Motorcycle Helmet Performance: Blowing the Lid Off

Searching for the truth behind motorcycle helmet design, helmet standards and actual head protection
Photography by Jim Brown

How good is your helmet? Will it actually protect your brain in your next crash?

These seem like easy questions, ones you probably think you can answer by reciting the lofty standards your helmet meets and the lofty price you might have paid for it. But the real answers, as you are about to see, are anything but easy.

There's a fundamental debate raging in the motorcycle helmet industry. In a fiberglass-reinforced, expanded-polystyrene nutshell, it's a debate about how strong and how stiff a helmet should be to provide the best possible protection.

Why the debate? Because if a helmet is too stiff it can be less able to prevent brain injury in the kinds of crashes you're most likely to have. And if it's too soft, it might not protect you in a violent, high-energy crash. What's just right? Well, that's why it's called a debate. If you knew what your head was going to hit and how hard, you could choose the perfect helmet for that crash. But crashes are accidents. So you have to guess.

To understand how a helmet protects—or doesn't protect—your brain, it helps to appreciate just how fragile that organ actually is. The consistency of the human brain is like warm Jello. It's so gooey that when pathologists remove a brain from a cadaver, they have to use a kind of cheesecloth hammock to hold it together as it comes out of the skull.

Your brain basically floats inside your skull, within a bath of cervical-spinal fluid and a protective cocoon called the dura. But when your skull stops suddenly—as it does when it hits something hard—the brain keeps going, as Sir Isaac Newton predicted. Then it has its own collision with the inside of the skull. If that collision is too severe, the brain can sustain any number of injuries, from shearing of the brain tissue to bleeding in the brain, or between the brain and the dura, or between the dura and the skull. And after your brain is injured, even more damage can occur. When the brain is bashed or injured internally, bleeding and inflammation make it swell. When your brain swells inside the skull, there's no place for that extra volume to go. So it presses harder against the inside of the skull and tries to squeeze through any opening, bulging out of your eye sockets and oozing down the base of the skull. As it squeezes, more damage is done to some very vital regions.

None of this is good.

Helmet designers have devised a number of different liner designs to meet the different standards. The Vemar VSR uses stiffer EPS than most, but has channels molded in to soften the assembly (to ECE specs) and enhance cooling.

To prevent all that ugly stuff from happening, we wear helmets. Modern, full-face helmets, if we have enough brains to protect, that is.

A motorcycle helmet has two major parts: the outer shell and the energy-absorbing inner liner. The inner lining is made of expanded polystyrene or EPS, the same stuff used in beer coolers, foam coffee cups, and packing material. Outer shells come in two basic flavors: a resin/fiber composite, such as fiberglass, carbon fiber and Kevlar, or a molded thermoplastic such as ABS or polycarbonate, the same basic stuff used in face shields and F-16 canopies.

The shell is there for a number of reasons. First, it's supposed to protect against pointy things trying to penetrate the EPS—though that almost never happens in a real accident. Second, the shell protects against abrasion, which is a good thing when you're sliding into the chicane at Daytona. Third, it gives Troy Lee a nice, smooth surface to paint dragons on. Riders—and helmet marketers—pay a lot of attention to the outer shell and its material. But the part of the helmet that absorbs most of the energy in a crash is actually the inner liner.

When the helmet hits the road or a curb, the outer shell stops instantly. Inside, your head keeps going until it collides with the liner. When this happens, the liner's job is to bring the head to a gentle stop—if you want your brain to keep working like it does now, that is.

The great thing about EPS is that as it crushes, it absorbs lots of energy at a predictable rate. It doesn't store energy and rebound like a spring, which would be a bad thing because your head would bounce back up, shaking your brain not just once, but twice. EPS actually absorbs the kinetic energy of your moving head, creating a very small amount of heat as the foam collapses.

The Schuberth S1 uses five separate foam parts glued together to meet the ECE standard.

The helmet's shell also absorbs energy as it flexes in the case of a polycarbonate helmet, or flexes, crushes and delaminates in the case of a fiberglass composite helmet.

To minimize the G-forces on your soft, gushy brain as it stops, you want to slow your head down over as great a distance as possible. So the perfect helmet would be huge, with 6 inches or mosre of soft, fluffy EPS cradling your precious head like a mint on a pillow.

Problem is, nobody wants a 2-foot-wide helmet, though it might come in handly if you were auditioning for a Jack in the Box commercial. So helmet designers have pared down the thickness of the foam, using denser, stiffer EPS to make up the difference. This increases the G-loading on your brain in a crash, of course. And the fine points of how many Gs a helmet transmits to the head, for how long, and in what kind of a crash, are the variables that make the helmet-standard debate so gosh darn fun.

The helmets are mounted on a 5-kilo (11 pound) magnesium headform and then dropped from a controlled height onto a variety of test anvils to simulate crash impacts on various surfaces and shapes. In the real world, your helmet actually hits flat pavement more than 85 percent of the time.

Standardized Standards

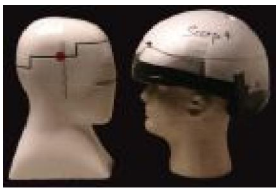
To make buying a helmet in the U.S as confusing as possible, there are at least four standards a street motorcycle helmet can meet. The price of entry is the DOT standard, called FMVSS 218, that every street helmet sold here is legally required to pass. There is the European standard, called ECE 22-05, accepted by more than 50 countries. There's the BSI 6658 Type A standard from Britain. And lastly the Snell M2000/M2005 standard, a voluntary, private standard used primarily in the U.S. So every helmet for street use here must meet the DOT standard, and might or might not meet one of the others. Just by looking at the published requirements for each standard, you would guess a DOT-only helmet would be designed to be the softest, with an ECE helmet very close, then a BSI helmet, and then a Snell helmet.

Because there are few human volunteers for high-impact helmet testing—and because they would be a little confused after a hard day of 200-G impacts—it's done on a test rig.

The helmets are dropped, using gravity to accelerate the helmet to a given speed before it smashes onto a test anvil bolted to the floor. By varying the drop height and the weight of the magnesium headform inside the helmet, the energy level of the test can be easily varied and precisely repeated. As the helmet/headform falls it is guided by either a steel track or a pair of steel cables. That guiding system adds friction to slow the fall slightly, so the test technician corrects for this by raising the initial drop height accordingly.

The headform has an accelerometer inside that precisely records the force the headform receives, showing how many Gs the headform took as it stopped and for how long.

If you test a bunch of helmets under the same conditions, you can get a good idea of how well each one absorbs a particular hit. And it's important to understand that as in lap times, golf scores and marriages, a lower number is always better when we're talking about your head receiving extreme G forces.



All the Snell/DOT helmets we examined use a dual-density foam liner. The upper cap of foam on this Scorpion liner is softer to compensate for the extra stiffness of the spherical upper shell area. Some manufacturers, including Arai and HJC, use a one-piece liner with two different densities molded together.

On The Highway To Snell

On the stiff, tough-guy side of this debate is the voluntary Snell M2000/M2005 standard, which dictates each helmet be able to withstand some tough, very high-energy impacts.

The Snell Memorial Foundation is a private, not-for-profit organization dedicated to "research, education, testing and development of helmet safety standards."

If you think moving quickly over the surface of the planet is fun and you enjoy using your brain, you should be grateful to the Snell Memorial Foundation. The SMF has helped create standards that have raised the bar in head protection in nearly every pursuit in which humans hit their heads: bicycles, horse riding, harness racing, karting, mopeds, skateboards, rollerblades, recreational skiing, ski racing, ATV riding, snowboarding, car racing and, of course, motorcycling.

But as helmet technology has improved and accident research has accumulated, many head-injury experts feel the Snell M2000 and M2005 standards are, to quote Dr. Harry Hurt of Hurt Report fame, "a little bit excessive."

The killer—the hardest Snell test for a motorcycle helmet to meet—is a two-strike test onto a hemispherical chunk of stainless steel about the size of an orange. The first hit is at an energy of 150 joules, which translates to dropping a 5-kilo weight about 10 feet—an extremely high-energy impact. The next hit, on the same spot, is set at 110 joules, or about an 8-foot drop. To pass, the helmet is not allowed to transmit more than 300 Gs to the headform in either hit.

Tough tests such as this have driven helmet development over the years. But do they have any practical application on the street, where a hit as hard as the hardest single Snell impact may only happen in 1 percent of actual accidents? And where an impact as severe as the two-drop hemi test happens just short of never?

Dr. Jim Newman, an actual rocket scientist and highly respected head-impact expert—he was once a Snell Foundation director—puts it this way: "If you want to create a realistic helmet standard, you don't go bashing helmets onto hemispherical steel balls. And you certainly don't do it twice.

"Over the last 30 years," continues Newman, "we've come to the realization that people falling off motorcycles hardly ever, ever hit their head in the same place twice. So we have helmets that are designed to withstand two hits at the same site. But in doing so, we have severely, severely compromised their ability to take one hit and absorb energy properly.

"The consequence is, when you have one hit at one site in an accident situation, two things happen: One, you don't fully utilize the energy-absorbing material that's available. And two, you generate higher G loading on the head than you need to. "What's happened to Snell over the years is that in order to make what's perceived as a better helmet, they kept raising the impact energy. What they should have been doing, in my view, is lowering the allowable G force.

"In my opinion, Snell should keep a 10-foot drop [in its testing]. But tell the manufacturers, 'OK, 300 Gs is not going to cut it anymore. Next year you're going to have to get down to 250. And the next year, 200. And the year after that, 185.'"

The Brand Leading The Brand

"The Snell sticker," continued Newman, "has become a marketing gimmick. By spending 60 cents [paid to the Snell foundation], a manufacturer puts that sticker in his helmet and he can increase the price by $30 or $40. Or even $60 or $100.

"Because there's this allure, this charisma, this image associated with a Snell sticker that says, 'Hey, this is a better helmet, and therefore must be worth a whole lot more money.' And in spite of the very best intentions of everybody at Snell, they did not have the field data [on actual accidents] that we have now [when they devised the standard]. And although that data has been around a long time, they have chosen, at this point, not to take it into consideration."

The Z1R ZRP-1 uses a soft, one-piece liner to soak up joule after joule of nasty impact energy.

A World Of Hurt

Dr. Hurt sees the Snell standard in pretty much the same light.

"What should the [G] limit on helmets be? Just as helmet designs should be rounder, smoother and safer, they should also be softer, softer, softer. Because people are wearing these so-called high-performance helmets and are getting diffused [brain] injuries ... well, they're screwed up for life. Taking 300 Gs is not a safe thing.

"We've got people that we've replicated helmet [impacts] on that took 250, 230 Gs [in their accidents]. And they've got a diffuse injury they're not gonna get rid of. The helmet has a good whack on it, but so what? If they'd had a softer helmet they'd have been better off."

How does the Snell Foundation respond to the criticism of head-injury scientists from all over the world that the Snell standards create helmets too stiff for optimum protection in the great majority of accidents?

"The whole business of testing helmets is based on the assumption that there is a threshold of injury," says Ed Becker, executive director of the Snell Foundation. "And that impact shocks below that threshold are going to be non-injurious. "We're going with 300 Gs because we started with 400 Gs back in the early days. And based on [George Snively's, the founder of the SMF] testing, and information he'd gotten from the British Standards Institute, 400 Gs seemed reasonable back then. He revised it downward over the years, largely because helmet standards were for healthy young men that were driving race cars. But after motorcycling had taken up those same helmets, he figured that not everybody involved in motorcycling was going to be a young man. So he concluded from work that he had done that the threshold of injury was above 400 Gs. But certainly below 600 Gs.

"The basis for the 300 G [limit in the Snell M2000 standard] is that the foundation is conservative. [The directors] have not seen an indication that a [head injury] threshold is below 300 Gs. If and when they do, they'll certainly take it into account."

So nobody is being hurt by the added stiffness of a Snell helmet, we asked.

"That's certainly our hope here," answered Becker. "At this point I've got no reason to think anything else."

European Style

The Snell Foundation may have no reason to think anything else. But every scientist we spoke to, as well as the government standards agencies of the United States and the 50 countries that accept the ECE 22.05 standard, see things quite differently.

The European Union recently released an extensive helmet study called COST 327, which involved close study of 253 recent motorcycle accidents in Germany, Finland and the U.K. This is how they summarized the state of the helmet art after analyzing the accidents and the damage done to the helmets and the people: "Current designs are too stiff and too resilient, and energy is absorbed efficiently only at values of HIC [Head Injury Criteria: a measure of G force over time] well above those which are survivable."

As we said, it's a lively debate.

If your brain is injured, swelling and inflammation often occur. Because there's no extra room inside your skull, your brain tries to squeeze down through the hole in the base of the skull. This creates pressure that injures the vital brain stem even further, often destroying the parts that control breathing and other basic body functions. If you're hit very violently on the jaw, as in a head-on impact, the force can be transmitted to the base of the skull, which can fracture and sever your spine. It's a common cause of death in helmeted motorcycle riders—and a very good reason to wear a full-face helmet and insist on thick EPS padding—not resilient foam—in the helmet's chin bar. When your brain collides with the inside of your skull, bony protrusions around your eyes, sinuses and other areas can cause severe damage to the brain. And if your head is twisted rapidly, the brain can lag behind, causing tearing and serious internal brain injury as it drags against the skull. A helmet is the best way to avoid such unpleasantries.

How Hurt is Hurt?

Doctors and head-injury researchers use a simplified rating of injuries, called the Abbreviated Injury Scale, or AIS, to describe how severely a patient is hurt when they come into a trauma facility. AIS 1 means you've been barely injured. AIS 6 means you're dead, or sure to be dead very soon. Here's the entire AIS scale:
AIS 1 = Minor
AIS 2 = Moderate
AIS 3 = Serious
AIS 4 = Severe
AIS 5 = Critical
AIS 6 = Unsurvivable

A patient's AIS score is determined separately for each different section of the body. So you could have an AIS 4 injury to your leg, an AIS 3 to your chest and an AIS 5 injury to your head. And you'd be one hurtin' puppy. Newman is quoted in the COST study on the impact levels likely to cause certain levels of injury. Back in the '80s he stated that, as a rough guideline, a peak linear impact—the kind we're measuring here&151of 200 to 250 Gs generally corresponds to a head injury of AIS 4, or severe; that a 250 G to 300 G impact corresponds to AIS 5, or critical; and that anything over 300 Gs corresponds to AIS 6. That is, unsurvivable.

Newman isn't the only scientist who thinks getting hit with much more than 200 Gs is a bad idea. In fact, researchers have pretty much agreed on that for 50 years.

The Wayne State Tolerance Curve is the result of a pretty gruesome series of experiments back in the '50s and '60s in which dogs' brains were blasted with bursts of compressed air, monkeys were bashed on the skull, and the heads of dead people were dropped to see just how hard they could be hit before big-time injury set in. This study's results were backed up by the JARI Human Head Impact Tolerance Curve, published in '80 by a Japanese group who did further unspeakable things to monkeys, among other medically necessary atrocities.

The two tolerance curves agree on how many Gs you can apply to a human head for how long before a concussion or other more serious brain injury occurs. And the Wayne State Tolerance Curve was instrumental in creating the DOT helmet standard, with its relatively low G-force allowance.

According to both these curves, exposing a human head to a force over 200 Gs for more than 2 milliseconds is what medical experts refer to as "bad." Heads are different, of course. Young, strong people can take more Gs than old, weak people. Some prizefighters can take huge hits again and again and not seem to suffer any ill effects other than a tendency to sell hamburger cookers on late-night TV. And the impacts a particular head has undergone in the past may make that head more susceptible to injury.

Is an impact over the theoretical 200 G/2 millisecond threshold going to kill you? Probably not. Is it going to hurt you? Depends on you, and how much over that threshold your particular hit happens to be. But head injuries short of death are no joke. Five million Americans suffer from disabilities from what's called Traumatic Brain Injury—getting hit too hard on the head. That's disabilities, meaning they ain't the same as they used to be.

There's another important factor that comes into play when discussing how hard a hit you should allow your brain to take: the other injuries you'll probably get in a serious crash, and how the effects of your injuries add up.

The likelihood of dying from a head injury goes up dramatically if you have other major injuries as well. It also goes up with age. Which means that a nice, easy AIS 3 head injury, which might be perfectly survivable on its own, can be the injury that kills you if you already have other major injuries. Which, as it happens, you are very likely to have in a serious motorcycle crash.

The COST study was limited to people who had hit their helmets on the pavement in their accidents. Of these, 67 percent sustained some kind of head injury. Even more percent—sustained leg injuries, and 57 percent had thorax injuries. You can even calculate your odds using the Injury Severity Score, or ISS. Take the AIS scores for the worst three injuries you have. Square each of those scores—that is, multiply them by themselves. Add the three results and compare them with the ISS Scale of Doom below.

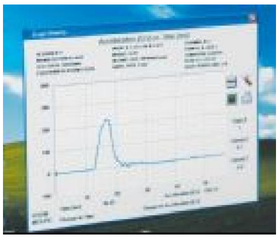
A score of 75 means you're dead. Sorry. Very few people with an ISS of 70 see tomorrow either.

If you're between 15 and 44 years old, an ISS score of 40 means you have a 50-50 chance of making it. If you're between 45 and 64 years old, ISS 29 is the 50-50 mark. And above 65 years old, the 50-50 level is an ISS of 20. For a 45- to 64-year old guy such as myself, an ISS over 29 means I'll probably die.

If I get two "serious," AIS 3 injuries—the aforementioned AIS 3 head hit and AIS 3 chest thump—and a "severe" AIS 4 leg injury, my ISS score is ... let's see, 3 times 3 is 9. Twice that is 18. 4 times 4 is 16. 18 and 16 is 34. Ooops. Gotta go.

Drop my AIS 3 head injury to an AIS 2 and my ISS score is 29. Now I've got a 50-50 shot.

Obviously, this means it's very important to keep the level of head injury as low as possible. Because even if the head injury itself is survivable on its own, sustaining a more severe injury—even between relatively low injury levels—may not just mean a longer hospital stay, it may be the ticket that transfers you from your warm, cushy bed in the trauma unit to that cold, sliding slab downstairs.



Department Of Testing

In the other corner of the U.S. helmet cage-fighting octagon is the DOT standard. It mandates a testing regimen of moderate-energy impacts, which happen in 90 percent or more of actual accidents, according to the Hurt Report and other, more recent studies.

Where the Snell standard limits peak linear acceleration to 300 G, the DOT effectively limits peak Gs to 250. Softer impacts, lower G tolerance. In short, a kinder, gentler standard.

The DOT standard has acquired something of a low-rent reputation for a number of reasons. First, it comes from the Gubmint, and the Gubmint, as we know, can't do anything right.

The DOT standard, like laws against, say, murder, also relies on the honor system; that is, there's only a penalty involved if you break it and sell a non-complying helmet and get caught. Manufacturers are required to do their own testing and then certify that their helmets meet the standards. But it also gives helmet designers quite a bit of freedom to design a helmet the way they think it ought to be for optimum overall protection. The question is, how well are those designers doing their job with all that freedom?

DOT, ECE BSI, SMF—Let's Call The Whole Thing Off

In a typical large motorcycle dealership you're likely to find helmets that conform to all these standards. Most U.S.-market full-face helmets made in Asia—Arai, HJC, Icon, KBC, ScorpionExo, Shoei, and most Fulmer models—are Snell M2000 or M2005 certified. (The Snell standard did not change substantially from M2000 to M2005.) Most helmets from European companies—Vemar, Shark, Schuberth, etc.—conform to the ECE 22-05 standard.

Suomy helmets sold under its own name conform to either the ECE or the BSI standard, but Suomy private-labels some helmets to brands such as Ducati that are built and certified to Snell. Some AGV models sold here are made to Snell standards, some to BSI. And a few Asian-made helmets are DOT-only. Among major manufacturers, Z1R (a subbrand of Parts Unlimited) and Fulmer Helmets sell DOT-only lids at the lower end of their pricing scales. You can also get 'em at Pep Boys under the Raider brand name.

Hurts So Good

To talk about helmet design and performance with any measure of authority, we should first look at the kinds of accidents that actually occur. The Hurt Report, issued in '81, was the first, last and only serious study on real motorcycle accidents in the U.S. The study was done by some very smart, very reputable scientists and researchers at the University of Southern California. The Hurt researchers came to some surprising and illuminating conclusions—conclusions that have not been seriously challenged since.

First, about half of all serious motorcycle accidents happen when a car pulls in front of a bike in traffic. These accidents typically happen at very low speeds, with a typical impact velocity, after all the braking and skidding, below 25 mph. This was first revealed in the Hurt Report but has been recently backed up by two other studies, a similar one in Thailand and especially the COST 327 study done in the European Union, where people have fast bikes and like to ride very quickly on some roads with no speed limits at all.

Actual crash speeds are slow, but the damage isn't. These are serious, often fatal crashes. Most of these crashes happen very close to home. Because no matter where you go, you always leave your own neighborhood and come back to it. And making it through traffic-filled intersections—the ones near your home—is the most dangerous thing you do on a street motorcycle.

The next-biggest group of typical accidents happens at night, often on a weekend, at higher speeds. They are much more likely to involve alcohol, and often take place when a rider goes off the road alone. These two groups of accidents account for almost 75 percent of all serious crashes. So the accident we are most afraid of, and the one we tend to buy our helmets for—crashing at high speeds, out sport riding—is relatively rare.

Even though many motorcycles were capable of running the quarter-mile in 11 seconds (or less) and topping 140 mph back in '81, not one of the 900-odd accidents investigated in the Hurt study involved a speed over 100 mph. The "one in a thousand" speed seen in the Hurt Report was 86 mph, meaning only one of the accidents seen in the 900-crash study occurred at or above that speed. And the COST 327 study, done recently in the land of the autobahn, contained very few crashes over 120 kph, or 75 mph. The big lesson here is this: It's a mistake to assume that going really fast causes a significant number of accidents just because a motorcycle can go really fast.

Another eye-opener: In spite of what one might assume, the speed at which an accident starts does not necessarily correlate to the impact the head—or helmet—will have to absorb in a crash. That is, according to the Hurt Report and the similar Thailand study, going faster when you fall off does not typically result in your helmet taking a harder hit.

How can this be? Because the vast majority of head impacts occur when the rider falls off his bike and simply hits his head on the flat road surface. The biggest impact in a given crash will typically happen on that first contact, and the energy is proportional to the height from which the rider falls—not his forward speed at the time. A big highside may give a rider some extra altitude, but rarely higher than 8 feet. A high-speed crash may involve a lot of sliding along the ground, but this is not particularly challenging to a helmeted head because all modern full-face helmets do an excellent job of protecting you from abrasion.

In fact, the vast majority of crashed helmets examined in the Hurt Report showed that they had absorbed about the same impact you'd receive if you simply tipped over while standing, like a bowling pin, and hit your head on the pavement. Ninety-plus percent of the head impacts surveyed, in fact, were equal to or less than the force involved in a 7-foot drop. And 99 percent of the impacts were at or below the energy of a 10-foot drop.

To Snell? Or Not To Snell?

In analyzing the accident-involved helmets, the Hurt researchers also addressed whether helmets certified to different standards actually performed differently in real crashes; that is, did a Snell-certified helmet work better at protecting a person in the real world than a plain old DOT-certified or equivalent helmet? The answer was no. In real street conditions, the DOT or equivalent helmets worked just as well as the Snell-certified helmets.

In the case of fatal accidents, there was one more important discovery in the Hurt Report: There were essentially no deaths to helmeted riders from head injuries alone.

Some people in the study, those involved in truly awful, bone-crushing, aorta-popping crashes, did sustain potentially fatal head injuries even though they were wearing helmets. The problem was that they also had, on average, three other injuries that would have killed them if the head injury hadn't.

In other words, a crash violent enough to overwhelm any decent helmet will usually destroy the rest of the body as well. Newman put this into perspective. "In most cases, bottoming [compressing a helmet's EPS completely] is not going to occur except in really violent accidents. And in these kind of cases, one might legitimately wonder whether there is anything you could do."

How many people were saved because their helmet was designed to a "higher" or "higher energy" standard than the DOT standard? As far as the Hurt researchers could ascertain, none.

But the Hurt Report was done nearly 25 years ago. There have been a couple of significant accident studies done since. Both of which, by our reading, tend to back up the Hurt Report's findings.

The COST 327 study investigated 253 motorcycle accidents in Finland, Germany and the United Kingdom, from '95-'98. Of these, the investigators selected 20 well-documented crashes and replicated the impact from those crashes by doing drop tests on identical helmets in the lab until they got the same helmet damage. This allowed them to find out how hard the helmet in the accident had been hit, and to correlate the impact with the injuries actually suffered by the rider or passenger. The COST 327 results showed that some very serious and potentially fatal head injuries can occur at impact levels that stiffer current helmet standards—such as Snell M2000 and M2005—allow helmets to exceed.

And remember, these guys are investigating crashes in Europe, where Snell-rated helmets are a rarity because they can't generally pass the softer ECE standard required there.

In other words, the latest relevant study, which used state-of-the-art methods and covered accidents in countries where there are plenty of 10-second, 160-mph superbikes running around, concluded that current standards—even the relatively soft ECE standards—are allowing riders' heads to be routinely subjected to forces that can severely injure or kill them. The COST study estimated that better, more energy-absorbent helmets could reduce motorcycle fatalities up to 20 percent. If that estimate is legitimate and was applied in the U.S., it would mean saving about 700 American riders' lives a year.

There's no good reason to think things are different here in the States than in Germany, Britain and Finland, all modern, well-developed, superbike-rich countries. Heads are heads, asphalt is asphalt, and falling bodies operate under the same laws of physics there as they do here in America.

If you ask most head-impact scientists or the representatives of the European helmet manufacturers how they like the Snell M2000/M2005 standard, they will generally tell you it's unrealistic, based more on supposition than on science, and forces manufacturers to make helmets that are stiffer than they should be.

If you ask the representatives of many of the top Snell-approved helmet companies, they'll say the Snell standard is a wonderful thing, and they'll imply helmets certified to lower-energy standards—that would be any other standard in the world—are suspicious objects, like smoked clams from the 99 Cents Only store. And not as good at protecting you in an extremely high-energy mega-crash as a Snell-approved helmet is.

What the Snell advocates won't tell you is that when these same makers sell their helmets in Europe, Japan and the U.K., they are not the same helmets they sell here, and they're not Snell rated. They are built softer, tailored to conform to exactly the same ECE or BSI standards as the European makers.

If you get these two groups of folks in a room together and ask these questions, we'd suggest wearing a helmet yourself.

Can Less Be More?

In the last 10 to 15 years a number of Asian-made helmet brands such as HJC, Icon, KBC and Scorpion have entered the market to challenge the once-reigning Japanese leaders, Shoei and Arai.

These new brands offer helmets that look and feel pretty much like the Arais and Shoeis we were used to wearing and seeing on all the magazine covers, but at substantially lower prices. Problem is, a lower price, especially in a potentially life-saving piece of safety equipment, can do as much harm as good to a brand. There's always the perception lingering in a buyer's mind that a product can't be as good or protect as well if it doesn't cost as much.

So what can a lower-priced maker do to enhance its brand reputation? Get Snell certified. Whether they think a Snell helmet is actually better at head protection or not—and there's no shortage of debate on that subject—they're essentially over a barrel. If they don't get Snell certified, they give the perception their products are not as good as the others on the shelf. And their helmets will sell like Girls Gone Wild videos at a Village People concert.

In six months of researching this article, I spoke to many helmet company representatives. Some in civil tones. Some not so much. One, in particular, summed up the Snell-or-not quandary best. It was Phil Davy, brand manager for the very popular Icon helmets and riding gear. "When you build a helmet for this market, meeting the Snell standard is your first, second, third, fourth and fifth concern. You can then start designing a helmet that's safe," he said.

It is important to note that every one of Davy's Icon helmets is Snell certified. He's no fool.

AVERAGE Gs
Fewer Gs = Less chance of brain injury

DOT-only helmets:

Z1R ZRP-1 (P)
- Average: 152 Gs
- LF: 148 gs
- RF: 176 gs
- LR: 153 gs
- RR: 130 gs

Fulmer AFD4 (P)
- Average: 157 Gs
- LF: 152 gs
- RF: 173 gs
- LR: 175 gs
- RR: 130 gs

Pep Boys Raider (P)
- Average: 174 Gs
- LF: 163 gs
- RF: 199 gs
- LR: 185 gs
- RR: 152 gs

BSI / DOT Helmets

AGV Ti-Tech (F)

- Average: 169 Gs
- LF: 156 gs
- RF: 199 gs
- LR: 195 gs
- RR: 129 gs

Suomy Spec 1R (BSI) (F)
- Average: 182 Gs
- LF: 192 gs
- RF: 215 gs
- LR: 197 gs
- RR: 126 gs

ECE 22-05 / DOT Helmets

Schuberth S-1 (F)
- Average: 161 Gs
- LF: 151 gs
- RF: 180 gs
- LR: 176 gs
- RR: 137 gs

Suomy Spec 1R (ECE) (F)
- Average: 171 Gs
- LF: 156 gs
- RF: 200 gs
- LR: 190 gs
- RR: 140 gs

Shark RSX (F)
- Average: 173 Gs
- LF: 166 gs
- RF: 187 gs
- LR: 201 gs
- RR: 141 gs

Vemar VSR
- Average: 174 Gs
- LF: 171 gs
- RF: 198 gs
- LR: 166 gs
- RR: 162 gs

Snell 2000 / DOT Helmets

Icon Mainframe (P)
- Average: 181 Gs
- LF: 168 gs
- RF: 217 gs
- LR: 189 gs
- RR: 152 gs

Icon Alliance (F)
- Average: 183 Gs
- LF: 179 gs
- RF: 200 gs
- LR: 179 gs

- RR: 175 gs

Scorpion EXO-400 (P)
- Average: 187 Gs
- LF: 185 gs
- RF: 212 gs
- LR: 193 gs
- RR: 158 gs

AGV X-R2 (F)
- Average: 188 Gs
- LF: 192 gs
- RF: 226 gs
- LR: 166 gs
- RR: 167 gs

Arai Tracker GT (F)
- Average: 201 Gs
- LF: 193 gs
- RF: 243 gs
- LR: 203 gs
- RR: 166 gs

HJC AC-11 (F)
- Average: 204 Gs
- LF: 195 gs
- RF: 230 gs
- LR: 231 gs
- RR: 163 gs

Scorpion EXO-700 (F)
- Average: 211 Gs
- LF: 207 gs
- RF: 236 gs
- LR: 226 gs
- RR: 176 gs

Impact Key: LF: Left Front, 7-foot drop, Flat Pavement. RF: Right Front, 10-foot drop, Flat Pavement. LR: Left Rear, 7-foot drop, Flat Pavement. RR: Right Rear, 7-foot drop, Edge Anvil. Shell Key: (P): Polycarbonate (F): Fiberglass

The Rules Rule

OK. We promised an actual helmet impact test, and it's time to give it to you.

We asked the major helmet brands sold in the U.S. to each pick one model of their helmets. We asked for two functionally identical helmets in the same size, medium or 714. Why two? To give us a look at the consistency of the manufacturer's production techniques. Why all one size? To make sure any differences we saw were due to design and production differences, not random differences due to sizing. And we wanted to use the same-size headform in all our testing, again for consistency. We were also interested in learning as much as we could about different helmet constructions, and about how helmets built to different standards vary. So if a manufacturer made both fiberglass-shell and plastic-shell helmets, we asked for a pair of each. And if a manufacturer made helmets to two different standards, we asked for both as well.

Icon and Scorpion sent both fiberglass and polycarbonate helmets, all Snell/DOT-rated. AGV sent a pair of Snell/DOT-rated X-R2s and a pair of BSI/DOT-rated TiTechs. And Suomy sent the same model, its Spec 1R, in both BSI-rated and ECE-rated versions.

In the end, we wound up with 16 models, 32 helmets in all. A look at the accompanying chart will give you a rundown of the helmet brands that elected to participate and the models they sent. A number of manufacturers chose not to participate: Bell, KBC, OGK, Shoei and Simpson were contacted repeatedly, but chose not to send helmets. We also tested a couple of full-face Raider helmets purchased from Pep Boys for $69.95 a pop.

Unlike other standards testing, where the test parameters are published years ahead of time, we did not reveal the actual tests we were going to perform before we did the testing. So there was, essentially, no chance for them to send mislabeled, ringer helmets.

We needed somebody to help us design the tests and do the actual testing. So we hired David Thom. Remember the Hurt Report? Thom was one of the USC researchers who went out to investigate all those motorcycle accidents and then helped pull it all together. Thom worked at USC with Professor Harry Hurt for many years, investigating all the various ways motorcyclists and other folk hurt themselves, and striving mightily to find better ways to protect them.

Thom subsequently formed his own company, Collision and Injury Dynamics. He has his own state-of-the-art helmet impact lab where he does impartial, objective certification testing for many helmet companies. The DOT standard, for instance, relies on companies certifying their own helmets, and Thom is one of the people they contract with to do the actual testing. In other words, he knows what he's doing.

We had no interest in checking to see whether our helmets conform to any specific standard. Because a helmet's job is protecting your head, not passing a standard. We came up with our own battery of tests designed to duplicate, as best we could, the impacts that really happen on a statistically significant basis.

Real motorcycle accidents don't end with a helmet hitting a machined stainless-steel anvil—they end up with a helmet bashing down on good old lumpy, gravel-studded asphalt. So the industrious Thom grabbed a square-foot piece of Sheldon Street in El Segundo, California, the street out in front of his lab, when the paving crew tore it up for resurfacing. Set in concrete, that would be our "anvil," as they say in the biz, for flat-surface impacts.

Three of the four impacts we planned for each helmet would be on that flat asphalt surface—simply because that's what real motorcyclists land on when they fall, more than 75 percent of the time. The Hurt Report established this, and in the recent Thailand helmet study 87.4 percent of the helmet hits were from the road surface or the shoulder. Helmets do hit curbs a small percentage of the time, but usually after sliding along on the road first, which means that in most cases they are actually hitting a flat surface—the vertical plane of the curb.

For the energy of each drop, we selected a range of hits typical of both the DOT and Snell testing regimens. We hit the left front and the left rear of the helmets with an energy of 100 joules, which translates to a drop of about 2 meters, or 6.6 feet. According to the Hurt Report, this drop represents the 90th-percentile energy of the crashes they investigated. We also did one high-energy drop with an energy of 150 joules, the same energy—about a 10-foot drop—as the hardest hit specified in the Snell standards, on the right front of each helmet. That's 66 percent more violent than the drop specified by the DOT standard for a medium-sized helmet, and represents the 99th-percentile impact seen in the Hurt Report. Which means 1 percent or fewer impacts seen on the street exceeded this energy level. So we weren't exactly taking it easy.

To see what happens when you're unlucky enough to rear-end a truck's lift gate, slide into a storm drain or be flung into the Eiffel Tower, we also did an edge hit onto a scary-looking piece of upright steel bar. We debated whether to do this hit at a 2-meter, 100-joule energy level or a more violent 3-meter, 150-joule impact level. We opted for the smaller hit, more to protect the helmet test rig than to play nice with the helmets. If a single helmet bottoms out and squishes its EPS liner flat, the total impact goes right into the headform and test rig—as it would to your head. And just like your head, the test rig is gonna break. We weren't sure all the helmets would survive the 150-joule edge drop, so we pulled back to the 100-joule level. Fracturing the rig would put us out of commission for days, and we didn't have the time—or money—to risk that.

In the end we were too conservative. When we inspected the helmets after the full course of testing, the 100-joule edge hit hadn't come close to bottoming any of the helmets—even the supposedly wimpy DOT-only ones. We are confident we could have done the edge test at the 99th-percentile 150 joules—the Snell edge-anvil test—and seen results commensurate with those we saw from the other impacts.

The results of all our laborious impact testing were exactly as expected—but still surprising as hell.

The helmets ranged from the softest regimen, the DOT standard, to the Snell standard, the stiffest. But would the real-world, production-spec helmets actually show that progression from soft to stiff? In other words, can you predict how stiff a helmet will be simply by looking at the standard label? Absolutely.

In fact, our results show that modern helmets are all made with an amazing degree of precision, with their shell construction, liner density and liner thickness all controlled very well in the production process. In other words, almost everybody designing serious helmets seems to know exactly how to get what they want—the only variable is deciding what they want. And for the most part, the standards make that decision for them, not flashes of genius on the parts of the helmet designers themselves.

All the helmets we tested performed exactly as the standards they were designed to meet predicted. And they seemed to exceed those standards—that is, the DOT-only helmets were better at high-energy impacts than they had to be just to pass the DOT standard, and the Snell helmets were better at absorbing low-energy impacts than they had to be to pass DOT or Snell.So choosing a helmet, at least in terms of safety, is not a question of choosing high or low quality, it's one of choosing what degree of stiffness you prefer, finding a helmet in that range by choosing a particular standard, and then worrying about fine points like fit, comfort, ventilation, graphics, racer endorsements or computer-generated spokesmodels.

How Hard Is Hard?

Not one helmet came close to bottoming in any of our tests. And they all handled the low-energy impacts, even the scary-looking edge impact, without strain.

In fact, in most cases the peak Gs in the edge impact were lower than the flat-anvil peak Gs for the same helmet at the same impact energy. Why is this? Because the edge impact flexes and/or delaminates the helmet shell sooner in the impact, letting the EPS inside—the real energy absorber in the system—start doing its work sooner.

In the high-energy impact, the 3-meter, 150-joule drop—the kind of hit a Snell helmet is, presumably, designed to withstand—the differences became more apparent.

The stiffest helmets in the Big Drop test, the Arai Tracker GTs, hit our hypothetical head with an average of 243 peak Gs. The softest helmets, the Z1R ZRP-1s, bonked the noggin with an average of 176 peak Gs. This is a classic comparison of a stiff, fiberglass, Snell-rated helmet, the Arai, against a softer, polycarbonate-shell, DOT-only helmet, the Z1R. OK. So let's agree that we want to subject our heads to the minimum possible G force. Should we pick an impressive, expensive fiberglass/Kevlar/unobtanium-fiber helmet—or one of those less-expensive plastic-shelled helmets?

Conventional helmet-biz wisdom says fiberglass construction is somehow better at absorbing energy than plastic—something about the energy of the crash being used up in delaminating the shell. And that a stiffer shell lets a designer use softer foam inside—which might absorb energy better.

Our results showed the exact opposite—that plastic-shelled helmets actually performed better than fiberglass. In our big 3-meter hit—the high-energy kind of bash one might expect would show the supposed weaknesses of a plastic shell—the plastic helmets transferred an average of 20 fewer Gs compared with their fiberglass brothers, which were presumably designed by the same engineers to meet the same standards, and built in the same factories by the same people.

Why is this? We're guessing—but it's a really good guess: The EPS liner inside the shell is better at absorbing energy than the shell. The polycarbonate shells flex rather than crush and delaminate, and this flexing, far from being a problem, actually lets the EPS do more of its job of energy absorption while transferring less energy to the head.

Remember, these polycarbonate helmets from both Icon and Scorpion are also Snell M2000 rated. So they are tested to some very extreme energy levels. And Ed Becker, executive director of the Snell Foundation, is on record as saying that a low-priced—that is, plastic-shelled—Snell-certified helmet is just as good at protecting your head as a high-priced—that is, fiberglass—Snell-certified helmet. So at the high end of impact energy, we have the Snell Foundation vouching for their performance. And our testing, without the extreme two-hit hemi test, says they're actually superior.

Score One For Faceless Government Bureaucrats

The DOT helmets we had were all plastic-shelled, and none cost more than $100. How did they do? They kicked butt. In what must be considered a head-impact Cinderella story, the DOT-only helmets from Z1R delivered less average G force to the headform through all the impacts than any others in the test.

And they still excelled in the big-hit, 150-joule impact&151a blast 66 percent harder than any actual DOT test for a medium-sized helmet.

The Z1R ZRP-1s continuously amazed us. After all the testing, its outer shell looked essentially unharmed: The slight road rash at the impact sites caused by our stubborn insistence on hitting actual pavement looked no worse than we'd expect if the helmet had fallen off the seat at a rest stop.

When we pulled the ZRP-1s apart, the EPS had cracked and compressed at the impact sites, just as it's supposed to do, and just as it did in every other helmet. But it had come nowhere near bottoming; there was still an inch or more of impact-absorbing foam left. And the plastic shell seemed completely unharmed, from the inside as well as the outside, even where it had taken the terrifying edge hit and the big three-meter bash.

This illustrates just how hard it is to tell from the outside whether a helmet has taken a severe hit. And why you should never, ever buy a used helmet.

Fiberglass helmets such as the the Arai Tracker (shown) showed substantial damage to their shells after the edge impact. The polycarbonate-shell helmets were largely unmarked. Neither result is essentially better: Either shell material can be used to make excellent helmets. Polycarbonate helmets generally transmit fewer Gs to the head in our testing than fiberglass-shell lids, even when certified to the same standards.

The Hardest Hits

So the softest DOT helmets came through our tests with protection to spare. But doubt lingered, in spite of everything we had seen: How would they do in a monster, wicked-big impact?

So we decided to kill them. We ran the Z1Rs up the test rig one last time. Not just to the 10-foot, 150-joule Snell test height, but all the way to the top of the rig: 3.9 meters, or 13 feet. This hit would be at 8.5 meters per second, an energy of 185 joules. That's higher and harder than any existing helmet standard impact. And, not coincidentally, the same height and energy called out in the COST 327 proposed standard, the one that may replace the current ECE 22-05 specification. We did one hit on the pavement and one on the curb anvil—the same hits called out in the COST proposal. We did them on the back of the helmets, in the center, because that was the only place we hadn't hit them before.

So this last test is not directly comparable to the others. But it showed, in no uncertain terms, just how tough—and how protective—an inexpensive helmet can be.

The peak Gs for the monster hits were 208 for the curb impact and 209 for the flat-pavement impact. Just a few Gs more, that is, than many of the Snell-rated helmets transmitted in their seven-foot hits on the flat anvil. And even after these mega hits, the EPS liners were still nowhere near used up.

The ZRP-1s are also well finished, quiet and very comfortable, though maybe a little short on venting. They're also light: Our ZRP-1s weighed only about an ounce more than the lightest helmets in the test, the Arai Tracker GTs. What's the cost for all this excellent impact absorption, comfort, light weight and highly durable finish? In a solid color, a ZRP-1 retails for $79.95.

The least-expensive helmets in the test, the $69.95 Pep Boys Raiders, also did well in all the standard impacts. But we can't recommend them because their chin bars have soft, resilient foam, not the EPS you need to absorb a severe head-on impact. Our advice is to spring for the extra $10 and treat yourself to a Z1R ZRP-1.

Another helmet that taught us a thing or two was the Schuberth S-1. The Schuberth is certified to the ECE 22-05 standard, which dictates impact energies marginally higher than the DOT standard. Like the Z1R ZRP-1 and the Fulmer AFD4, it has relatively large outer dimensions, leaving room in the shell for thicker, and presumably softer, EPS. And like the DOT-only lids, it soaked up energy like a sailor soaks up Schlitz. If you can't bring yourself to wear a $79.95 helmet just to get excellent energy management, you'll feel very comfortable with the Schuberth, which sells for $640 to $700.

The other helmets we pulled apart used either a one-piece or a two-piece EPS liner. The S-1, on the other hand, uses a complex, five-piece liner, with separate front, rear and overear pads glued to a central foam hat. Leave it to the Germans to use five parts to do what the Z1R does with one.

A few of the European helmets—the Vemars, the Sharks and the Suomys—use a different kind of EPS liner than we're used to seeing in Asian-built helmets. Instead of a solid foam liner of a specific density, these Euro-lids use stiffer, more rigid foam with deep channels in it to soften up the assembly and vent air through the shell. The effect is that of a highly vented bicycle helmet stuffed into the requisite hard outer shell. The ECE-rated Vemars and Sharks and the ECE and BSI-rated Suomys performed well on the impact torture rack, showing generally lower G-transmission than we saw in typical Snell-rated helmets.

The Human Race

"But I'm a racer," we hear you rationalizing. "I go really fast. I go so fast, in fact, that I need a very special, high-energy helmet to protect my wonderful manliness and fastness." Not so, Rossi-breath.

If you're going to land on flat pavement when you crash—and you almost always do—you can afford to wear a softer ECE or DOT helmet, because softer helmets do a very good job of absorbing big impacts—even really, really big impacts—on flat surfaces. Remember, the hard part about getting a helmet past the Snell standard involves surviving that mythical steel orange very hard twice in the same spot on the helmet, simulating a monster hit—or two—on, say, a car bumper. Been to Laguna Seca recently? No car bumpers or steel oranges anywhere.

Racers don't typically hit truck parts, storm drains, sign posts, tree shredders or the Watts Towers. They fall off, sometimes tumble, and almost always hit the racetrack. Or maybe an air fence, a sand trap or hay bale. In other words, the racetrack is the best-controlled, best-engineered, softest, flattest environment you're going to find. Racers are even more likely to hit flat pavement than street riders—and street riders hit flat pavement around 90 percent of the time.

The AMA accepts DOT, ECE 22-05, BSI 6658 Type A or Snell M2000-rated helmets. That's for going 200 mph on a superbike at Daytona. The FIM, which sanctions MotoGP races all over the world, accepts any of the above standards but DOT. Why not DOT if DOT helmets are comparable to ECE helmets? Because the DOT is an American institution, and the FIM doesn't really do American. And because the DOT standard doesn't require any outside testing—just the manufacturers' word that their helmets pass.

Yes, Size Does Matter

There's one more issue with the Snell and BSI standards we should mention, even if we didn't specifically address it in our testing.

Snell and BSI dictate that every helmet be impact-tested with the same-weight headform inside, no matter the size of the helmet. That is, an XS helmet is required to withstand exactly the same total impact energy as an XXL.

The DOT and ECE standards vary the energy of the impacts by varying the weight of the headform, under the reasonable rationale that a very small head weighs less than a very big one. In the eyes of the governments of both the U.S. and the European community, in other words, helmet makers should tailor the stiffness of their helmets to suit the head sizes of the wearers to protect everybody's brain equally.

What does this mean to you? If you have a relatively heavy head, the difference in stiffness between a Snell helmet and a DOT or ECE helmet will be relatively small. If you are a man, woman or child with a lighter head, on the other hand, the difference in stiffness between a Snell helmet and a DOT or ECE helmet will be relatively huge.

So if you are concerned after reading all this that a Snell helmet might be too stiff for you, Mr. XXL, you should be even more concerned about putting your XS wife or child into a Snell or BSI helmet. The Snell Foundation's position on this is that they have no proof big heads weigh more than small heads. Hmmm. Isn't a head basically a shell of thin bone filled with water? Doesn't more bone and water weigh more than less bone and water?

And it's not just us. One study by Mr. Thom concluded that head weight does increase with head circumference. He found there is good evidence that smaller heads weigh less and that smaller helmets should thus be softer.

As Thom says regarding the Snell Foundation's position on this: "They are not in touch with reality."

All Helmets Are Great. We Investigate.

The good news in all this is that helmets—all helmets—are getting better. The last time we did an impact test on helmets was back in '91, in the November issue if you're rummaging through that pile in the garage next to your 1929 Scott Flying Squirrel.

We did some of the same impacts this time, a 7-foot flat drop and a 10-foot flat drop, as we (and Thom) did in '91. So the results, at least on those tests, are highly comparable.

Back in '91, both DOT and Snell/DOT helmets routinely exceeded 250 Gs in the 7-foot drop, and often spiked past 300 Gs in the 10-foot drop. Ouch.

In our new results, no helmet exceeded 250 Gs in the 10-foot drop, and the vast majority of the 7-foot drops stayed well below 200 Gs. So falling at a 10-foot energy level today—a 99th-percentile crash—is like falling at a 7-foot energy level was back in '91. That means more and more people are being protected better and better. It also means that in well over 90 percent of the impacts we did, the rider would probably have come out with no more than an AIS 3—or serious—brain injury.

Helmets are getting better, and some of the least-expensive helmets provide truly amazing protection. But just how good can helmets get? Stay tuned—we'll explore that topic very soon.

Snell Responds:

An Open Letter
May 12, 2005
From: The Snell Memorial Foundation
To: The motorcycling public

I've been several months waiting for the helmet comparison write up that has finally come out as the "Blowing the Lid Off" article in the June issue of Motorcyclist. This same comparison has been done before. During my second year with the Foundation, 1991, some of the same people involved in the current article participated in an effort titled "Breaking Some Eggs." This earlier article also created a stir. They told any number of people that their good helmets were bad. Fortunately, hardly any of them panicked and a sober assessment of the facts indicated that the egg breakers were mistaken. Now, they've done it again. When I hear someone yell "Fire!" in a crowded theater, like most sensible people, I won't stampede for the exits but I'm apt to sniff the air before I start to wonder about who did the yelling. This time, after a little sniffing, I've got to tell you, I'm not smelling smoke. I'm happy to say that the worst is they may have broken the wrong egg again or lifted the wrong lid. In any case, the smell will dissipate quickly so we all can get back to the feature.

The most important item in the article is the helmet comparison itself. They based their comparison on flat impact performance and looked for the lowest peak acceleration. The authors maintain that flat surface impacts are the most common and "Fewer Gs = Less chance of brain injury." Flat impact performance is important, there's no doubt about it but looking at flat impact performance only is like judging a beauty pageant looking through a keyhole. The article holds that more than 75% of impacts will be against a flat surface but this implies that a substantial number of impacts may still be against some other, more threatening surface. The COST 327 report, the same European study mentioned in the article, goes further. It suggests that this number will be much larger than 25% and the resulting hazard much greater than mere flat impact imposes. Their crash study indicated impact surfaces as follows:

"A round object was the most frequently struck, 79%, and the severity of injury was fairly evenly distributed. An edge object, for example a kerbstone was the least likely to be struck, 4%, but the most likely to cause a severe, AIS 5, injury. A flat object was struck in 9% of cases but was the least likely to cause an injury."

The immediate conclusion is: the asphalt slab testing is, at best, incomplete. Impacts against flat surfaces will not tell anyone all they need to know about protective performance. Flat impacts are not the whole story and, if the European data is good, and I've got no reason to doubt it, flat impacts may be the least important crash consideration.

But there's still another weakness, the "fewer Gs = less chance" statement is, at the very least, misleading. All the standards, Snell M2000 and M2005 included, presume a threshold model of injury. That is: so long as a threshold G limit is not exceeded, there will not be a serious injury. A corollary conclusion is that any G exposure not exceeding this G limit is no better or worse than any other G exposure not exceeding this limit. If a G exposure below this limit is safe, another exposure 40 G's lower cannot be any safer.

The difficulty about this threshold is that no one is certain just where it is but there is some confidence about where it isn't. In the 1950's, BSI helmet testing relied on force measurements and used a test criteria that equated to about 450 G in current terms. The first Snell standard in 1959 set a criterion of 400 G but, because the headform was heavier, today's equivalent work out to 435 G. During the 1960's, the Foundation began to lower this G criterion. Snell certified helmets were no longer just for young, tough auto racers. The American public was taking up motorcycling and while many were as tough as anybody on four wheels, many others needed an additional margin of protection. The motorcycling environment itself raised some qualms. Snell standards and helmets were first developed for use in well ordered competition. No one thought the mean streets would require any less than that. If the helmet hadn't already been all the protection the industry could manage, I'm sure Snell would have asked for more. By 1998, the Foundation's criterion settled on 300 G. It was down some 33% from the levels set in England in the 1950's. Why was it down? Likely because the 50's estimates were based on the needs of soldiers and young, healthy males while today's helmets are intended for almost everyone.

What about the Wayne State Curve and all the other advances in the science of head injury during the last fifty years? Much of it was good work by gifted and dedicated scientists but, to this day, no one is quite certain what hammer blows to cadaver skulls and air blasts to the exposed brains of test animals have to say about the risks of helmeted impact. We're all still waiting for the breakthrough that will relate helmet parameters to head injury hazards. Right now, the most directly useful information developed for helmeted impacts has come from crash studies. Those findings suggest that current test criteria are working. If they weren't, COST 327 would not have considered flat impact "the least likely to cause an injury."

The fact is, all the major crash helmet standards call out G figures greater than those in the article. It's 300 G for Snell, BSI 6658, and FIA 8860, the Advanced Helmet Specification set out by FIA in 2004. It's 275 G for ECE 22-05. It's all of 400 G for DOT. Yes, yes, I know they said 250, they said a lot of things. Their rationale is that DOT's "time duration criteria" effectively set a new G limit of 250 rather than the 400 G limit in the standard. This may even be true for flat impact but DOT also calls out impacts against the hemispherical anvil. They even said so in the article. But they did not tell you that the "effective" G limit for the hemi is still 400 G. And, drawing on COST 327, it's there against the shaped hazard anvils like the hemi, the edge or the kerbstone that serious helmets will prove themselves.

The upshot is they seemed to have based their comparison on incomplete tests and drawn their conclusions from inconsequential differences. Anyone who was happy with his helmet before reading this article has been given no real reason to feel any differently now.

Now, ordinarily, at this point we'd fill in the grave, sing a few hymns and go home. But I've got a few more stakes here and the certain feeling we're dealing with the undead. So keep your garlic at the ready because I'm going in again.

The article also takes Snell to task for impact severity. The complaint is that by the time a rider takes that kind of hit, he's dead anyhow. The article proposed to trade that impact management away for softer liners. Yes, it's a trade. We cannot have both. For a given liner thickness, the softer the liner, the lower the energy management. We've been at just about at the limit of acceptable liner thickness for some time. However, there's no real assurance that softer liners would yield any benefit in reduced incidences of fatality or serious injury while, contrary to the article, the COST 327 report concludes that there would be a substantial benefit from increased energy management:

"Head impact energy is proportional to head impact speed, which, in turn, indicates to what extent helmets need to be improved to give a corresponding reduction in injury severity. This was calculated and it was estimated that an increase in helmet energy absorbing characteristics of some 30% would reduce 50% of the AIS 5/6 casualties to AIS 2-4."

There are others who agree. When TRL, one of the companies participating in the COST 327 project, made helmet recommendations to FIA, the controlling body for Formula 1, their advice culminated in FIA

8860, the Advanced Helmet Specification. This specification demands considerably more impact management than the most severe Snell standard. A study of Snell test results has shown that the double impact test against the hemispherical anvil equates, on average, to a single impact of about 185 Joules. FIA 8860 tests helmets against this same hemi anvil and applies a single impact of 225 Joules.

It doesn't take too much imagination to see why this additional impact management might be valuable. When a rider goes off a bike at speed, even if he's got the good fortune to hit smooth pavement with an 8 foot drop or less, his body will still be sliding along the roadway at his initial cruising speed. Since leathers, denim and human skin aren't nearly as effective at braking as a good set of tires, this rider is likely to slide for some considerable distance and every obstacle he encounters offers a considerable head impact hazard. His helmet may have to do considerably more than see him through the first thump. A famous movie star some years ago crashed and received his most serious head injury smacking into a curb after sliding some distance from his bike.

It could be even worse. Frequently, when a rider spills onto the pavement, he will not be able to maintain a controlled slide while his cruising velocity gets scrubbed off. If he gets even a little out of shape he'll start to tumble and sustain multiple strikes to all his extremities. His helmet may need to manage a succession of impacts. And there's also no doubt that if he goes off his bike and strikes something less friendly than flat pavement, for example: a vehicle turning left across his right of way, even that first impact by itself may be considerably more serious than any eight foot drop could ever be.

The article also takes Snell to task for two hits. Snell calls for the helmet to be tested in 150 Joule impact (about 7.75 meters/second) followed by a 110 Joule impact (about 6.6 meters/second) at the same point on the helmet. Snell standards have always been two hits against the flat and hemi anvils and so have DOT and BSI 6658. I've already described how a helmet might sustain more than one hit in a crash and I've seen a number of helmets with signs of several severe impacts and at least a few where those signs overlapped. But there's at least one other justification for the two hit protocol. Back in 1959, when Dr. George Snively was developing the first Snell standard, the favored test device was the "swing-away" rig. This device was an improvement on anything that came before it but it demanded a high ceiling even for a very moderate shot. The only reasonable way for Snively to stress the helmet properly was to hit it twice. By the mid '60's, Snively switched over to the guided fall rig, the same type Snell, BSI 6658 and DOT use today but, by that time he'd also bumped up the test severities. He still needed the double hit.

But the Motorcyclist article went further. Not content with impugning Snell standards, the article slyly suggested fraud. They quoted one of their sources saying, "The Snell sticker has become a marketing gimmick." and implying that riders were being hustled for as much as $100 a hat. Nonsense, we live in the most market savvy country in history. I've grown up seeing and seeing through more slick ad campaigns and smears than my great grandparents would ever have dreamed possible. The half-life for a marketing gimmick these days is surely no more than a few months while Snell is coming up for its fiftieth anniversary. Certainly Abe Lincoln was right, nobody could have fooled all the people for this long. If I wasn't already insulted as a Snell guy, I'd be insulted as an American. We're no gimmick and neither are any of the helmets we certify.

Snell certified helmets come in a range of prices, the least expensive cost not much more than Harry Hurt's bargain basement items. Of course, the production costs are higher, Snell test fees and stickers may add a dollar or so but the bulk of the costs is likely to be the internal quality control measures necessary to succeed in the Snell programs. But, if I'm to wear their helmets, I don't want manufacturers going light in this department in any case.

And not everyone wants to shop the bargain basement and I'm not sure that everyone should. There's more to good helmets than protective performance. Riders demanding premiums of comfort, fit quality and good looks may have to move up to the higher shelves. But here again, they can get real value for their money. No one will stay with a helmet that's ugly or uncomfortable, at least, not for very long and a helmet that isn't worn is no bargain no matter how inexpensive.

Snell can't really help with comfort, fit quality or style issues. They're all matters in which riders can tell us much better than we could ever tell them. But I will try to offer a little advice in the matter of fit. The less expensive helmet lines use no more than two helmet configurations to cover the full range of head sizes and some offer just one. A size medium rider is apt to wind up wearing a size x-large helmet stuffed with thick comfort padding to bring it down to his head dimensions. But on the higher shelves, a helmet line might include as many as four or five distinct configurations and at least one manufacturer configures different lines for different head shapes. The result is that almost everyone can find a good fit. The catch is that more configurations imply shorter production runs and, in turn, more expensive production methods. The saving grace is that the value is there, in the helmet. The price reflects the production costs. No one is laying out an extra $30, $40, $60 or $100 dollars for just a Snell sticker. The competition among Snell certified manufacturers is too fierce for that. Riders are getting the protective performance called out in Snell standards and they're getting the comfort, fit and style they demand at the best price our economic system can deliver.

I've attempted, as the writer at Motorcyclist did, to inject some humor into this. But even as I've worked on it, I've been getting emails from concerned riders who want to know whether we've been misleading them and whether their helmets were ever any good. I hope all of you will look past anything you might find frivolous or inappropriate here and understand that Snell standards and Snell certified helmets represent the best solution to head impact protection that we here at the Snell Memorial Foundation can propose.

Snell and helmets have come a long way in fifty years. Back in the late 1950's when Dr. Snively was drafting the first Snell standard, he was working with a clean slate. Almost anything he might do would be an improvement. But in fact, he was startlingly deft in all his choices and policies. He did better than improve helmets, he worked a revolution. Thanks to his effort and genius, and to the support of Snell helmet manufacturers and all the riders and drivers who wear Snell certified helmets, Snively has gifted us all with a tremendous legacy. And with that legacy comes a tremendous burden. A poorly chosen policy or a mistaken technical judgment at this point could well destroy that legacy and endanger all those riders who depend on Snell certified helmets. We're part way up a mountain on a narrow trail and a wrong step will mean a long, long fall. The good news, though, is we're on the right trail and we're moving upward. If we suck it up, watch the signs and ignore the mosquitoes we will continue to make progress.

Sincerely,
Snell

Head: Motorcyclist's Response

As you can see, the Snell Memorial Foundation is not pleased with our helmet-testing story, "Blowing The Lid Off", in the June '05 issue.

Our intention in doing the tests and writing the original story was not to attack the Snell Foundation, the Snell M2000/2005 Standard, or any helmet brand. And a fair reading of the story would show that we didn't. We simply devised our own tests, designed to represent the vast majority of actual crashes we and our readers actually have, based on the best scientific information we could get. We tested the helmets, fairly and objectively, and let the chips fall where they fell. And the overwhelmingly positive response we got from you, our readers, showed that you appreciated the effort.

The scientists we quoted, Dr. Jim Newman, Professor Harry Hurt and Dave Thom, were sometimes frank in their criticism of the Snell Foundation. Where were the scientists who are in favor of the Snell Standard? Why didn't we quote them? The answer is really simple. In all our research, in the U.S., England and Europe, over most of a year, we haven't found one.

On The Edge

If the Snell Foundation wanted to criticize our methodology and our story, we would have hoped that they would have portrayed the story accurately. This quote from their response showcases their selective reading: "They (Motorcyclist) based their comparison on flat impact performance..."

They ignored the 32 individual tests we made, not on a flat surface, but on an edge anvil, a nasty-looking piece of upright stainless steel bar Snell uses in its own standard testing. We calculated these edge-anvil tests into the average peak g graphs, just like the flat-pavement tests. We wrote about these edge-anvil tests repeatedly in the story. They are clearly delineated in the key to the comparison graph. There's a picture of one of these edge-anvil tests on the second spread—complete with a caption. Snell missed the edge-anvil tests, proceeding as if we had never done them. And then attacked our testing because it was all done on flat surfaces. Which it wasn't.

Major Impact

Snell also reasserts their scientifically unsupportable position that taking violent impacts to the head is "non-injurious," so long as you take less than their 300g limit. Well, the list of scientific papers, accident studies and eminent head-injury scientists the world over who disagree with Snell on this is overwhelming.

Dr. Jim Newman, a highly respected head-injury scientist and a former Director of the Snell Memorial Foundation, has stated that a 200g impact to the head can be fatal, that a 200-250g impact corresponds to an AIS 4, or severe, head injury, that 250g-300gs relate to an AIS 5, or critical head injury, and that a blow over 300g corresponds to AIS 6. AIS 6 means dead.

Military Standards

Even our military disagrees with Snell on this. The U.S. Army Aeromedical Research Laboratory (USAARL) has created a g-tolerance standard for helicopter crewpersons' helmets. For a two-meter drop height, the same drop height we used in 3/4 of our testing, the Army allows no more than 150 gs to the earcup areas of the head, which they have determined are especially vulnerable, and no more than 175 gs on other areas. Should we motorcyclists—who are often older, not as fit, and not quite so willing to die or sustain head injuries as eager young soldiers—accept g tolerance levels of 300g for the same hits?

Round Table Discussion

In their response, Snell picks a paragraph from the European COST 327 Final Report—the most recent major motorcycle-accident and head-injury study. The paragraph says that helmeted riders struck a "round object" 79% of the time. And Snell is using it to justify their controversial hemispherical anvil testing, the tests that make Snell-rated helmets stiffer than others.

The "round object" figure directly contradicts the findings of at least 6 reputable motorcycle accident studies, done all over the world over the last 30 years, that have shown that between 75% and 87% of helmet impacts happen on the flat road surface. Which makes sense. Because a huge majority of the time, the road is what you're riding on when you fall. And when you fall, you fall down. It's that darned gravity thing.

Some scientists we've talked to, who are just as mystified as we are with this particular COST 327 finding, have suggested that this data came from examining helmets in the lab after crashes, and finding round marks on the helmets. But when you hit a flexible, essentially round helmet on a flat surface, you get a round mark on the helmet—which may have been misinterpreted by the lab staff as the impact of a "round object".

If the COST 327 people really thought 79% of victims hit their helmets on "round objects," one would think they would have put a "round object" hemi anvil into their proposed helmet standard. They did not. The COST people propose to hit helmets on a flat anvil and a curb anvil—no hemi anvils at all.

Here's what Dr. Bryan Chinn, the Editor-In-Chief of the COST 327 Final Report, says about the hemispherical anvils Snell dictates: "From our research, the (hemispherical anvil test) is a particularly severe test and can result in a very stiff liner that possibly detracts from performance in other types of impact, particularly on the flat."

Calculating the COST

It's probably a bad idea, in the long run, for Snell to support their position with a couple out-of-context graphs and snippets from the 327-page COST Final Report. Because there is no shortage of places in which the COST study directly contradicts the Snell "300gs is OK" position.

Such as this quote: "Peak linear acceleration (to the head) should be less than 250g." (COST 327 Introduction, page v)

Or this one: "Current (helmet) designs are too stiff and too resilient, and energy is absorbed efficiently only at values of HIC (Head Injury Criterion, a measure of g force over time) well above those which are survivable." (COST 327 Introduction, page x).

Or figure 7.28, page 166. This graph shows how the actual observed head-injury level of accident victims rises with the peak linear gs the victims received in their crash. At 250g, accident victims had an 80% chance of an AIS 3, or serious, head injury. At 300gs, the probability of an AIS 3 injury went up to 93%. As anybody who can read a graph can see, getting hit less hard is, well, less bad.

Or the final proposed COST 327 helmet standard itself. This contradicts just about everything Snell espouses. It actually requires higher-energy hits than any Snell-M2000/2005 impact, and dictates lower allowable peak gs for those impacts—275g vs. Snell's 300g. It has no Snell-type hemi-anvil hits. It has no Snell-type double hits. It uses a two-tiered impact-test regimen, with lower, 180-g limits for lower-energy impacts, the ones that actually happen a huge majority of the time. And unlike Snell, it graduates the headform masses according to head size, to keep people with lighter heads—small men, women and children—from taking harder hits in a crash.

Also unlike the Snell Standard, the COST Standard includes a chin-bar test that limits peak gs. This is important, because a blow straight to the face is a relatively common accident—and one that often results in a fatality, from a basilar skull fracture.

We think the COST 327 standard, which is proposed to replace the current UN/ECE 22.05 regimen, is the smartest off-the-rack standard we've seen—the best reflection of current knowledge about human tolerance and the helmet making-and-testing state of the art.

Malcontents

The Snell Foundation has also been less than kind to some renowned head- injury scientists for trying to find, and give our readers, the truth.

We expected more from a foundation that many of us, for many years, have trusted with our money, our lives, our health and the welfare of our families.

In one e-mail, to a member of the Norton Owners List, Snell's Executive Director called our article "an attack," perpetrated by "malcontents."

Here are a few of the people who helped with our research, or who have expressed their agreement with our testing methods and our conclusions—it's pretty much a who's who of eminent head-injury scientists around the world:

Dr. Bryan Chinn, Editor in Chief, UN/ECE COST 327 Final Report.

Dr. Jim Newman, former Snell Foundation director, and highly respected head-injury scientist. Dr. Newman is an actual rocket scientist, has been inducted into the International Health and Safety Hall of Fame, and holds several helmet patents.

Dr. Terry Smith, of Dynamic Research Incorporated, another internationally respected motorcycle- and automobile-accident researcher and head-protection scientist.

Andrew Mellor, of the FIA Institute, a renowned helmet-design scientist and originator of the FIA Super Helmet specification for Formula 1 drivers.

Dave Thom, of Collision and Injury Dynamics, an enthusiastic rider and eminent motorcycle-accident researcher and scientist. He's worked with us for many years trying to prevent accidents, improve helmets and save lives.

And Professor Emeritus Harry Hurt, of the Head Protection Research Laboratory Professor Hurt ran the HPRL head-injury lab at the University of Southern California for many years. And the Hurt Report he helmed is still one of the most important, most credible studies of motorcycle accidents the world has ever seen.

Malcontents, indeed.

Dialogue. Not Diatribe.

We'd be happy to engage in any productive exchange of ideas with the Snell Foundation, helmet companies, scientists, or anybody else who's dedicated, not just to maintaining the status quo in helmet standards and helmet design, but to making helmets safer and more protective. The bottom line here is in preventing injuries and saving lives. If anybody sincerely wants to help us in this quest, they know where to find us.