and therefore in more head and brain injury.

The inevitable conclusion is that there must be no diminishment of ultimate protective capacity without some conclusive demonstration that a significant decrease in bicycle accident morbidity and mortality is achievable and that a diminishment of protective capacity is a critical factor to attain this decrease.

The Harborview findings imply at least one more item relevant to this discussion. The argument for softer helmets contends that the level of shock transmitted by current helmets is too high causing helmeted riders to be injured by impacts within the design range of the helmets capacity. The Harborview findings do suggest that the riders are being injured by impacts within the design ranges of their helmets but the rate of these injuries is low and the injuries do not increase as the damage scores of the helmets increase.

Helmet testing experience teaches that for virtually every helmet currently available, the peak shock transmitted through the helmet increases with increasing impact severity. Even though the most efficient helmet imaginable would transmit a single level of shock for every level of impact, the curvature of the human head and the properties of modern helmet materials make this impossible. Thus, the damage scores assigned in the helmet analysis should correlate with the peak shock transmitted to the wearer's head in the impact.

If current helmets are too stiff, one would expect a significant increase in the brain injury rate as the damage score proceeds from minimal damage through moderate damage and major damage. In fact, there is no dramatic increase. Instead, the results suggest that every shock lower than the current 300 G peak implies the same low risk of injury.

However, the Harborview findings do not support complacency. Although the rates are low, the fact that there is some head and brain injury with helmet damage scores seemingly within the protective capacities of the helmets indicates that riders are still sustaining injuries that may be preventable. The preponderance of impacts at the edges of the helmets suggest that more coverage is necessary. The numbers of catastrophically damaged helmets collected along with the injury correlations directly imply that thicker helmets with higher ultimate protective capacity would result in fewer brain and head injuries. Finally, even though there is nothing in the study that supports making helmets softer, neither is there any finding that suggests softer helmets need be more dangerous. However, in order to preserve ultimate protective capacity, anyone desiring softer helmets should seek softer, thicker helmets.
