VOLUNTEER TESTS ON HUMAN TOLERANCE LEVELS OF PRETENSION FOR REVERSIBLE SEATBELT TENSIONERS IN THE PRE-CRASH-PHASE

PHASE I RESULTS: TESTS USING A STATIONARY VEHICLE

Bernd Lorenz, Dimitrios Kallieris, Peter Strohbeck-Kuehner, Rainer Mattern
Institute of Legal and Traffic Medicine, University of Heidelberg, Germany

Uwe Class, Michael Lueders
TRW Occupant Safety Systems, Alfdorf, Germany

ABSTRACT

It is the aim of this current study to define the maximum force of seatbelt pretension in the pre-crash-phase tolerable for a car passenger. This is attempted by volunteer tests using a car fitted with a prototype of a reversible system for belt pretension. The volunteers (14 f, 10 m, aged 16 to 73) represent a broad spectrum of car-users.

Up to now 64 tests were conducted in a stationary vehicle to determine the tolerable strain especially under Out of Position (OOP) conditions.

The head acceleration measured through accelerometers which were mounted on individually fitted dental adapters, was rather low in all tests with some increase for the OOP-experiments (a_{max}= 2,9 g).

Belt forces were 0,16 kN < F_{Bmax} < 0,29 kN.

Under the present test set up and conditions, the loadings were assessed by the test persons as tolerable and acceptable. In general, the belt forces measured with shorter and lightweight persons were higher than those measured with tall and heavier persons. This can be improved by a special algorithm e.g. in connection with a weight-sensor in the car seat so as to better adapt the system to the anthropometric parameters of the occupant.

Key words: reversible seatbelt tensioner, safety belts, volunteers, tolerances, soft tissue

ADVANCED RESTRAINT SYSTEMS are being intensively researched on, in order to improve the safety of car passengers. Reversible systems are the first step to integrate seatbelts into active safety of cars (pre-crash phase). The reversible seatbelt tensioner system is developed to reduce slack of the seatbelt system in critical situations of the vehicle. Further a better positioning of the occupant is achieved and Out of Position (OOP) situations can be avoided.

It is the aim of the current study to define the maximum force of belt pretension in the pre-crash-phase tolerable for a car passenger. This is attempted by volunteer tests using a car fitted with a prototype of a reversible system for belt pretension. The reversible belt tensioner is mounted at the B-pillar. Presently, the reversible tensioner is limited to the maximum belt forces measured by the performance of the motor available.

This study consists of two major parts. In phase 1, tests were conducted in a stationary vehicle to determine the tolerable strain especially under OOP conditions. Phase 2 consists of driving tests simulating emergency situations (in progress).

Several studies have been published on related subjects. There are some studies on effects and injury mechanisms of restraint systems, i.e. 3-point-belts and air bags in real collisions and under laboratory conditions (p. ex. Kallieris et al. [5]-[8]; see: References). However, no comparable studies were found on the effects of reversible seatbelt tensioners, that, on one hand, generate distinctly lower belt forces and belt velocities, but on the other hand, show performance characteristics over a much longer period of time in contrast to the pyrotechnic seatbelt tensioners, which ignite only on the occasion of a collision. In the meantime, some studies have been published on the problems of OOP during extreme driving manoeuvres, i.e. ABS braking and simultaneous evasive action. These studies emphasize the necessity for reducing the forward displacement of the passenger so as to take the passenger back to a defined better or ideal position (p. ex. Kümpfbeck et al. (1999, [9]) and Zuppichini et al. (1997, [24])).

METHOD

THE GROUP OF RESPONSIBLE TEST SUBJECTS: Fourteen female (aged 16-73 yrs) and ten male (aged 32-62 yrs.) persons, with two exceptions all members of the institute, volunteered for the experiments (cf. table in the appendix). Each participant received detailed instructions on the study and course of the experiment according to suggestions from the ethics commission. Participation was entirely voluntary and each test subject took responsibility for their own tests, continuing or discontinuing the experiment at any given moment without showing cause or incurring any disadvantage whatever.

KIND AND NUMBER OF TESTS: Each test subject would, generally, participate in at least two tests. Ten pre-tests were designed to give a rough idea of the involved forces and to test the measurement technology including its periphery.

A total of 64 tests (cf. tabular overview in the appendix) has so far been conducted. Wherever possible, each test subject would participate in one test for normal or ideal seating position („In Position" IP) and in one for an Out Of Position-situation (OOP).

Figs. 1+2: Examples of OOP-situations (V 39, V41)

For the first IP-test, each test subject could adjust the seat to a subjectively comfortable and relaxed seating position. The OOP-situation was also simulated according to personal preferences, ideally leaving the person doubled over with the head close to the dashboard (resembling the position while tying shoe-laces or reaching for a handbag, cf. Figs. 1 and 2).

MEASUREMENT

Points of measurement on the volunteers

Head acceleration was taken using individually fitted (if accepted by the volunteers) dental adapters (cf. Figs. 3 and 4) on which three uniaxial accelerometers were mounted. The dental adapters are similar to those used by Lorenz et al. (1999).

Fig. 3: impressions of the upper jaw with adapters

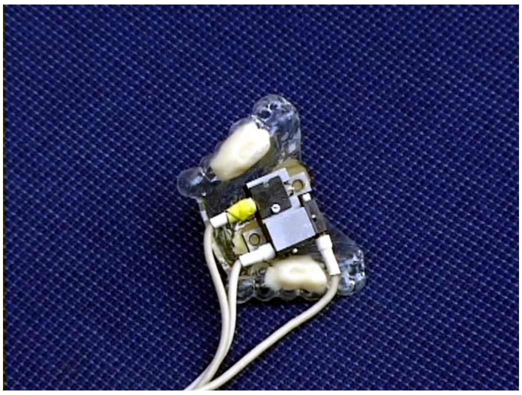

Fig. 4: Adapter with accelerometers

As parameters for physiological refernce, measurements of muscle tonus, skin surface resistance and pulse frequency were taken using a compact measurement equipment named BIOPAC developed by Dr. Maus Elektronik, Frankenthal (cf. Fig. 5)

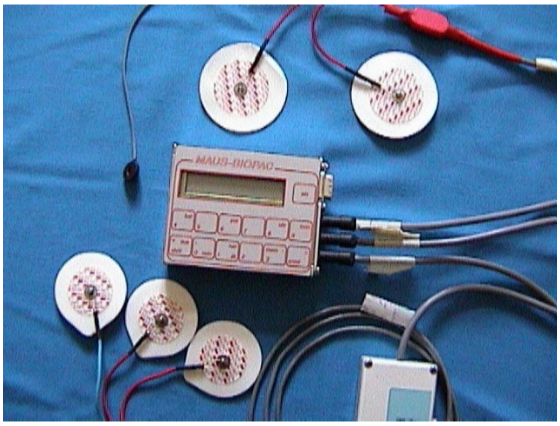

Fig. 5: BIOPAC with sensors for measuring muscle tonus, skin surface resistance, pulse frequency

Signals of muscle tonus were derived through three adhesive electrodes (two active, one passive, cf. Fig. 6) connected to the BIOPAC and attached to the skin of the test persons on the left shoulder next to the cervical vertebrae (trapezius muscle).

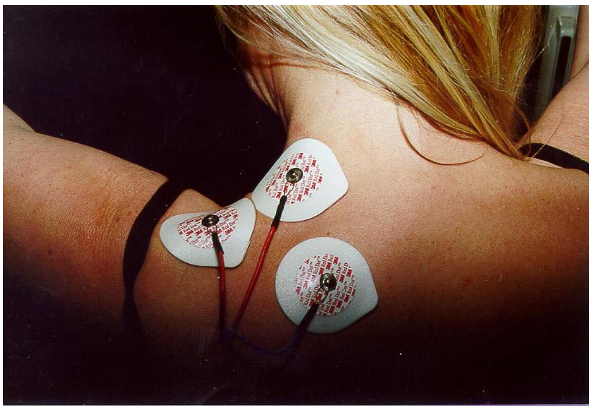

Fig. 6: Adhesive electrodes for measuring muscle tonus in position

Skin resistance was measured with two electrodes on the palms of the right hand.

Measuring pulse frequency on the right ear lobe turned out the be impracticable and unreliable, later infra-red measurements were carried out on the right arm.

The BIOPAC was modified several times throughout the current series of tests by Dr. Maus Elektronik (p. ex. Adjustment of sensitivity for muscle tonus measurements)

Measurement on the reversible belt tensioner system

Belt forces were measured through a belt force transducer attached to the seat belt at shoulder of the test person.

Belt movement was derived from the analysis of high speed video films.

For tests No. 59 to 64 an opto-electronic belt movement sensor was at our disposal (resolution 0,25 mm).

Belt velocity was calculated from the measured belt movement.

A measuring shunt for taking the motor current intensity was also available from test 59 onwards.

DOCUMENTATION: The tests were documented using a high-speed video camera (500 colour expositions per second) and standard video cameras.

Additional photographs were taken immediately before the tests to document the seating position.

PSYCHOLOGICAL ASSESSMENT AND PHYSIOLOGICAL PARAMETERS: Subjective statements whether a particular stimulus is rated as pleasant, neutral, or unpleasant not only depend on the stimulus itself but also on the person´s expectation, psychological well-being, and activation since these factors have an impact on the individual´s threshold of perception. Hence, in studies like this, it is necessary to consider that rather anxious persons have negative expectations that can lead to a lower threshold of perception and, consequently, to a more intense perception.

In order to control these effects in the present study, state of anxiety and subjective activation of the test subjects were assessed using the short form of the General Activation-High Anxiety-State-Scale (GA-HA-State-KF; Wieland-Eckelmann, 1992; a German adaption of the Activation-Deactivation-Check-List by Thayer, 1967). This self-report check-list consists of eight adjectives representing two sub-scales: „General Activation“ (GA) and „High Anxiety“ (HA). Immediately before the test, test persons were asked to fill in the check-list on how they actually feel.

In order to investigate potential effects of the test persons´ anxiety and activation on the rating of the present tests, the results obtained through the GA-HA-State-KF check-list of the present study were compared with the results of two other samples obtained in other settings using the same check-list. One sample to be compared were 180 persons undergoing a medical-psychological driver selection setting (sample I). The other sample consisted of 48 volunteers participating in an experiment on the impact of music on attention (sample II).

INTERVIEW AND PHYSICAL EXAMINATION: The test subjects were questioned concerning their personal impressions and examined physically by a medical doctor if necessary immediatly after each test. The interviews were documented on video and minuted.

The medical findings, if any, were documented.

RESULTS AND DISCUSSION

The results evaluated so far (belt forces, belt movement, belt velocity and head acceleration) are available in tabular form (maximum values) in the appendix. The table also includes the relevant anthropometric data for each test person.

The head acceleration was rather low in all tests with some increase for the OOP-experiments ($a_{cresmax}$= 2,9 g), which is why it was not recorded during later tests.

Belt forces were 0,16 kN < F_{Bmax} < 0,29 kN.

Fig. 7 shows a typical belt force time history for an OOP-test including the head acceleration time history of the test with the highest measured head accelerations. Fig. 8 shows the plots for a IP-test.

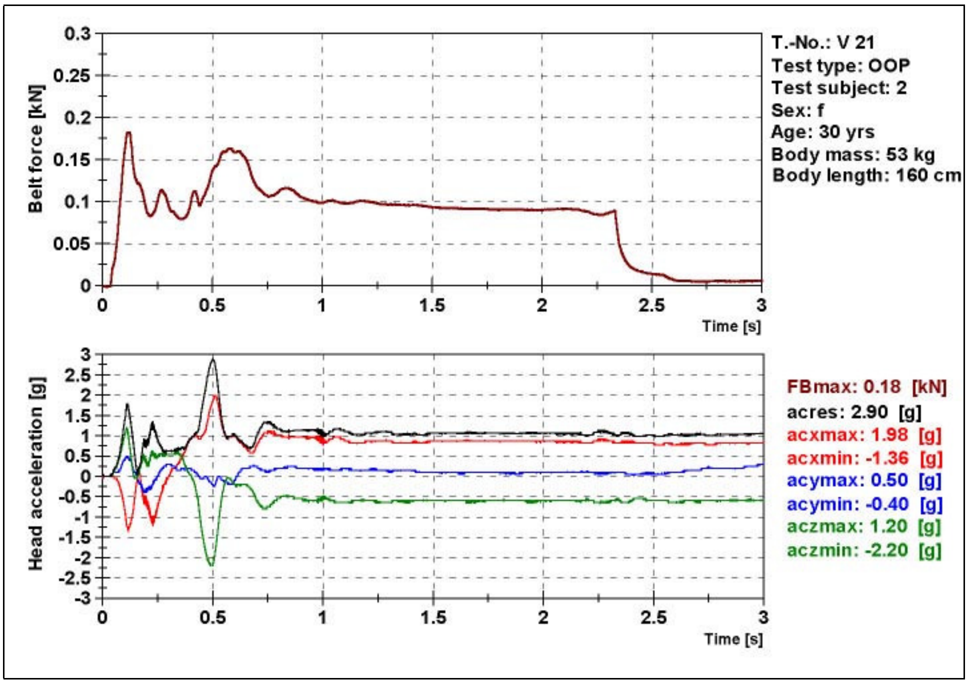

Fig. 7: Belt force and head acceleration of an OOP-test

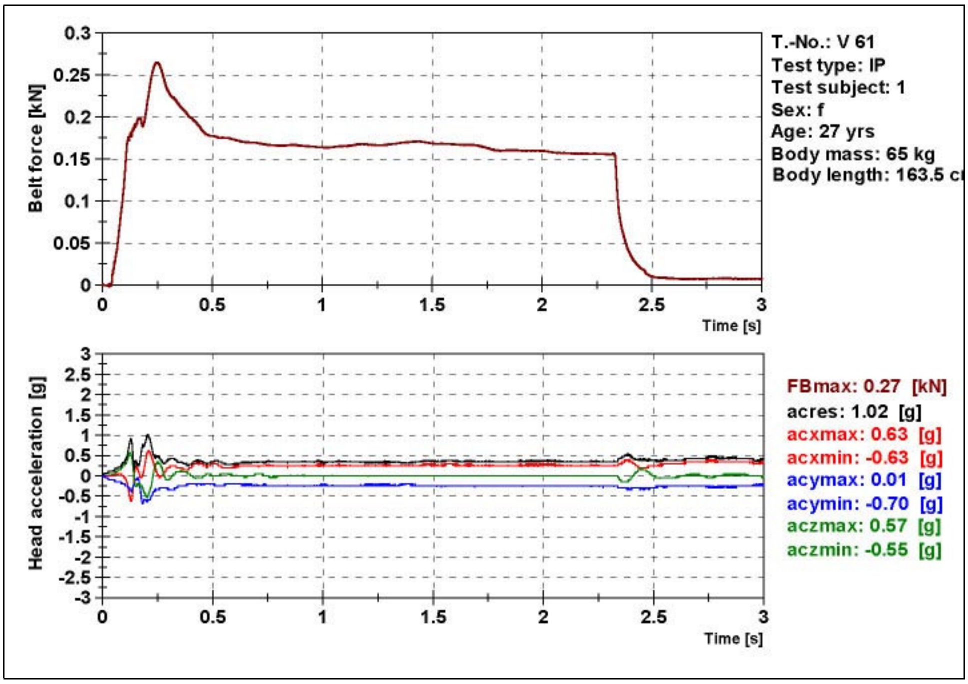

Fig. 8: Belt force and head acceleration of an IP-test

In general, it proved to be impossible to avoid a certain anticipation of test subjects, despite all efforts to the contrary in creating a relaxed and comfortable situation. This impression was also supported by physiological data (with reservation as to future data evaluation).

Only in one experiment (test subject 4), when, due to a defect in the switch, the tensioner was tightened inadvertently a second time was the test subject genuinely surprised while he was removing the dental adapter and electrodes. There were, however, no ill effects.

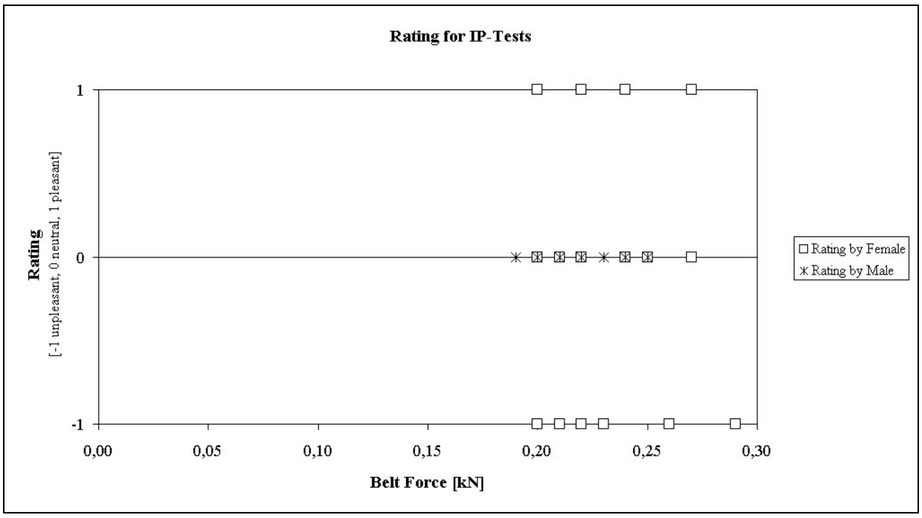

Fig. 9: Rating of volunteers for IP-tests

The male test persons suffered no discomfort during either the IP or with one exception the OOP tests (cf. Figs. 9 and 10). The system was felt to be neither particularly pleasant or unpleasant, at most as unproblematic and well tolerable. Two of the bigger and heavier male test subjects (numbers 6 and 20, 193 cm, 93 kg and 183 cm, 120 kg, respectively) doubted, however, that the belt force would be sufficient to pull them back from an OOP-position during braking.

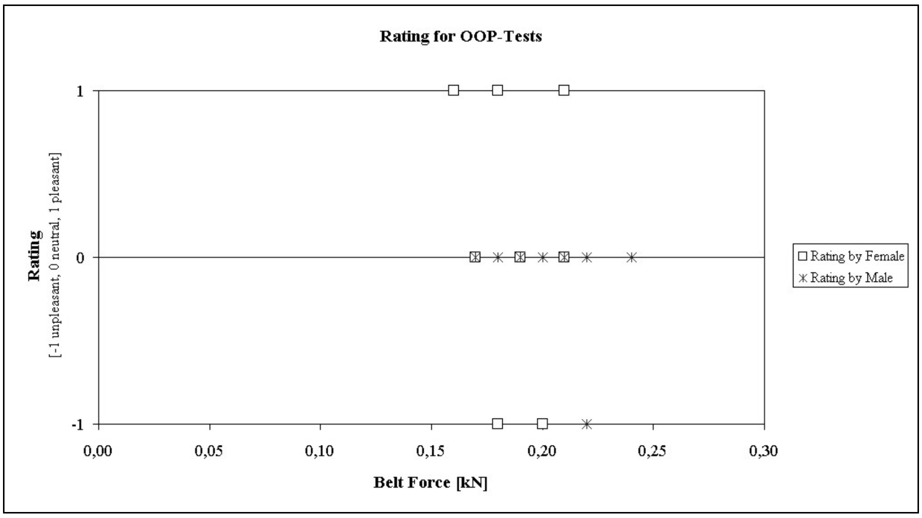

Fig. 10: Rating of volunteers for OOP-tests

Belt force tended to be higher in IP-situations (cf. Fig. 11) especially for lightweight and shorter persons. The highest measurement occurred in normal seating position during test 10, test subject 7, a female of 57 kg and 38 years old. The seat had been moved as far back as possible. The test subject criticized the system after the test as unpleasant and complained of the feeling of high pressure exerted on the thorax by the seat belt („thorax is compressed“). There were, however, neither lasting complaints nor medical findings on the skin.

After analysing high speed video films and comparing data from several tests, an assumption was made that the force of belt pre-tension was decicively influenced not only by seating position, body mass and height, but also by the clothes due to friction. Therefore, the test person 7 (f) was asked to repeat the test wearing different clothes (tests 45 and 46) and the same clothes as in the tests 10 and 15 (tests 47 and 48). The forces measured with clothes made out of synthetical fibres (95% polyamid and 5% elasthan) were higher than those measured with other fabrics.

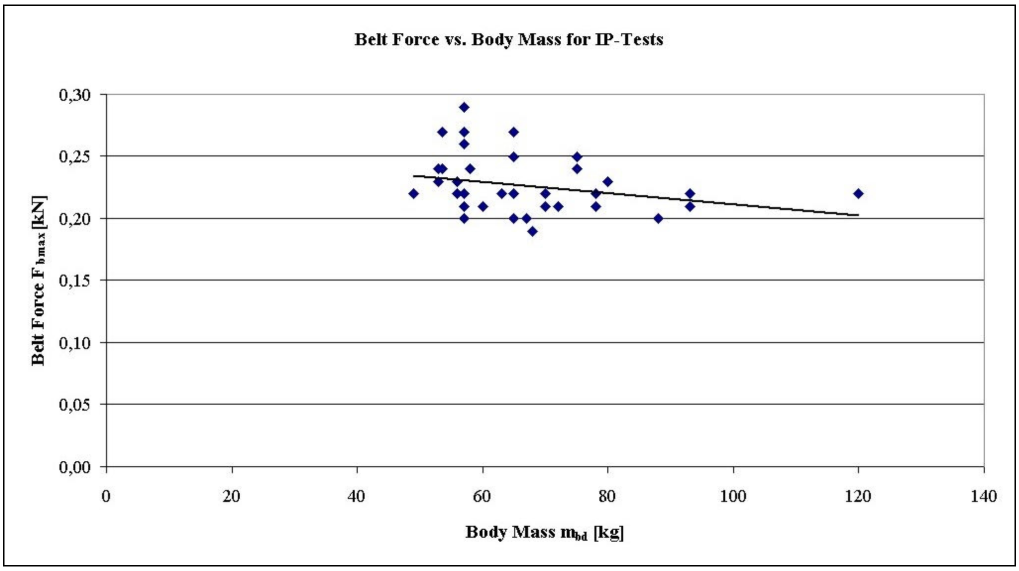

Fig. 11: Belt force vs. body mass for IP-tests

Belt force tended to be lower in OOP-situations (cf. Fig. 12), and subjective assessment of the system for OOP-situations also provided one unexpected result. Four female test subjects (7, 10, 14, 15) claimed the feeling of being pulled back from the OOP-position to be very pleasant.

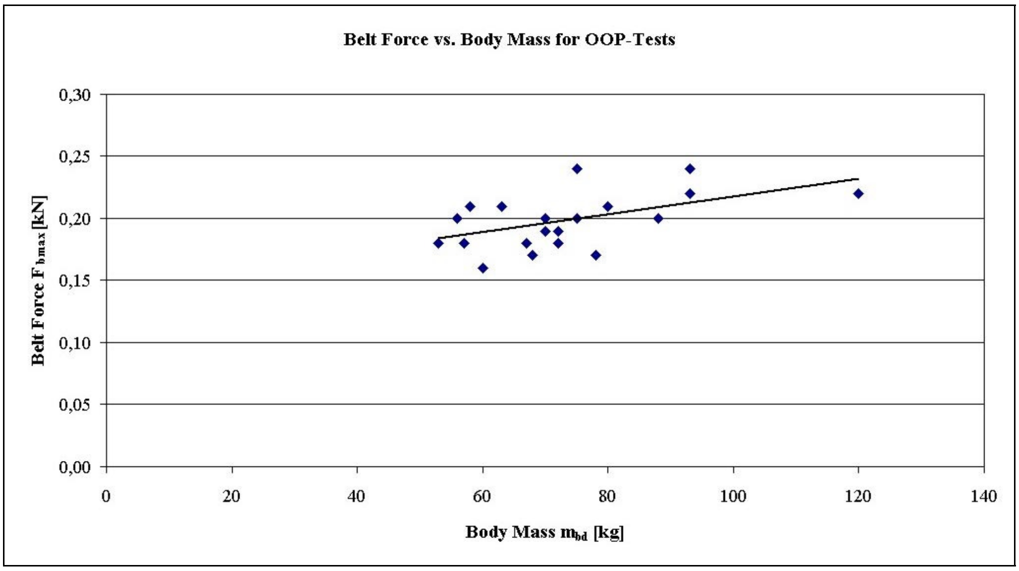

Fig. 12: Belt force vs. body mass for OOP-tests

One further unexpected result occurred for tests (40, 41) with a 16-year-old test subject (19), who already reported some slight pain on the clavicle even after the first test. She insisted on another (OOP) test, a medical examination immediately afterwards showed distinct redness of the skin. On the following day, both redness and pain had subsided entirely, but the impression of the belt on the skin was still clearly visible.

Although the test subject had earlier witnessed other tests and was in anticipation, she showed clear signs of being startled on the release of the system both times. It should be mentioned that her clavicles protrude slightly more than usual.

In order to verify this result, it was searched for more persons with similar protruding clavicles among the institute members. Two test subjects (23 and 24) were found and volunteered for the tests. They did not know what the aim of the tests was. Both test persons have not reported any problems in the area of clavicles; however, they rated the tests as rather unpleasant.

The oldest test subject (72 yrs, subject 16) claimed to have suffered no discomfort during either IP- or OOP-test (cf. Fig. 1). However, she, too, was clearly startled in both tests, notwithstanding her anticipation.

Fig. 13 shows the time histories of belt force, belt movement, belt velocity and motor current intensity for an IP-test with test subject 13.

The opto-electronic belt movement sensor was at our disposal only for the last IP-tests (tests No. V 59 to V 64). The measured belt movement is about 80 to 96 mm and similar to those values for IP-tests derived from high speed film analysis (80 to 105 mm).

The calculated belt velocity was about 1 m per sec.

The belt movement for the OOP-tests depends on the seating position respectively how far the test subjects were bent forward. The range was from 105 to 500 mm.

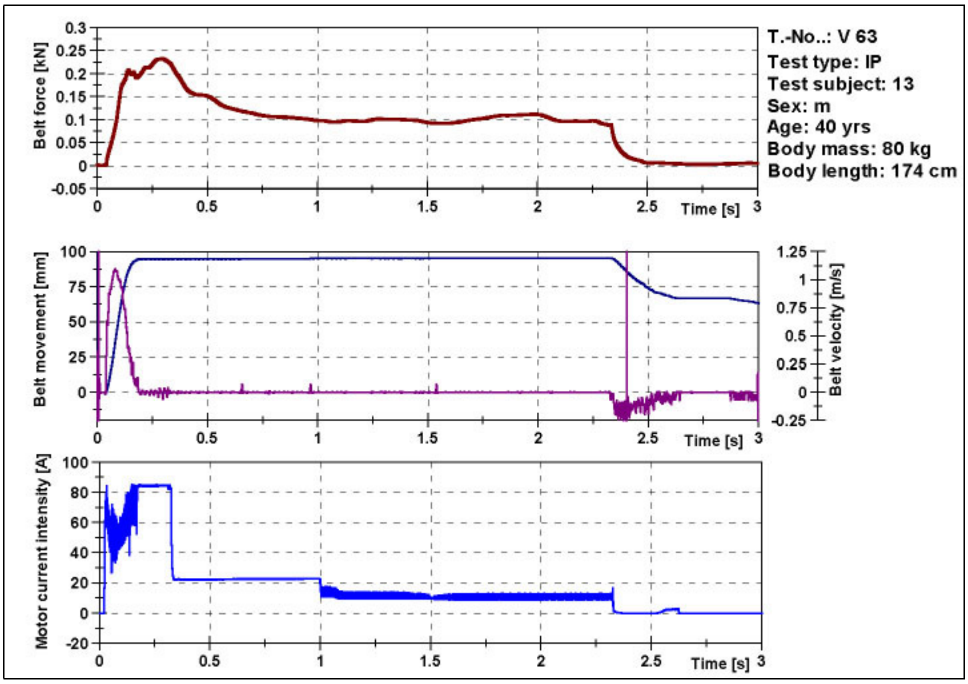

Fig. 13: Time histories of belt force, belt movement, belt velocity and motor current intensity

Out of the 64 tests, 11 tests were rated by test persons as pleasant, 40 as neutral (neither pleasant nor unpleasant), and 13 as unpleasant.

Regarding the effect that anxiety and activation might have had on the rating of the tests, the present study and samples I and II were compared. The mean of the sum-scores of the anxiety check-list was with 6.51 significantly lower ($p<0.01$) in the present study than the mean of sample I (8.87). In contrast, there was no difference to sample II (mean 7.08). As far as activation was concerned, the data of the persons in the present study were similar to those in sample I. In contrast, the test subjects of the present study reported a lower subjective activation than the volunteers of sample II.

These results show that the test subjects of the present study have not reacted to the test with any remarkable anxiety or increased activation. Consequently, the risk that the assessment of the stimulus was influenced by changes in the psychological well-being of the test subjects caused by a test situation can be rated as rather low.

Furthermore, it was analysed whether the test subjects who have rated the test as „unpleasant“ have, at the same time, reported increased anxiety or activation. Those test persons who have described the test as „unpleasant“ have shown a higher mean of state anxiety (7.37) than those who have assessed the test as „neutral“ or „pleasant“ (mean 6.32). In contrast, as far as the subjective activation was concerned, there have not been noticed any considerable differences in the means. Due to the small sample size of test subjects who have described the test as „unpleasant“, no further statistical analysis was performed.

CONCLUSIONS

Under the present test set up and conditions, the loadings applied by the prototype of the reversible belt tensioner were assessed by the test persons as tolerable and acceptable. However, risk groups (e.g. pregnant women or persons with osteoporosis) would need a separate assessment of their potential injury risk.

In general, the belt forces measured with lightweight and shorter persons were higher than those measured with tall and heavier persons. This could be improved by a special algorithm e.g. in connection with a weight-sensor in the car seat so as to better adapt the system to the anthropometric parameters of the occupant.

The represented results of the first phase of the project still have to be validated through driving tests that are already in preparation. Furthermore, the final version of the reversible belt tensioner (changed trigger and motor algorithms) would need a repeated examination through volunteers.

ACKNOWLEDGEMENTS

Special thanks to all our volunteer colleagues for their dedicated assistance without which this study would not have been possible.

REFERENCES

[1] Campbell, B. J.: Safety Belt Injury Reduction Related to Crash Severity and Front Seated Position. Journal of Trauma, Vol. 27, No. 7, pp. 733-739, 1987.

[2] DiPiro, P. J.; Meyer, J. E.; Frenna, T. H.; Denison, C. M.: Seat Belt Injuries of the Breast: Findings on Mammography and Sonography. AJR, Vol. 164, pp. 317-320, Feb. 1995.

[3] Evans, L.: Fatality Risk Reduction from Safety Belt Use. Journal of Trauma, Vol. 27, No. 7, pp. 746-749, 1987.

[4] Huelke, D. F.; Sherman, H. W.: Seat Belt Effectiveness: Case Examples from Real-world Crash Investigations. Journal of Trauma, Vol. 27, No. 7, pp. 750-753, 1987.

[5] Kallieris, D.; Mellander, H.; Schmidt, G.; Barz, J.; Mattern, R. Comparison Between Frontal Impact Tests with Cadavers and Dummies in a Simulated True Car Restrained Environment. Paper-No. 821170, Proc. 26. STAPP Car Crash Conf., P-113, pp.. 353-367, SAE, Ann Arbor, Mich.; USA, 1982.

[6] Kallieris, D.; Rizzetti, A.; Mattern, R.: The Biofidelity of Hybrid III Dummies. Proc. IRCOBI Conf., pp. 135-154, Brunnen, Switzerland, 1995.

[7] Kallieris, D.; Rizzetti, A.; Mattern, R.; Morgan, R.; Eppinger, R.; Keenan, L.: On the Synergism of the Driver Air Bag and the 3-Point Belt in Frontal Collisions. Paper No. 952700, Proc. 39. STAPP Car Crash Conf., P-299, SAE, San Diego, USA, 1995.

[8] Kallieris, D.; Del Conte-Zerial, P.; Rizzetti, A.; Mattern, R.: Prediction of Thoracic Injuries in Frontal Collisions. 16. ESV-Conference, P- 98-S7-O-04, pp. 1-14, Windsor, Canada, June 1-4, 1998.

[9] Kümpfbeck, M.; Oertel, D.; Pilatus, K.: Occupant Kinematics During Emergency Breaking - An Investigation with Regard to the Out of Position issue for Passengers. Proc. IRCOBI Conf., pp. 443-454, Sitges, Spain, 1999.

[10] Leung, Y. C.; Tarrière, C.; Fayon, A.; mairesee, P.; Delmas, A.: A Comparison between Part 572 Dummy and Human Subject in the Problem of Submarining. SAE Paper-No. 791026. 23. Stapp Car Crash Conf., 677-719, 1979.

[11] Leung, Y. C.; Tarrière, C.; Lestrelin, D.; Got, C.; Guillon, C.; Patel, A.; Hureau, J.: Submarining Injuries of 3 Pt. Belted Occupants in Frontal Collisions - Description, Mechanism and Protection. Proc. 26. STAPP Car Crash Conf., P-113, pp. 173-205, SAE Paper No. 821158, Ann Arbor, Mi., USA, 1982.

[12] Lorenz, B.; Kallieris, D.; Mattern, R.; Wienecke, P.: Volunteer and Dummy Tests for the Validation of Biomechanical Assessment Criteria under the Euro-NCAP: Proc. IRCOBI Conf., pp. 385-404, Sitges, Spain, 1999.

[13] Martinez, R.; Sharieff, G.; Hooper, J.: Three-Point Restraints as a Risk Factor for Chest Injury in the Elderly. The Journal of Trauma, Vol. 37, No. 6, pp. 980-984, 1994.

[14] Meßner, G.; Hübner, W.: Unfallforschung: Konsequenzen für die Auslegung von Rückhaltesystemen. Verkehrsunfall und Fahrzeugtechnik, Heft 7/8, S. 186-190, 1997.

[15] Otte, D.; Richter, M.: Häufigkeit und Mechanismen von Armverletzungen bei gurtgeschützten Pkw-Fahrern. Verkehrsunfall und Fahrzeugtechnik, Heft 1, S. 2-9, 1999.

[16] Patrick, L. M.; Trosien, K. R.: Volunteer, Anthropometric Dummy, and Cadver responses with Three and Four Point Restraints. Automotive Engineering Congress, SAE Paper-No. 710079, 1971.

[17] Sato, T. B.: Effects of Seat Belts and Injuries Resulting from Improper Use. Journal of Trauma, Vol. 27, No. 7, pp. 754-7758, 1987.

[18] Schmidt, G. Injury Patterns of Fatally Impacted Car Front Passangers in Regard to the Three-Point Seat Belt and Related Occupant Injury Modes. Int. Congress & Exposition, Detroit, Mich., USA, Paper-No. 870225, SAE, Feb. 23-27, 1987

[19] Siegel, J. H.; Mason-Gonzalez, S.; Dischinger, P.; Cushing, B.; Read, K.; Robinson, R.; Smialek, J.; Heatfield, B.; Hill, W.; Bents, F.; Jackson, J.; Livingston, D.; Clark, C. C. Safety Belt Restraints and Compartment Intrusions in Frontal and Lateral Motor Vehicle Crashes: Mechanisms of Injuries, Complications, and Acute Care Costs. The Journal of Trauma, Vol. 5, No. 34, pp. 736-759, 1993.

[20] Sleet, D. A.: Motor Vehicle Trauma and Safety Belt Use in the Context of Public Health Priorities. Journal of Trauma, Vol. 27, No. 7, pp. 695-702, 1987.

[21] States, J. D.; Huelke, D. F.; Dance, M.; Green, R. N.: Fatal Injuries Caused by Underarm Use of Shoulder Belts. Journal of Trauma, Vol. 27, No. 7, pp. 740-745, 1987.

[22] Thayer, R.E.: Measurement of Activation Through Self-Report. Psychological Reports 20, pp. 663-678, 1967.

[23] Wieland-Eckelmann, R.: Kognition, Emotion und psychische Beanspruchung. Hogrefe, Göttingen, 1992.

[24] Zuppichini, F.; Bigi, D.; Bachi, E.; Adamich, A. de: How Drivers Behave in Pre-Impact Emergency Situations. Proc. IRCOBI Conf., pp. 433-441, Hannover, Germany, 1997.

APPENDIX

Table 1: test data, anthropometric data and rating by volunteers for IP-Tests

appIP.xls IP Data IRCOBI

Test No.	Belt Force	Belt Mov.	Belt Vel.	Head Acceleration				Volunteer	Sex	Age	Body Mass	Body Length	Body Index	Seating Position		Rating
	Fb_{max}	s_b	v_b	a_{cx}	a_{cy}	a_{cz}	a_{cres}	No.			m_{bd}	l_{bd}	BI	IP/OOP	Type	by Volunteer
	[kN]	[mm]	[m/s]	[g]	[g]	[g]	[g]			[yrs]	[kg]	[cm]	[kg/m]			
VT 06	**0,19**	95	-	-0,2	-0,26	-0,36	0,38	5	m	54	68	169	40,24	IP	normal	neutral
V 32	**0,20**	100	-	0,32	-0,19	-0,55	0,64	15	f	33	67	170	39,41	IP	normal	neutral
V 35	**0,20**	90	-	0,2	0,25	-0,29	0,3	17	m	36	88	172	51,16	IP	normal	neutral
V 46	**0,20**	80	-	-	-	-	-	7	f	38	57	165	34,55	IP	normal	unpleasant
V 59	**0,20**	80	-	-0,44	0,2	-1	1,05	1	f	27	65	163,5	39,76	IP	normal	pleasant
VT 03	**0,21**	100	-	-0,22	0,1	-0,3	0,32	3	m	62	72	173	41,62	IP	normal	neutral
V 11	**0,21**	95	-	1,2	-0,36	-0,64	1,35	8	m	56	93	183	50,82	IP	normal	neutral
V 12	**0,21**	90	-	0,2	0,1	-0,3	0,36	3	m	62	72	173	41,62	IP	normal	neutral
V 22	**0,21**	80	-	-0,31	0,23	-0,55	0,58	11	m	43	70	169	41,42	IP	normal	neutral
V 29	**0,21**	90	-	0,44	-0,2	-0,5	0,63	14	f	56	60	165	36,36	IP	normal	neutral
V 47	**0,21**	85	-	-	-	-	-	7	f	38	57	165	34,55	IP	normal	unpleasant
V 51	**0,21**	90	-	-	-	-	-	18	f	59	78	170	45,88	IP	normal	neutral
V 52	**0,21**	70	-	-	-	-	-	22	m	32	72	176	40,91	IP	normal	neutral
V 64	**0,21**	96	1,15	-	-	-	-	7	f	38	57	165	34,55	IP	normal	unpleasant
VT 08	**0,22**	80	-	0,2	0,07	0,2	0,26	6	m	40	93	192	48,44	IP	normal	neutral
V 13	**0,22**	105	-	-0,96	1,03	0,85	1,23	9	f	53	63	164	38,41	IP	normal	pleasant
V 25	**0,22**	85	-	-	-	-	-	12	f	55	70	167	41,92	IP	normal	neutral
V 34	**0,22**	95	-	-	-	-	-	16	f	73	63	162	38,89	IP	normal	neutral
V 37	**0,22**	100	-	0,2	0,15	-0,31	0,34	18	f	59	78	170	45,88	IP	normal	neutral
V 43	**0,22**	80	-	-	-	-	-	20	m	51	120	183	65,57	IP	normal	neutral
V 45	**0,22**	90	-	-	-	-	-	7	f	38	57	165	34,55	IP	normal	unpleasant
V 50	**0,22**	90	-	-	-	-	-	21	f	33	56	168	33,33	IP	normal	pleasant
V 54	**0,22**	75	-	-	-	-	-	23	f	49	49	168	29,17	IP	normal	unpleasant
V 60	**0,22**	86	0,97	-0,53	0,69	-0,75	0,9	1	f	27	65	163,5	39,76	IP	normal	pleasant
VT 02	**0,23**	-	-	0,39	0,15	0,4	0,53	2	f	30	53	160	33,13	IP	normal	unpleasant
V 27	**0,23**	90	-	-0,29	-0,16	-0,2	0,36	13	m	40	80	174	45,98	IP	normal	neutral
V 40	**0,23**	90	-	-	-	-	-	19	f	16	56	165	33,94	IP	normal	unpleasant
V 49	**0,23**	70	-	-	-	-	-	2	f	30	53	160	33,13	IP	normal	unpleasant
V 63	**0,23**	95	1,07	-	-	-	-	13	m	40	80	174	45,98	IP	normal	neutral
V 14	**0,24**	90	-	0,93	-0,44	-1,25	1,53	10	f	31	58	162	35,80	IP	normal	neutral
V 20	**0,24**	90	-	0,68	-0,2	-0,59	0,8	2	f	30	53	160	33,13	IP	normal	neutral
V 56	**0,24**	280	-	-	-	-	-	4	m	38	75	177,5	42,25	OOP	wide forward bent	neutral
V 57	**0,24**	65	-	-	-	-	-	24	f	26	53,5	168	31,85	IP	normal	pleasant
V 62	**0,24**	80	1,05	-	-	-	-	2	f	30	53	160	33,13	IP	normal	neutral
VT 01	**0,25**	-	-	0,49	0,24	-0,76	0,88	1	f	27	65	163,5	39,76	IP	normal	neutral
V 55	**0,25**	70	-	-	-	-	-	4	m	38	75	177,5	42,25	IP	normal	neutral
V 48	**0,26**	95	-	-	-	-	-	7	f	38	57	165	34,55	IP	normal	unpleasant
V 15	**0,27**	80	-	0,27	-0,15	-0,25	0,31	7	f	38	57	165	34,55	IP	normal	neutral
V 58	**0,27**	60	-	-	-	-	-	24	f	26	53,5	168	31,85	IP	normal	pleasant
V 61	**0,27**	98	1,12	0,63	-0,7	0,57	1,02	1	f	27	65	163,5	39,76	IP	normal	pleasant
V 10	**0,29**	90	-	0,31	-0,15	-0,35	0,45	7	f	38	57	165	34,55	IP	normal	unpleasant

Table 1: Test Data, Anthropometric Data and Rating by Volunteers for IP-Tests

Table 2: test data, anthropometric data and rating by volunteers for OOP-Tests

appOOP.xls OOP Data IRCOBI

Test No.	Belt Force	Belt Mov.	Belt Vel.	Head Acceleration				Volunteer	Sex	Age	Body Mass	Body Length	Body Index	Seating Position		Rating
	Fb_{max}	s_b	v_b	a_{cx}	a_{cy}	a_{cz}	a_{cres}	No.			m_{bd}	l_{bd}	BI	IP/OOP	Type	by Volunteer
	[kN]	[mm]	[m/s]	[g]	[g]	[g]	[g]			[yrs]	[kg]	[cm]	[kg/m]			
V 30	**0,16**	300	-	-1,11	0,5	0,8	1,34	14	f	56	60	165	36,36	OOP	wide forward bent	pleasant
VT 07	**0,17**	185	-	-0,87	-0,68	0,61	1,13	5	m	54	68	169	40,24	OOP	forward bent	neutral
V 38	**0,17**	345	-	0,97	0,4	0,7	1,15	18	f	59	78	170	45,88	OOP	wide forward bent	neutral
V 16	**0,18**	290	-	-1,09	0,55	-0,8	1,19	7	f	38	57	165	34,55	OOP	wide forward bent	pleasant
V 21	**0,18**	400	-	1,98	0,5	-2,2	2,9	2	f	30	53	160	33,13	OOP	wide forward bent	unpleasant
V 33	**0,18**	480	-	0,98	0,45	-0,85	1,33	15	f	33	67	170	39,41	OOP	wide forward bent	pleasant
V 53	**0,18**	270	-	-	-	-	-	22	m	32	72	176	40,91	OOP	wide forward bent	neutral
V 18	**0,19**	135	-	-0,44	-0,1	0,4	0,56	3	m	62	72	173	41,62	OOP	forward bent	neutral
V 26	**0,19**	350	-	-	-	-	-	12	f	55	70	167	41,92	OOP	forward bent	neutral
V 31	**0,19**	350	-	1,21	-0,4	0,85	1,29	3	m	62	72	173	41,62	OOP	wide forward bent	neutral
VT 04	**0,20**	105	-	-0,7	-0,25	1	1,17	4	m	38	75	177,5	42,25	OOP	forward bent	neutral
VT 05	**0,20**	145	-	-1,32	0,25	1,4	1,89	4	m	38	75	177,5	42,25	OOP	in forward motion	neutral
V 23	**0,20**	360	-	1,84	0,45	-1,35	2,06	11	m	43	70	169	41,42	OOP	forward bent	neutral
V 36	**0,20**	290	-	*1,26*	*-1,67*	*-3,13*	*3,35*	17	m	36	88	172	51,16	OOP	forward bent	neutral
V 41	**0,20**	500	-	-	-	-	-	19	f	16	56	165	33,94	OOP	wide forward bent	unpleasant
V 19	**0,21**	390	-	1,03	0,55	-1,3	1,61	10	f	31	58	162	35,80	OOP	wide forward bent	pleasant
V 24	**0,21**	245	-	-1,11	0,45	1,25	1,72	9	f	53	63	164	38,41	OOP	forward bent	neutral
V 28	**0,21**	320	-	1,02	-0,63	-0,45	1,3	13	m	40	80	174	45,98	OOP	forward bent	neutral
V 39	**0,21**	300	-	-	-	-	-	16	f	73	63	162	38,89	OOP	wide forward bent	neutral
VT 09	**0,22**	120	-	-1,13	-0,3	0,75	1,36	6	m	40	93	192	48,44	OOP	in forward motion	neutral
V 42	**0,22**	340	-	-0,97	0,29	-0,8	1,05	8	m	56	93	183	50,82	OOP	forward bent	unpleasant
V 44	**0,22**	270	-	-	-	-	-	20	m	51	120	183	65,57	OOP	forward bent	neutral
V 17	**0,24**	180	-	0,58	0,25	0,33	0,71	8	m	56	93	183	50,82	OOP	forward bent	neutral
V 56	**0,24**	280	-	-	-	-	-	4	m	38	75	177,5	42,25	OOP	wide forward bent	neutral

Table 2: Test Data, Anthropometric Data and Rating by Volunteers for OOP-Tests