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Harnesses: Will they work?

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Since Dale Earnhardt's tragic death there has been renewed attention on racing restraint systems. Many professionals have come to see that what they *didn't* know about harnesses, seats, and head restraint systems could hurt them. In this article we hope to make you aware of the most important things to consider in making decisions about what is generally your first the step in an effort to enhance the safety of your track car: purchasing and installing after-market harnesses.

Our review of the topic has led us to conclude that: (1) OEM seat belts aren't that bad, and (2) most people have serious deficiencies in their after-market harnesses that could result in worse injuries than if they were wearing the stock factory three point inertia belt system. Before we defend these two statements, a disclaimer is necessary. We don't pretend to be experts on restraint systems and what we present here is not, by itself, sufficient for you to know what is the best combination of devices, installation options, and accessories. However, we hope it will reveal to you what the important issues are and help you to raise the most important questions. In the end you will be balancing the potential advantages of harnesses against cost, convenience, and comfort considerations.

Crashes: What Happens…

Crashes can vary greatly in the forces and vehicle motions involved and few types have been studied in comprehensive detail. The most studied and, probably, best understood is the frontal crash into a solid barrier. Imagine yourself in your car moving at 30 miles an hour when it collides head-on with a concrete barrier. The instant before impact you and the car are moving at the same 30 mph speed. As the front bumper contacts the wall it begins to crush, dissipating energy and the car begins to slow down rapidly. The car will crush about two feet and come to a stop in about 0.16 seconds[1]. This is the "car collision" part of the crash. Overlapping the car collision is the human collision part of the crash.[2] The seat you are sitting on and the three points your seat belt is attached to have slowed with the rest of the car, the belt retractor has locked, and the latch plate receptacle (pyrotechnic or spring) has tightened. The slack in the belt is taken up as it begins to restrain your forward motion, but since it is elastic it stretches. As your body decelerates rapidly, it is, at this time, exerting a force on the seat belt equal to roughly 15 times your weight, maybe a ton of force altogether. The belt *really* stretches and your body deforms around the belt; if you could take a snapshot, you would see 6 to 8 inches of daylight between the seatback and your torso. About half your weight is in your pelvis and legs, the

rest is above your lap and its momentum is being absorbed by the shoulder belt. This pulls the lap belt down tight if the belt can slide through the buckle clip where the lap and shoulder portions meet. The lap belt bites into your lap just below the points of your pelvic bone, keeping you from sliding under it (submarining).

As the car and, then, your skeletal structure slows, your neck at first extends, then restrains your head. But since it is connected to the base of your skull, your head pivots and your chin slams into your chest and your head may impact the interior of the car. Keep in mind that with the big G forces, your 11 pound[3] head acts like it weighs 165 pounds (plus the multiplied weight of the helmet). There is no way your neck muscles can resist this pull.

Inside your body cavity, as your skeletal structure is restrained, your internal organs continue forward. Your organs crash into your skeleton and into each other – this is the third collision, the internal collision. As the energy dissipates, the car comes to rest and the belts snap you back against the seat. Your head is propelled back against the headrest. (Air bag systems may reduce this whip-lashing of the head.) Throughout all this, your arms and legs are also being severely jostled by the rapid deceleration that may exceed 15g.

All of these things happen in less than a quarter of a second. Researchers know about the exact sequence and the severity of the forces involved through filmed testing with heavily instrumented cars and crash dummies.

What doesn't happen…

The foregoing paragraphs describe a complicated sequence of events, many of which were engineered and tested to occur in just that sequence. By considering what did not happen, we get to see what can go wrong.

You didn't slip under the lap belt. Consequently the lap belt did not catch you in the gut and squeeze your innards. Your knees and legs were not jammed into the dash under a ton of violent force. Your upper torso did not slam into the steering column. In fact some of its forward momentum was dissipated as it pivoted on the shoulder strap.

Four Point, Five Point, and Six Point harnesses.

We are guessing about this. Up to this point, actual crash test data on the complete system (car, attachment points, seats, and belts) grounds our hypothetical scenario. Whatever belts your car came with met certain required tests. Engineers competent in the design of all the components resolved the issues that might produce unintended outcomes… at least so we hope.

First let's look at inherent problems once you move away from the OEM seat belts. Your after-market harness was probably engineered to do the job if installed in a certain way. The components probably underwent testing and the

complete harness may have been subjected to dummy/sled testing to comply with standards[4]. However, it was probably never tested just as you installed it; it was *not* attached as you attached it in a car *exactly* like yours. The harness is only one element of a system that also includes the seat, the belt anchors, and the car itself. Your installation may be unique in the entire world.

The primary reasons for installing aftermarket belts are to improve retention in normal track driving (low G) and to improve restraint in a crash (high G). Retention and restraint are not synonymous. Many aftermarket belt systems improve retention but may not significantly improve restraint.

With four-point belt systems the obvious problem is the tendency for the lap portion to be lifted up and off the pelvic bone even as the shoulder straps are simply tightened, let alone loaded in a crash. The momentum of the legs and hips pulls the body down and forward so that the belt catches in the gut causing serious internal damage as it squeezes internal organs up toward the chest cavity. There is research underway to develop four point belt systems for OEM applications but the characteristics of these systems bear little resemblance to currently available four point aftermarket belts.

There are a number of ways that harness systems can be configured with additional, “anti-submarine”, straps. Most commonly, a single strap is routed from the release buckle through a hole in the seat to the floor on a line 0-20 degrees towards the back of the car from a line tangent to the shoulder belts. This strap in a five point harness is effective in keeping the buckle from riding up into the midsection when the shoulder belts are tightened. This configuration has effective retention characteristics. It is also effective in restraining the driver in rear impacts. However, in a frontal impact the strap comes into play as an anti-submarine strap only after the lower torso has moved a significant distance. Additionally, the restraint force is borne on a particularly sensitive and weak part of the male body. The further forward the strap is mounted, the less effective it is – forward mounting will allow the buckle to move further up into the midsection as the lower torso moves forward.

Increasingly common, is the replacement of the single strap with a dual strap to form a six point harness. Generally, the dual strap, whether it is in the V-type, T-bar type, D-ring type, or “Hybrid” type configuration is mounted in the same manner as the single strap in the five point harness and has, at best, only marginally improved functionality.

To be effective the “anti-submarine” straps have to be short and routed diagonally backwards and sideways so that (1) they come into play early in the restraint sequence, (2) the restraint force is borne on the insides of the thighs, and (3) they are effective in a rear impact. The D-ring (a.k.a. formula style) configuration is, arguably, the most effective six point harness type. Properly mounted, this configuration can achieve both goals: improved retention and

improved restraint. A dramatic illustration of the motion of a well restrained test dummy in a 100G crash simulation can be seen at www.mgaresearch.com/Highlights/2003/Mar03/Century_Sled.htm.

Recently Bjorn did an informal survey of the cars in the paddock for a Lime Rock event. He could find deficiencies in the installation of almost every one. Here are some of the things he observed:

1. Lap belts attached too far behind seat.
2. Shoulder belts attached too far behind seatback.
3. Shoulder belts adjusted too short to allow lap belt to ride low and tight.
4. Shoulder belts positioned too wide to stay on shoulders in a crash.
5. Shoulder belts positioned too close to neck increasing likelihood of broken collar bone.
6. Shoulder belts anchored so far below shoulder level that compression of spine likely on impact.
7. “anti-submarine” strap routed around the front of the seat cushion
8. “anti-submarine” strap(s) mounted to likely cause serious groin injury in a crash.
9. Buckles secured belts to anchors without pivots. (This makes “dumping” and tearing of the belt more likely.)
10. Belts not correctly threaded through slots of three bar adjusters
11. Three bar adjusters positioned too far from anchor making slip more likely.
12. Belting frayed, sun bleached, and deteriorated.

There were doubtless other problems. Factory belts are anchored to points engineered to withstand the forces of impact. After-market belts are often anchored with fender washers and bolts in locations that may not withstand the forces of impact.

Many harness systems were installed in cars with adjustable seats. Under the best of circumstances the location of the anchors for the lap, shoulder and “anti-submarine” strap(s) would be optimum for only one combination of seat and seatback position. Most of these harnesses have adjustments that allow the owner to modify the length of each strap so that the lap belt is low and tight and the shoulder straps can be tightened without pulling the lap belt up. However, these adjustments are specific to seat position, and when the seat is moved forward or back they need to be re-adjusted; we suspect they seldom are.

After all of these considerations we hope you will feel motivated to re-examine your restraint system and give some serious thought to upgrading both the type of harness and the way it attaches to the car. If you have been thinking about forsaking your OEM seatbelts for a fancy after-market harness, perhaps you will be in a better position to discern whether it will really enhance your safety. Some useful information about harness belts can found at the FIA web site (www.fia.com) under the “Technical and Sporting Regulations” link and at www.bsrsafety.com/tips.

Motor sports are inherently dangerous and no restraint system makes driving at speed “safe” no matter how well installed. Careful choices and attention to installation details can significantly reduce risk.

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[1]:www-nrd.nhtsa.dot.gov/pdf/nrd-01/NRDmtgs/2001/1101Hinch_EDR.PDF
[2] www.nhtsa.dot.gov/kids/research/crashtest/index.html
[3] danny.oz.au/anthropology/notes/human-head-weight.html
[4] www.fia.com, www.sfifoundation.com, www.tuv.com