

Determination of the Pressure Distribution Beneath Two- and Three-Inch Wide Racing Safety Belts

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ABSTRACT

This study examines the static pressure distribution under both width belts in the shoulder and the pelvis of 15 volunteer subjects. The subjects applied the belt loads to themselves through a lever and pulley system. The configuration of the belts simulated the typical arrangement of a six-point belted upright-seated racing driver. The pressure distribution between the belt and the volunteer's body was determined and recorded with Tek-Scan pressure sensing grids. The paper presents the results of the measurements by comparing the actual area of significant loading beneath the two widths and materials of both lap and shoulder belts. In general, there no significant increase in loaded area for the wider belts.

INTRODUCTION

In the past, racing sanctioning bodies have required the use of three-inch (76 mm) wide shoulder and lap belts almost universally. Such belts are generally stiffer and stronger than their two-inch (50 mm) counterparts when made of the same nylon webbing. This added strength and stiffness was considered an advantage in providing effective restraint of the racing driver in a frontal crash.

The introduction of polyester webbing in racing safety belts has allowed the development of two-inch (50 mm) wide belts with the same stiffness and strength as three-inch (76 mm) wide belts. Restraint systems certified to SFI Standard 16.5 meet these requirements. With the issues of strength and stiffness differences eliminated between the two widths of polyester belts, the only remaining advantage of the wider belts was thought to be better distribution of the belt loads on the shoulders and pelvis. The stiffer polyester material may not be as flexible as the previously used nylon belts. This can result in

poor fit in the pelvic area, especially for smaller males and female drivers. Effective belt restraint requires very good fit of the pelvis in order to provide early restraint of forward pelvic motion.

The purpose of the study reported here was to determine the distribution of pressure of both widths of belts on volunteers with self-imposed loading on their shoulders and hips. Both nylon and polyester three-inch (76 mm) wide belts and polyester two-inch (50 mm) belt systems were evaluated.

METHODS

This study examined the static pressure distribution under both width and types of material belts in the shoulder and the pelvis of 15 volunteer subjects. The use of volunteers in this study was approved by the Wayne State University Human Investigation Committee. The volunteer subjects, healthy males and females aged 18 to 39 years old, were recruited by flyers. They were screened for pre-existing joint or spinal pain. A range of sizes and body types were chosen to represent the population of racecar drivers. The anthropometric characteristics of the subjects are listed in Table 1. The subjects applied the belt loads, either to the shoulders or the pelvis, to themselves through a lever and pulley system (shown schematically in Figure 1) in which pulling back on a steering wheel applied increased force, due to the amplification of the pulling load through the pulley system, to the belts. The configuration of the belts simulated the typical arrangement of a six-point belted upright-seated racing driver. Special load cells (Denton Indy Car biaxial load cells, Robert A. Denton, Inc. Rochester Hills, MI) measured the overall belt loads.

Volunteer	Height, inches	Weight, lbs.	Chest Circum- ference, inches	Pelvic Circum- ference, inches	Age, years	Sitting Height, inches
v01	64	128	35	34	19	34
v02	67	154	34	31	32	36.5
v03	67	130	34	32	30	36
v04	68	150	35	38	26	35
v05	70	200	40	42	26	34
v06	70	150	35	38	18	35
v07	70	175	37	37	19	35
v08	70	215	45.5	45	30	36
v09	62	135	35.5	39	30	31
v10	66	155	35.5	38	22	34
v11	71	210	43.5	39	25	36
v12	65	115	29	37	27	32
v13	67	122	34	32	39	36
v14	72	170	36	42	31	35
v15	70	215	44	43	30	34

Table 1. Volunteer Subject Anthropometry

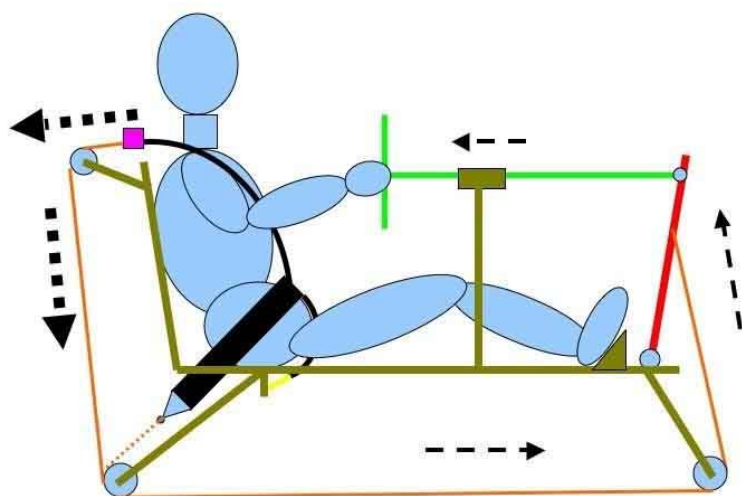


Figure 1. Schematic of Self-Loading System.



Figure 2. Typical Volunteer Test Configuration

The subjects were seated in the test frame and asked to put on the belt restraint system. After the belt restraint system had been adjusted for fit, the subject was asked to pull on the steering wheel to apply load to the belts (shown in Figure 2). At first this was only low-level loading to accustom the subject to the nature of the loading system. Once acclimated, the subject was asked to apply a series of increasing loads, working up to what they felt was maximal for them. After a brief rest period, the pressure measuring foil was placed either under the shoulder belt or the pelvis belt and the subject was asked to repeat the maximal loading sequence two times with rest periods between loading. This procedure was conducted six times, once for shoulder belt loading with both width belts and with both belt materials and once for lap belt loading with both width belts and both belt materials. A video record of the subject's test series was made.

In addition to the volunteer tests, an advanced anthropomorphic test device (ATD) called THOR was placed in the test fixture (shown in Figure 3) and shoulder belt loads only were applied at levels higher than the volunteers achieved to investigate the effect of a higher belt tension on the pressure distribution under the belts. THOR was chosen because of its relatively realistic shoulder structure.

The pressure distribution between the belt and the subject's body was determined and recorded with a Tekscan Pressure Measurement System (Tekscan Corporation, Boston, MA) which consists of a thin, flexible array of 96 pressure sensing pads arranged in six rows of sixteen pads (shown in Figures 4 and 5). The width of the sensor array was three inches (76 mm) and the length was 8 inches (203 mm). Figure 6 shows a typical distribution of pressures on the Tekscan pads for a three-inch wide polyester belt test. In order to simplify the analysis of the general pressure distribution across the belt width, a subprogram of the Tekscan I-Scan[®] analysis software was used to sum the pressures in each cell along the entire length of adjacent pairs of rows of Tekscan grid cells. For the two-inch wide belts, two sets of the four rows under one of the belts, denoted mid pad and inner pad, were analyzed. The summations of the two rows outside the two-inch (50 mm) belt were also reported as outer pad because of some sensitivity of the flexible array to bending and curvature. For the three-inch wide belts, three sets of two rows, also denoted outside pad, mid pad and inner pad, were analyzed.

There were three different belt systems used in these tests. The two-inch belts were a polyester Schroth 6-point belt system with two-inch wide shoulder and lap belts (denoted 2ps and 2pl, respectively in the data). The three-inch wide shoulder and lap belts were Simpson DSL type 6-point belt systems. The nylon belt system was a Simpson DSL (denoted 3ns and 3nl in the data). The polyester belt system was a Simpson Platinum DSL (denoted 3ps and 3pl in the data). The letters a and b at the end of each belt type designation refers to the first and second test for each system.

RESULTS

The results of the summed strip analysis for each volunteer can be found in Appendix A. The shoulder belt and lap belt loads applied by the volunteers ranged between 200 N (45 lbf) and 400 N (90 lbf) for an individual belt. These values depended on the size of the volunteer and, in some cases, the determination to exert themselves. The applied belt load on the THOR was about 600 N (135 lbf).

A typical example of the analysis is shown in Figure 6. Note that for the two-inch shoulder belt tests the predominant loading occurs on two adjacent rows of the grid. This is consistent throughout the data for all volunteers. Placement of the grid beneath the belt accounts for whether it is the outer- and mid-rows or the mid- and inner-rows. In contrast, the three-inch shoulder belts tended to produce loading on the outer- and inner-rows with reduced loading in the mid-row for both nylon and polyester belts. The THOR data shown in Figure 7 demonstrates these same features at higher belt loads.

The two-inch lap belt data was less uniform than the shoulder belt data. In particular, the larger subjects exhibited a distribution that was concentrated on the inner and outer edges of the two-inch lap belt. For the smaller subjects the distribution on the two-inch lap belt was more uniform. The distributions under the three-inch wide lap belts were rarely even across all three strips. In addition to edge loading, similar to that found in the three-inch shoulder belts, some of the larger subjects loaded only one edge heavily.

In general the peak strip loads were similar in magnitude for two-inch belts, three-inch nylon belts and three-inch polyester belts in both the shoulder and lap positions.



Figure 3. Tekscan Grid



Figure 4. Tekscan Grid in Place Under 2-inch (50 mm) Belt on THOR ATD