3.1 Publishable Summary

The following table summarises the project data

Project acronym and full name		ADSEAT Adaptive seat to reduce neck injuries for female and male occupants	
Contract Number		233904	
Date of start	01 October 2009	**Duration**	42 months
Coordinator details Name: Dr. Astrid Linder Title: Research Director, Traffic Safety Organisation: Swedish National Road and Transport Research Institute, VTI Address: Box 8072, 402 78 Göteborg, Sweden Telephone: + 46 31 750 2603 E-mail: astrid.linder@vti.se			

Consortium	**Participant Organisation Name**	**Participant Short Name**	**Country**
Statens väg- och transportforskningsinstitut		VTI	Sweden
Chalmers University		CHALMERS	Sweden
Ludwig-Maximilians-Universität Muenchen		LMU	Germany
Folksam Ömsesidig Sakförsäkring		FOLKSAM	Sweden
Technische Universität Graz		GUT	Austria
Université de Strasbourg		UdS	France
Stiftung Arbeitsgruppe für Unfallmechanik		AGU	Switzerland
Loughborough University		LU	United Kingdom
Humanetics Europe GmbH (name changed from FTSS as per 1 Jan 2011)		Humanetics	Germany
Fundacion Cidaut		CIDAUT	Spain
Volvo Personvagnar AB		Volvo	Sweden
Faurecia Sièges d´Automobile		FAURECIA	France

Web site: www.adseat.eu

Summary description of project context and objectives

The (Adaptive Seat to Reduce Neck Injuries for Female and Male Occupants) ADSEAT project is an EU funded project within the 7th Framework which started 1 October 2009 and will end 31 March 2013. The overall objective of ADSEAT is to provide guidance on how to evaluate the protective performance of vehicle seat designs aiming to reduce the incidence of Whiplash Associated Disorders (WAD), also known as whiplash injuries. The work concentrates on evaluating the protective performance of seats beneficial to female, as well as, male motor vehicle occupants. For this purpose a Finite Element (FE) model of an average female dummy will be developed. This new research tool will be used in conjunction with the currently available rear impact dummy of an average male, the Biofidelic Rear Impact Dummy (BioRID) II, when evaluating enhanced whiplash injury protection.

Context

Whiplash injuries sustained in vehicle crashes is a worldwide problem. It is estimated that annually 300 000 citizens suffer whiplash injuries in the European Union, of which 15 000 result in long term suffering with an associated socio-economic impact of approximately € 4 billion per annum (insurance estimates). In Sweden, such injuries account for ~70 percent of the costs for the insurance companies of injuries due to vehicle crashes. The majority of those experiencing initial neck symptoms recover within a week of the car crash, however, 5-10 percent of individuals experience different levels of permanent disabilities. Whiplash injuries occur at relatively low velocity changes (typically <25 km/h), and in impacts from all directions. Rear impacts, however, occur most frequently in crash statistics. It is firmly established that the whiplash injury risk is higher for females than for males, even in similar crash conditions. Injury statistics from the mid 1960´s until today all show that females have a higher risk of sustaining these injuries than males, ranging from 1.5 to 3 times higher. Females and males have different anthropometry and mass distribution. Such differences may influence the interaction of the upper body with the seat back rest and head restraint, and thus the injury risk.

Crash test dummies are used when developing and evaluating the occupant protection performance of a vehicle. The 50th percentile male crash test dummy corresponds to a ~90th - 95th percentile female with regards to stature and mass, resulting in females not being well represented by the existing low velocity rear impact male dummies: the BioRID and the RID3D. Consequently, the current seats and whiplash protection systems are primarily adapted to the 50th percentile male dummy available today, without considering female properties, despite a higher whiplash injury risk in females.

The detailed objectives of ADSEAT

The overall objective of ADSEAT is to improve seat design to reduce whiplash injury. The project will focus on innovative adaptive seat design that can be adjusted to provide benefit for both male and female occupants. By focusing project resources on the latter group, the influence of gender and additional factors on whiplash injury risk will be established. The project aims at establishing the properties for a model of an average female and to implement those in a FE model in order to provide an improved tool for the development and evaluation of adaptive systems, with special focus on protection against whiplash injuries.

The ADSEAT project is divided into seven Work Packages (WP) including management (WP6) and dissemination (WP7). The aims of the five technical WPs are:

To analyse real world data and perform literature review(WP1)
To establish biological data of females (WP2)
To develop a FE model of an average female (WP3)
To establish injury criteria and thresholds for females (WP4)
To develop a seat demonstrator illustrating how whiplash protection can be achieved for a wider population, using adaptive seat design. In addition, seat evaluation guidelines will be specified.(WP5)

Description of work performed and achievements within the ADSEAT project as of September 2012.

Real world data, WP1

A literature review and analysis of databases, available within the consortium, was carried out. The results showed that weight and height close to the average female is appropriate for a dummy model representing females. Analysis of insurance data indicates that the average weight and height for females reporting whiplash injuries correspond quite well with the average sized female among the European countries. Real world data analysis carried out showed that existing whiplash protection concepts are more effective for males than females. In the Driving Trials it was found that the head posture in driving situations most at risk for WAD lies in small ranges for lateral, longitudinal and rotational positions for about 50 percent of the traceable time.

Biological data, WP2

The anthropometry of the 50th percentile female for a rear impact crash dummy model was established in WP2 and the details of the specification formed part of the PhD thesis "Addressing Female Whiplash Injury Protection – A Step Towards 50th Percentile Female Rear Impact Occupant Models" by Anna Carlsson. The data were used as input for determining the seating for the downscaled BioRID 50F used in the WP4 sled testing, and the development of the EvaRID model in WP3.

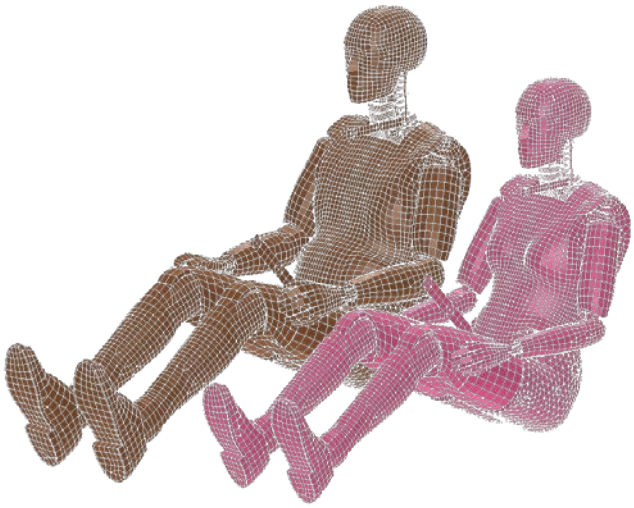
New volunteer tests comprising eight male and eight female volunteers were performed in November 2010 in a new laboratory seat that allowed for larger and more representative head restraint gaps. The analysis of the test results were carried out during 2011 and were later included in the second stage of the development and tuning of the FE model, EvaRID in WP3. The results gave new insights into differences between female and male occupants in terms of head and torso forward accelerations, and head relative to torso linear and angular displacements. In collaboration with WP3, an upgraded seat model was implemented and modifications to EvaRID were suggested by WP2, and implemented in WP3.

Whiplash testing included exposure in rearward, lateral and frontal direction collision scenarios. Variations in the acceleration pulse were used as means of illustrating the difference between female and male occupants. Pressure responses were found to be extremely sensitive to acceleration magnitude. This indicates that the higher T1 acceleration recorded in female volunteers compared to males, has a direct influence on the spinal loading and on the pressure magnitudes that are believed to cause nerve cell dysfunction in the

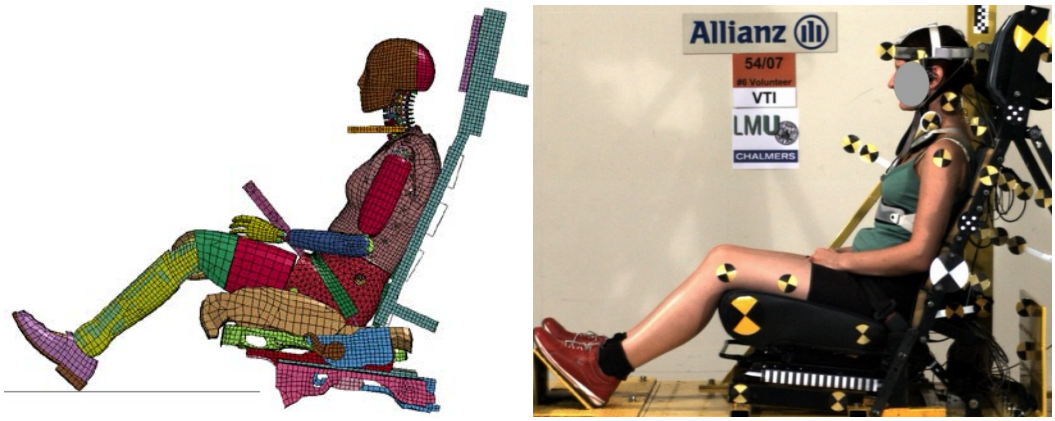
cervical posterior nerve root ganglia. The results support the recommendation by WP4 to decrease injury criteria levels for females. It demonstrates, in particular, the sensitivity of the Neck Injury Criterion (NIC) when predicting pressure transient magnitudes in the spinal canal. Post Mortem Human Subject (PMHS) tests comprising 4 individuals in a total of 16 tests have been finalised. High speed X-ray movies and high speed video recordings were obtained together with pressure recordings of the spinal canal. The pressure time histories and magnitudes were close to those recorded in the animal tests. Pressure sensitivity to acceleration magnitude also showed the same trends as in the whiplash tests.

Computational modelling, WP3

A FE dummy model of an average female, EvaRID, was developed in the computer code LS-Dyna. EvaRID is based on the same design concept as the 50th percentile male rear impact dummy, the BioRID II. The dynamic response of EvaRID was compared to data from rear impact tests comprising female volunteers. It was found that it was necessary to further adjust the stiffness of the spinal joints in order to fully mimic the motion of the volunteers. Evaluation of EvaRID against biomechanical requirements showed that the model response correlates reasonably well with the test data. Based on these results, model refinement was conducted to tune those parameters that influence the neck spine response.



The average female model, EvaRID V1.0, developed in the ADSEAT project and the average male model, BioRID II.



EvaRID V1.0 model run in a test set-up to compare its dynamic response to those recorded in volunteer tests run in the same test configuration.

Injury Criterion, WP4

WP4 addressed the topic of injury criteria and corresponding threshold values by analysing real-world data, performing computer simulations and conducting sled tests. All parts of WP4 were carried out as intended. The WP was completed and a corresponding report delivered.

To assess the female injury risk, modification of existing injury criteria, particularly the NIC and Nkm is suggested. The theoretical approaches considering the real-world injury risk were complemented by computer simulations and sled testing to investigate their practical applicability. Thereby the computer simulations made use of the EvaRID dummy model which was established in this project. Furthermore, computer simulations with a BioRID II dummy model, as well as, human body head-neck models of a male and a female were performed. For the performance of sled testing, a loading device representing the 50th percentile female anthropometry was developed (called BioRID50F).

The BioRID 50F, a prototype dummy of an average female developed in the ADSEAT project.

Sled testing with this device allowed direct comparison to the dynamic performance of the same seat models when loaded with the existing BioRID II. Eight sled tests were conducted in line with European New Car Assessment Programme (Euro NCAP) test procedure, using the prescribed medium severity crash pulse. Generally, the results confirm that different kinematics is to be expected when a seat is loaded with a loading device representing a female instead of a male. Sled testing and computer simulations indicated that the suggested modifications for female NIC were a good starting point. The work of WP4 when presented to the public received considerable positive attention, particularly among car manufacturers.

Seat Evaluation, WP5

Sled tests of four different currently available seats were performed with BioRID II. The seats were evaluated according to the Euro NCAP dynamic rating. Furthermore, the results of the sled tests provide a basis for the benchmark simulations and validation of a generic seat model. Within the benchmark, the differences of BioRID II and EvaRID were highlighted and the simulations results with the BioRID II were compared with the physical test results. The same seats were used in the benchmark studies and in the physical tests.

A prototype seat was optimised for female occupants, based on the benchmark results. This seat was built and will be tested with the BioRID II dummy. Simulation results of the prototype seat and the physical sled tests will highlight the properties of the optimised seat. FE simulations with the prototype seat, loaded with the BioRID and EvaRID models, will be performed to confirm that a single seat can be designed for different types of occupants. Furthermore, FE model simulations with a generic seat model were performed to determine the influence of different seat configurations on both males and females.

The development of a Design Illustrator (Illustrator) based on generic seat simulations with BioRID II and EvaRID has started. The Illustrator will be published on the project website, www.adseat.eu. . Once completed, the Illustrator will demonstrate the improved protection for male or female occupants, and be made available to the public. Finally, seat evaluation guidelines will be developed based on findings of the project. The work is in progress and will be published on the ADSEAT website. The guidelines constitute a part of the Illustrator.

Management, WP6

The work executed in the ADSEAT project has been performed on time and to a high standard. All beneficiaries have contributed with top quality involvement. The management of the project has arranged meetings, e.g., 5 Project Assemblies, AG meetings, etc., and has followed up on reports/activities/deliverables/deadlines, as well as, beneficiaries' commitment and work progress via e-mails and telephone. An updated version of Annex 1 was submitted and accepted on 21 September 2011 due to one beneficiary having been declared bankrupt.

Dissemination, WP7

The results of the ADSEAT project have resulted in numerous publications and presentations listed below.

Linder A (2010) Biomechanical Data for a Computational Model of an Average Female, *6th World Congress on Biomechanics*, Singapore.
Carlsson A, Siegmund G P, Linder A, Svensson M (2010) Motion of the Head and Neck of Females and Male Volunteers in Rear Impact Car-to-Car Tests at 4 and 8 km/h, *Int. IRCOBI Conf. on the Biomechanics of Injury*, Hannover, Germany.
Kullgren A, Krafft M (2010) Gender Analysis on Whiplash Seat Effectiveness: Results from Real-world Crashes, *Int. IRCOBI Conf. on the Biomechanics of Injury*, Hannover, Germany.
Schick S, Kullgren A, Tomasch E, Jakobsson L, Linder A, Gales N, Hell W, Schmitt K-U (2010) Basics for Developing a Female Occupant Model for Investigating Cervical Spine Distortion Injury (CSD), *ESAR conference,* Hannover, Germany.
Schick S, Thorsteinsdottir K, Horion S, Hell W (2010) Risikofaktoren für die Inzidenz des WAD (Whiplash Associated Disorder) - Unterschiede zwischen Mann und Frau? *Jahrestagung der Deutschen Gesellschaft für Rechtsmedizin,* Berlin, Germany.
Tomasch E (2010) Gleichberechtigung bei den Dummy modellen, *Virtual Vehicle Magazin, Virtual Vehicle Magazin,* Issue Number. 8, 2010-4.
Chang F, Carlsson A, Lemmen P, Svensson M, Davidsson J, Schmitt K-U, Zhu F, Linder A (2010) EvaRID, A dummy model representing females in rear end impacts, *Whiplash 2010 Neck Pain in Car Crashes Conference,* Munich, Germany.
Ljungdahl K (2010) Datormodell av en genomsnittlig kvinna ska minska pisksnärt-skadorna. *VTI aktuellt nr 4.*
Linder A, Svensson M, Carlsson A, Lemmen P, Chang F, Schmitt K-U, Kullgren A. (2011) EvaRID -Anthropometric and biomechanical specification of a finite element dummy

model of an average female for rear impact testing. *22nd ESV Conference;* June 13–16 Washington, USA.
Linder A (2011) Tool for evaluation of adaptive seat to reduce neck injuries for female and male occupants, *IQPC 6th International Conference Innovative Seating*, Frankfurt, Germany.
Kreuzinger, T (2011) Euro NCAP Whiplash Rating - Toyota Position & Proposal
Carlsson A (2011) EvaRID**:** A 50th percentile female Rear Impact Dummy FE Model, Fifth *International Whiplash Trauma Congress*, Lund Sweden.
Svensson M (2011) Whiplash injury research at Chalmers – A review including the latest developments in the EU-ADSEAT project. *2011 International Conference on Vehicle Noise, Vibration and Safety Technology" (ICVNVST2011) Chongqing, China*
Linder A (2011) EvaRID – a crash test dummy model of an average female, *Gender Summit,* 8 October, Brussels, Belgium.
Gales N, Kunz S.N, Hell W, Schick S (2011) Grundlagenforschung zur Verletzungsentstehung an Strukturen der Halswirbelsäule am Schwein, 20. Frühjahrstagung der DGRM-Süd in Verbindung mit dem 41. *Treffen der Oberrheinischen Rechtsmediziner, 20.05.2011,* Muenchen, Abstractband Seite 11
Carlsson A, Siegmund GP, Linder A, Svensson MY (2012) Motion of the Head and Neck of Female and Male Volunteers in Rear Impact Car-to-Car Impacts, *Traffic Inj. Prev.* Vol. 13. Issue 4.
Carlsson A (2012) Addressing Female Whiplash Injury Protection – A Step Towards 50th Percentile Female Rear Impact Occupant Models, *PhD thesis, Chalmers University.*
Linder A, Schick S, Hell W, Svensson M, Carlsson A, Lemmen P, Schmitt K-U, Tomasch E. (2012) ADSEAT – Adaptive Seat to Reduce Neck Injuries for Female and Male Occupants. *TRA Conference,* 23-26 April, Athens, Greece.
Linder A, Olsén, S, Eriksson, J, Carlsson A, Svensson M (2012) Influence of Gender, Height, Weight, Age, Seated Position and Collision Site related to Neck Pain Symptoms in Rear End Impacts, *IRCOBI Conference*, 12-14 September, Dublin, Ireland.
Carlsson A, Chang F, Lemmen P, Kullgren A, Schmitt K-U, Linder A, Svensson M (2012) EvaRID - A 50th Percentile Female Rear Impact Finite Element Dummy Model, *IRCOBI Conference,* 12-14 September, Dublin, Ireland.
Schmitt K-U, Weber T, Svensson M, Davidsson J, Carlsson A, Björklund M, Jakobsson L, Tomasch E, Linder A (2012**)** Seat testing to investigate the female neck injury risk – preliminary results using a new female dummy prototype, *IRCOBI Conference,* 12-14 September, Dublin, Ireland.
Gutsche A, Tomasch E, Sinz W, Cerrillo X, Levallois I, Schmitt K-U, Weber T, Steffan H (2012) Basic comparison of the injury risk of a male and female dummy model in rear impact collisions, *IRCOBI Conference*, 12-14 September, Dublin, Ireland.

Two newsletters have been published, describing the most recent results of the project and distributed to more than 600 e-mail recipients. Most of the email addresses were collected from the Cover Dissemination Database. The newsletters are available for download from the ADSEAT website. ADSEAT Newsletter # 1 containing 4 pages was sent in November 2011 to 608 recipients, out of which 31.3 % opened the newsletter. ADSEAT Newsletter # 2 containing 5 pages, was sent in June 2012 to 613 receivers, 30.8 % of the recipients opened the second newsletter.

Three AG meetings were held to receive feedback on current work and take further steps to improve in accordance with experts' opinions and needs. The ADSEAT AG consists of representatives from: Toyota Europe, Saab Automobile, IIHS (Insurers Institute for Highway Safety), JARI (Japan Automobile Research Institute), BASt (German Federal Highway

Research Institute), pdb (Partnership for dummy technology and biomechanics), NHTSA (National Highway Traffic Safety Administration) and MAPFRE Insurers.

The expected final results and their potential impact and use (including the socio-economic impact and the wider societal implications of the project so far)

The final result of the project has to a certain extent been achieved in that the following has been completed: A world first dummy model of an average female has been developed. The FE model is called **EvaRID** (Eva female, RID – Rear Impact Dummy). License for the usage of EvaRID is available from the ADSEAT partner Humanetics. The developed FE model of an average female makes it possible, for the first time in the history of crash testing, to address occupant protection for both female and male.

Furthermore, the anthropometry of the average female for a rear impact crash dummy model was established based on data found in the scientific published literature. Data from volunteer tests using male and female volunteers in identical test conditions were collected and analysed. Corridors for dynamic female response were established. New volunteer tests were performed in a seat that allowed for larger head restraint gaps. These results will be scientifically published under the remaining part of the project, and thus made available to the community.

In addition, a prototype dummy model of an average female, named **BioRID 50F** has been constructed. These models have been used as research tools in conjunction with the current low severity rear impact model of an average male when assessing the safety performance of car seats. The BioRID 50F, when presented to the public, received considerable positive attention, particularly among car manufacturers. The prototype dummy model, BioRID 50F, has been run in seats in the same test conditions performed by Euro NCAP. The comparison shows that different seat designs can have a substantial different influence on the dynamic response of an average sized male or female occupant in a rear impact. These results show how vehicle safety assessment can be improved and have the potential to influence the consumer and legislation testing, and thus reduce the risk of soft tissue neck injuries in the future. The usage and specifications of the BioRID 50F will be scientifically published under the remaining part of the project and thus made available to the community.

The socio economic impact of the project will be established during the remaining time of the project. A Design Illustrator based on generic seat simulations with BioRID II, the dummy model of an average male, and EvaRID, the dummy model of an average female, is under development. Once the Illustrator is completed it will be available to the public on the ADSEAT website, www.adseat.eu., to demonstrate the improved protection male and female occupants will have in a rear-end car crash.

The address of the project public website

www.adseat.eu