

# OTEKON 2018

## 9. OTOMOTİV TEKNOLOJİLERİ KONGRESİ

INTERNATIONAL AUTOMOTIVE TECHNOLOGIES CONGRESS

ULUSLARARASI OTOMOTİV TEKNOLOJİLERİ KONGRESİ

07 - 08 Mayıs / May 07<sup>th</sup> - 08<sup>th</sup> 2018  
Sheraton Hotel / BURSA

PROCEEDINGS / BİLDİRİLER KİTABI

Editors / Editörler

Dr. Öğr. Üyesi Erol SOLMAZ, Prof.Dr. Necmettin KAYA, Prof.Dr. Ferruh ÖZTÜRK



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Uludağ Üniversitesi Mühendislik Fakültesi  
Uludag University Engineering Faculty  
Otomotiv Mühendisliği Bölümü  
Automotive Engineering Department

Uludağ University Engineering Faculty  
Automotive Engineering Department

## **OTEKON 2018**

**ULUSLARARASI 9. OTOMOTİV TEKNOLOJİLERİ  
KONGRESİ BİLDİRİLER KİTABI**

**Proceedings of the International 9<sup>th</sup>  
Automotive Technologies Congress  
May 7-8, 2018, Bursa, Türkiye**

**Editörler / Editors :**

Dr. Erol Solmaz,

Prof. Dr. Necmettin Kaya

Prof. Dr. Ferruh Öztürk

**BURSA – 2018**

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Uludağ University Engineering Faculty  
Automotive Engineering Department

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## ÖNSÖZ / PREFACE

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*The International 9th Automotive Technologies Congress was held at the Sheraton Hotel from 7 to 8 May, 2018, in Bursa, Türkiye. It is our pleasure to express gratitude to all those who attended this congress and made this event a great success with 587 attendees. The International 9th Automotive Technologies, OTEKON 2018 took place in Bursa with technical papers, posters, keynote speeches and exhibitions.*

*We do express our sincere thanks to all of keynote speakers, authors presented their works, reviewers, scientific and advisory committee members and sponsors for their great support to make this event a great success.*

*The first Automotive Technologies Congress (OTEKON2002) was organized in Bursa in 2002, subsequent seven OTEKON Conferences were held in every two years in Bursa. In the past decades, Türkiye has achieved remarkable growth and enhancements in automotive industry and has become one of the important automobile manufacturers. Bursa is the city of one of Turkey's leading automotive industry region where there are several automotive production factories in Bursa and in the near region of Bursa. Bursa is the city which is also known for its rich history and culture.*

*OTEKON 2018 Congress was a unique platform to gain an insight on the latest research activities and discuss the trends that related to the latest automotive technologies and their applications in automotive industry.*

*Focused on automotive technologies and their industrial applications, Proceedings of The International 9th Automotive Technologies Congress consist of technical papers and posters through the theoretical works and industrial applications.*

*The International 10th Automotive Technologies Congress (OTEKON 2020) will be held in April, 2020 in Bursa, Türkiye. We look forward to welcoming you to OTEKON2020 Congress, join us at this major event in beautiful city Bursa.*

**Congress Chair**

**Prof. Dr. Ferruh Öztürk**

Automotive Engineering Department  
Uludağ University

## **BİLİMSEL PROGRAM / SCIENTIFIC PROGRAM**

---

### **07 MAY 2018, Monday**

|               |   |
|---------------|---|
| 08.30         | <b>Registration</b>   |
| 09.30 - 09.45 | <b>Opening Ceremony</b><br><br>Ergun Türkay ( BUSİAD President )<br>Baran Çelik ( UİB President / Beyçelik Holding CEO )<br>Prof.Dr. Yusuf Ulcay ( Uludağ University Rector )   |
| 09.45 - 11.00 | <b>Keynote Speakers</b><br><br>Prof.Dr. Jac Wismans ( SAFETEQ, The Netherlands and SAFER / Chalmers University of Technology, Sweden )<br>Prof.Dr. Thomas Tröster ( Paderborn University, Institute for Automotive Lightweight Design (LiA), Germany )<br>Prof.Dr. Giuseppe Carbone ( Politecnico di Bari, Dipartimento di Meccanica, Matematica e Management, Italy )<br>Prof.Dr. Orhan B. Alankuş (Okan University, ARPROGED Coordinator Engineering Faculty, İstanbul )<br><br><b>Moderator</b><br>Doç.Dr. İbrahim Korkmaz (TOFAŞ Türk Otomobil Fabrikası A.Ş., Bursa) |
| 11.00 - 11.15 | <b>Coffee Break</b>   |
| 11.15 - 13.00 | <b>Keynote Speakers</b><br><br>Erkan Polat ( TOFAŞ - R&D Product Engineering Director )<br>Çağlayan Altınok ( OYAK-RENAULT – R&D Director )<br>Ozan Nalcıoğlu ( FORD Otomotiv Sanayi A.Ş. – Engineering Director )  |
| 13.00 - 14.00 | <b>Lunch</b>  |

14.00 - 15.30 TECHNICAL SESSIONS

15.30 - 16.00 **Coffee Break**

16.00 - 17.30 TECHNICAL SESSIONS

17.30 - 18.00 **Coffee Break**

18.00 - 20.00 TECHNICAL SESSIONS

**08 MAY 2018, Tuesday**

09.00 - 10.30 TECHNICAL SESSIONS

10.30 - 11.00 **Coffee Break**

11.00 - 12.30 TECHNICAL SESSIONS

13.00 - 14.00 **Lunch**

14.00 - 15.30 TECHNICAL SESSIONS

15.30 - 16.00 **Coffee Break**

16.00 - 17.30 TECHNICAL SESSIONS

17.30 - 18.00 **Coffee Break**

16.00 - 17.30 TECHNICAL SESSIONS

18.00 - 20.00 TECHNICAL SESSIONS

20.00 **Closing Ceremony**

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## ASSESSMENT OF THE HUMAN BODY DISCOMFORT IN THE VEHICLE

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### ABSTRACT

Driver comfort is one of the most important tasks of vehicle manufacturers. In the design stage and vehicle seat development, a posture of vehicle drivers is a critical factor that has to be considered carefully. Long-term driving can affect driver performance, especially in an inadequate posture. In this paper, different angles of the seat back are considered, with the aim of determining the optimal positions of the driver. Position while driving and resting condition, hands on the body, are also examined. Anthropometrics characteristics of the driver has significant role in vehicle design. The anthropometric data of male and female subjects of eleven populations were analyzed; 1% and 99% of the population were used. Software package Ramsis was used to perform posture analysis of “mannequin” in driving and resting condition. The obtained values of fatigue and discomfort, as body parts discomfort, were different for all kinds of subjects.

**Keywords:** vehicle, driver, Ramsis, fatigue, discomfort

### 1. INTRODUCTION

Vehicle manufacturers design their product to fully meet the needs of passengers, both for safety and comfort. The description of comfort has been widely studied, but a clear definition could not yet be established. Comfort is a subjective phenomenon (Looze, continued, 2003). Many researchers have studied factors that influence subjective comfort (Helander and Zhang, 1997), (Vink, 2005), (Kuijt-Evers, 2007), (Zenk, 2008). Factors include posture, muscular activity, pressure, stiffness and suspension of the seat cushion and backrest. These studies concluded that there is a relationship between comfort and measured factors (age, anthropometry, vibration, body parts in contact, etc.).

It is necessary to know certain knowledge in order to fulfill all the requirements in the right way. Ergonomics is a science that helps manufacturers makes vehicles as comfortable as possible. This science has several roles. The first is to increase the efficiency and productivity of production, then the improvement of health, and finally the safety and comfort man in his work environment (Bridger, 2009). There is a possibility to know in advance the possibility of driver movement during driving process, using knowledge of this science and modern technology, such as computer-aided design and numerical simulations. Using digital human models (Duffy, 2008) the assessment of discomfort is done through a discomfort assessment method such as RULA (McAtamney and Corlett, 1993), REBA (Hignett and McAtamney, 2000), etc.

Performing different movements in driving process, driver is fatigued. Driver posture is one of the most important issues to be considered in the vehicle design process. A review of contemporary literature shows that physical fatigue is mainly caused by driving posture (Porter and Gyi, 1998). Appropriate seat backrests proved to decrease loads on the spine (Hirao, continued, 2006), (Graf, 2004), (Lapa, continued, 2000). The optimal seatback inclination ranges between 100 and 110 ° to horizontal (Schmidt, continued, 2014).

In this paper, the digital human models are used in order to enable determination of the fatigue and discomfort, as well as body parts discomfort, for different sitting positions. Eleven different male populations were analyzed. The driving and resting condition of all models were investigated in the virtual environment of the lower medium class vehicle (Fig. 1). The influence of the anthropometric data of male of eleven populations on the fatigue and discomfort, in two different sitting conditions, were investigated. For this purpose, the software packages Catia v5 R18 and Ramsis (Rechnergestutztes Anthropometrisches Mathematisches System zur Insassen-Simulation) were used, (URL 1). Software package enable to set a mannequin at a specific position and to analyze its environment.

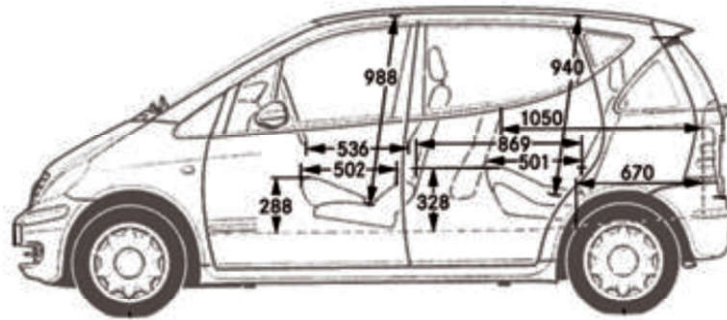


Figure 1. Dimensions of the vehicle

## 2. METHODS

For many years in the automotive industry digital human models have application for testing purposes. This way show how the vehicle's design and the position of the various components meet driver's needs. Definition of the final layout of a vehicle from an ergonomic point of view requires knowledge about body dimensions of the driver. The first task of this study was to create a working environment of the mannequin in the vehicle. The Catia v5 R18 software package (Part Design and Assembly modules) was used for vehicle interior modeling. The next task was to set the mannequin in the sitting position and to set boundary conditions (figure 2) by application of Ramsis software. This software has the option to operate with two types of human models - kinematic and geometric. The first takes into account the human skeleton and it is wire frame model, while the second represents surfaces. Geometric model of the mannequin with five fingers, and foot legs with shoes were used in this paper.

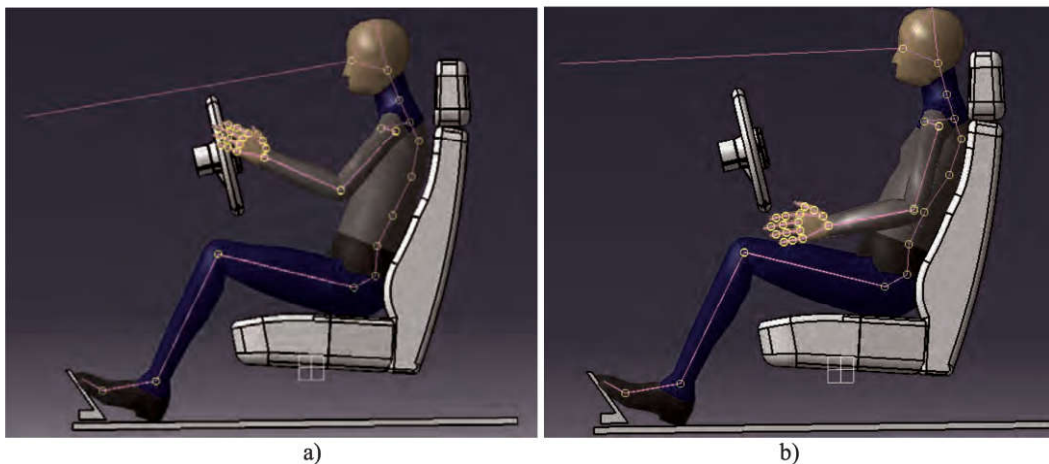


Figure 2. Modeled environment inside the vehicle: a) driving condition, b) resting condition

Eleven different male and female populations which anthropometric data are presented in Tables 1 (URL 2), are analyzed in this paper. These populations belong to the age group of 18-70 years, both for 1% female and 99% male populations. Seat backrest angle was determined with respect to horizontal plane and angles of 80°, 85°, 90°, 100° and 105° were analyzed. Passengers were in driving and resting conditions (figure 2 a and b),

**Table 1.** The anthropometric data of analyzed 1% female and 99% male populations [16]

| Population        | Height (mm) |      | Sitting height (mm) |      | Foot length (mm) |     | Shoulder breadth (mm) |     |
|-------------------|-------------|------|---------------------|------|------------------|-----|-----------------------|-----|
|                   | 1%          | 99%  | 1%                  | 99%  | 1%               | 99% | 1%                    | 99% |
| West Africa       | 1402        | 1833 | 720                 | 906  | 206              | 286 | 341                   | 462 |
| North India       | 1412        | 1805 | 750                 | 940  | 199              | 278 | 305                   | 429 |
| Eastern Europe    | 1502        | 1885 | 814                 | 980  | 217              | 293 | 354                   | 506 |
| North Europe      | 1541        | 1952 | 823                 | 1020 | 217              | 288 | 353                   | 514 |
| Australia         | 1521        | 1933 | 810                 | 1000 | 212              | 286 | 331                   | 506 |
| South East Europe | 1485        | 1865 | 790                 | 970  | 212              | 293 | 358                   | 499 |
| Central Europe    | 1518        | 1845 | 903                 | 1010 | 212              | 298 | 357                   | 509 |
| South East Africa | 1442        | 1815 | 750                 | 930  | 202              | 288 | 348                   | 479 |
| Middle East       | 1496        | 1838 | 780                 | 967  | 214              | 288 | 348                   | 486 |
| South India       | 1351        | 1755 | 723                 | 897  | 194              | 273 | 318                   | 449 |
| North Asia        | 1469        | 1874 | 780                 | 986  | 199              | 285 | 341                   | 479 |

The goal of the vehicle manufacturer is to design vehicles comfortable to wide a human population for 1% female and 99% male population. The most vehicle designers are focused on 5% female and 95% male population. Widening of vehicle users populations enable more massive vehicle production. Besides vehicle safety, improvement of the vehicles ride comfort is very significant task for vehicle designers. Determination of ride comfort or discomfort in vehicle in the sitting condition can be conducted in field conditions, laboratory conditions and it is confronted with expensive and long lasting investigations on humans. The RAMSIS software, enables vehicle comfort analyzes and assessment by application of different human manikin in different vehicles interiors. Assessments of discomfort respect to whole body and different human body parts can be performed. The data for comfort assessment was acquired through experiments conducted on more than 100 subjects in sitting conditions (Ramsis, 2012). Discomfort and fatigue is defined by numeric values based on performed experiments. Comfortable sitting and driving is valued as 2.5. Discomfort value assessed higher than 5.5 represents very uncomfortable conditions.

The health assessment of the spinal column is based upon an assessment model which converts the posture-related angular misalignment of vertebral bodies against one another into increased pressure loads on the intervertebral disks, from which in turn the model derives a damage assessment. In line with medical findings, the load in the area of the lumbar spine is the most intensive. The posture of the lumbar spine has therefore the most influence by far on health assessment in RAMSIS, followed by that of the cervical spine - the thoracic spine has the least influence of all (Ramsis, 2012).

### 3. RESULTS

The RAMSIS posture prediction is based on statistical analysis of results obtained from the conducted experiments, (Ramsis, 2012). After obtaining the anthropometric data of the virtual driver population, digital human models was generated with appropriate degrees of freedom. By application of abovementioned software and ECE/TRANS/180/Add.3 standards (URL 3), the analysis of the interactions between driver and seat, driver and steering wheel, and driver and pedal were conducted, in order to determine the fatigue and discomfort. Example of the obtained results is given in figure 3. The red column shows the results while driving, while the yellow column shows the assessment in the resting condition. Difference column represents the difference between red and yellow columns.

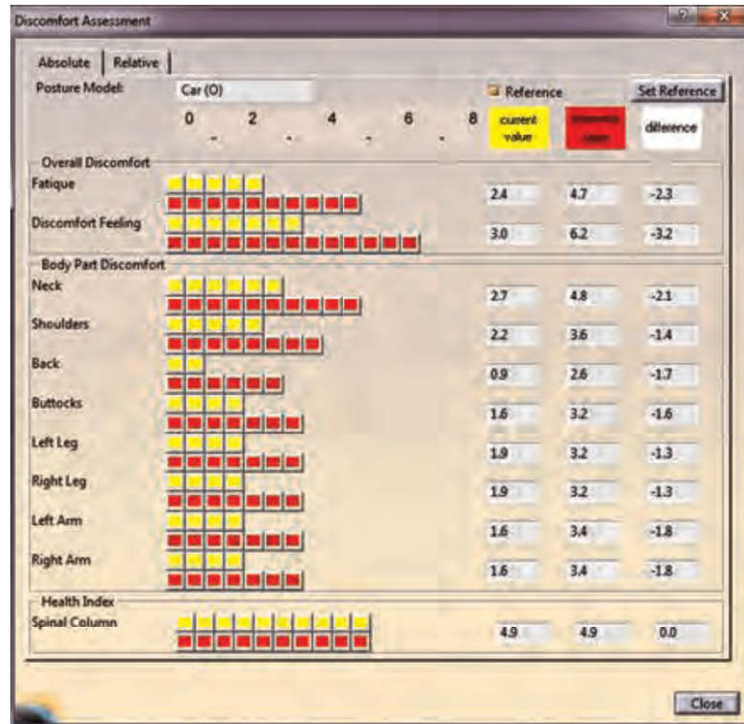


Figure 3. The results of discomfort assessment in the case of West Africa 99% population

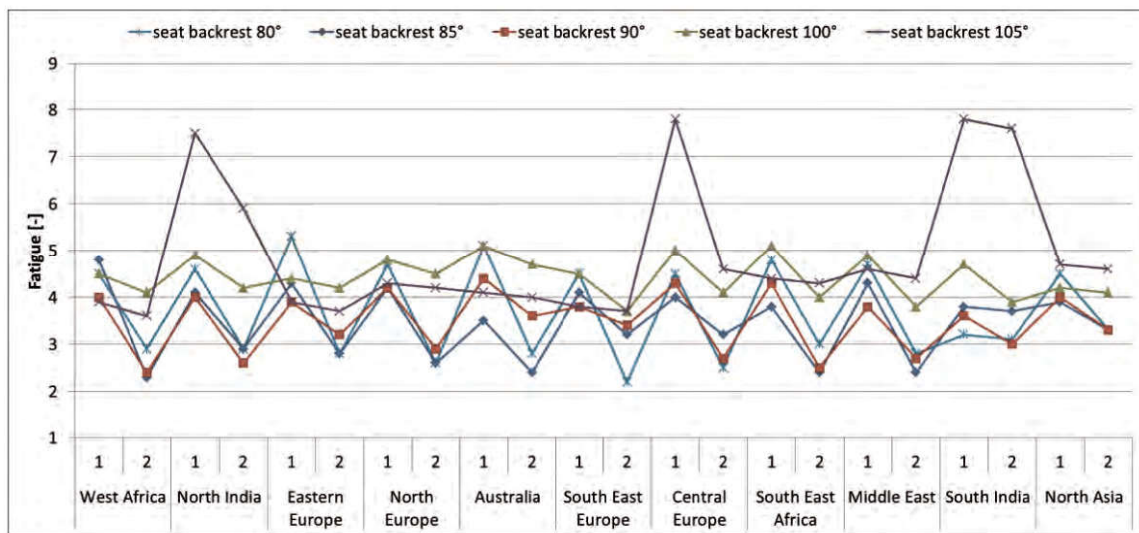
Partial results of the discomfort analysis for different seat backrest angles in different sitting position are given in figure 4 and figure 5. Descriptive statistics of fatigue values for both populations are given in table 2. The lowest fatigue values are for 90° seat backrest angle. For 1% female population fatigue and discomfort values are the lowest for angle of 85° respect to mean value of data, Table 2 and Table 3. Increase of seat backrest angle caused increase of discomfort in both sitting condition. Driving condition is more uncomfortable than resting position of human for both populations. Discomfort values are higher than recommended 5.5. Observed female population feels higher discomfort than male population.

Table 2. Descriptive statistics data of fatigue values of 1% female and 99% male populations

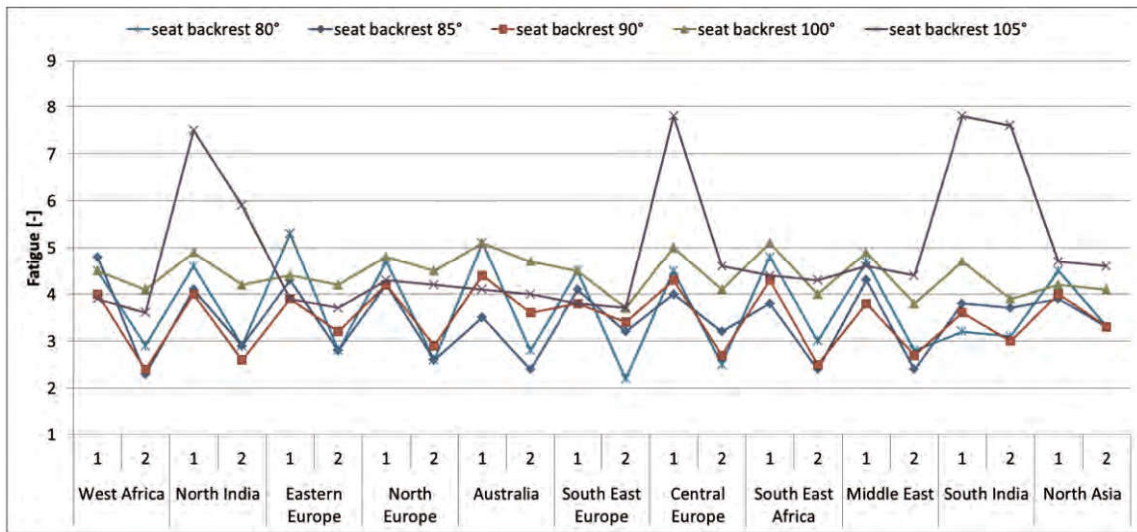
| Seat backrest angle, ° | Fatigue [-] |          |                |          |           |          |           |          |                    |          |
|------------------------|-------------|----------|----------------|----------|-----------|----------|-----------|----------|--------------------|----------|
|                        | mean        |          | standard error |          | Median    |          | mode      |          | standard deviation |          |
|                        | 1% female   | 99% male | 1% female      | 99% male | 1% female | 99% male | 1% female | 99% male | 1% female          | 99% male |
| 80                     | 3.69        | 2.74     | 0.213          | 0.079    | 3.25      | 2.65     | 4.5       | 2.5      | 0.999              | 0.375    |
| 85                     | 3.45        | 2.55     | 0.159          | 0.075    | 3.6       | 2.5      | 2.4       | 2.3      | 0.746              | 0.355    |
| 90                     | 3.48        | 2.41     | 0.137          | 0.052    | 3.6       | 2.35     | 4         | 2.3      | 0.644              | 0.244    |
| 100                    | 4.42        | 2.54     | 0.091          | 0.191    | 4.45      | 2.20     | 4.50      | 2.00     | 0.427              | 0.897    |
| 105                    | 4.48        | 4.32     | 0.305          | 0.094    | 4.35      | 4.40     | 4.60      | 4.40     | 1.432              | 0.441    |

**Table 3.** Descriptive statistics data of discomfort values of 1% female and 99% male populations

| Seat backrest angle, ° | Discomfort [-] |          |                |          |           |          |           |          |                    |          |
|------------------------|----------------|----------|----------------|----------|-----------|----------|-----------|----------|--------------------|----------|
|                        | mean           |          | standard error |          | median    |          | mode      |          | standard deviation |          |
|                        | 1% female      | 99% male | 1% female      | 99% male | 1% female | 99% male | 1% female | 99% male | 1% female          | 99% male |
| 80                     | 4.93           | 3.63     | 0.318          | 0.124    | 4.45      | 3.45     | 6.4       | 3.4      | 1.492              | 0.585    |
| 85                     | 4.66           | 3.11     | 0.254          | 0.115    | 4.95      | 3        | 2.9       | 2.6      | 1.194              | 0.540    |
| 90                     | 4.77           | 2.98     | 0.227          | 0.072    | 5.05      | 2.9      | 5.9       | 2.9      | 1.066              | 0.338    |
| 100                    | 5.68           | 3.20     | 0.164          | 0.263    | 5.60      | 2.80     | 6.30      | 2.50     | 0.771              | 1.234    |
| 105                    | 5.83           | 5.56     | 0.239          | 0.161    | 5.50      | 5.35     | 4.80      | 5.20     | 1.123              | 0.775    |



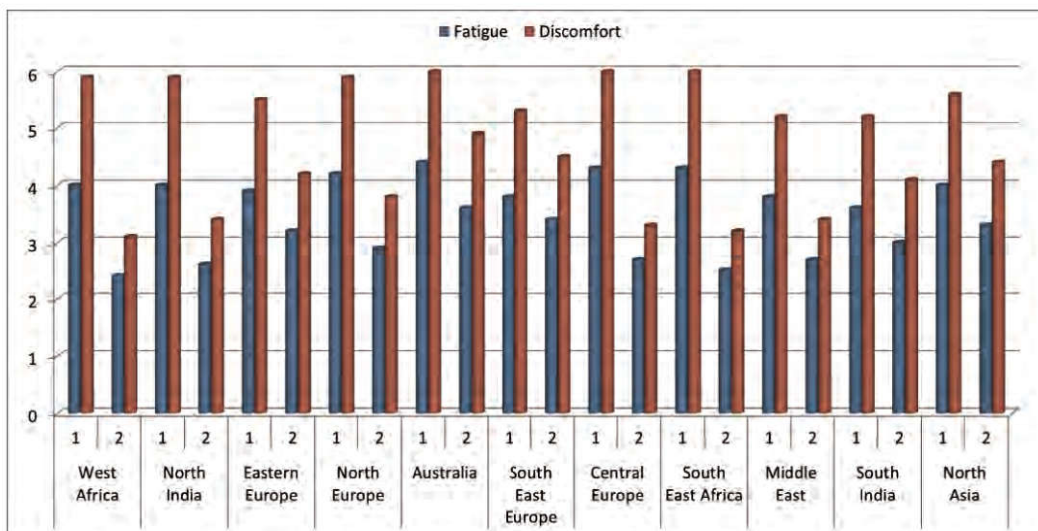
**Figure 4.** The discomfort analysis of 99% male population in driving (1) and resting position (2) under different seat backrest Angle



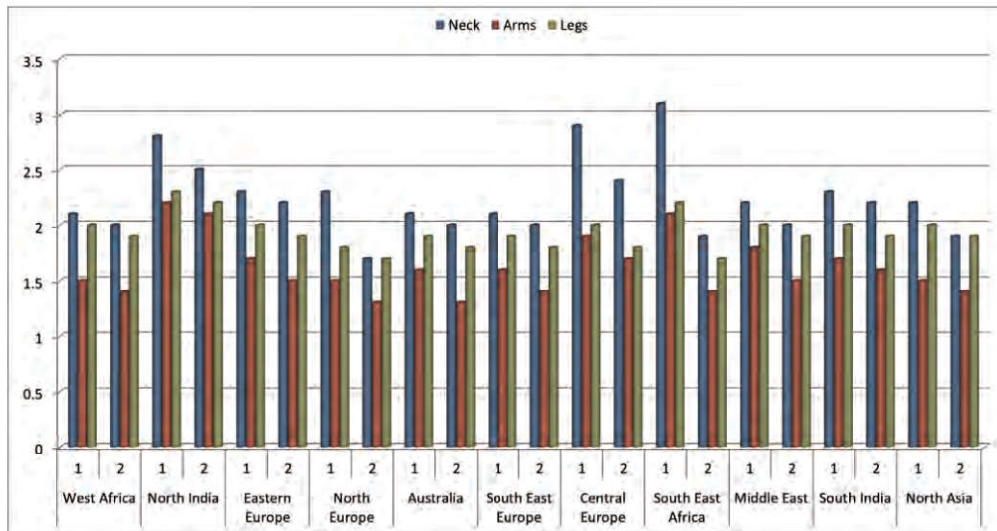
**Figure 5.** The discomfort analysis of 1% female population in driving (1) and resting position (2) under different seat backrest angle

Based on data partially presented in figures 4 and 5 can be noticed that fatigue values for female 1% population is higher than for male 99% population for both sitting condition.

The most uncomfortable sitting position is with seat backrest angle of 105°. In worst seat backrest angle condition (105°) maximum values of discomfort and fatigue for both human populations is driving condition (1), Table 4.



**Figure 6.** The discomfort and fatigue analysis of 1% female population in driving (1) and resting position (2) under 90° seat backrest angle



**Figure 7.**The discomfort body part assessment of 99% male population in driving (1) and resting position (2) under 90° seat backrest angle

Correlation coefficients between discomfort and fatigue values are height and sitting height are determined for seat backrest angle 105° and are given in Table 5.

There is negative correlation between fatigue and discomfort and height of female population is given in Table 5. Positive and strong correlation can be observed between height of male population and discomfort.

**Table 4.** Descriptive statistics of discomfort values of 1% female and 99% male populations for seat backrest angle 105° in driving position (1) and resting position (2)

|                         | Fatigue |        | Fatigue |        | Discomfort |        | Discomfort |        |
|-------------------------|---------|--------|---------|--------|------------|--------|------------|--------|
|                         | 1       | 2      | 1       | 2      | 1          | 2      | 1          | 2      |
|                         | Female  | Male   | Female  | Male   | Female     | Male   | Female     | Male   |
| Mean                    | 5.164   | 4.536  | 4.600   | 4.109  | 6.045      | 6.227  | 5.627      | 5.091  |
| Standard Error          | 0.499   | 0.128  | 0.356   | 0.108  | 0.377      | 0.192  | 0.300      | 0.087  |
| Median                  | 4.400   | 4.600  | 4.300   | 4.100  | 5.600      | 6.400  | 5.500      | 5.200  |
| Mode                    | 3.900   | 4.600  | 3.700   | 4.400  | 4.800      | 6.300  | 4.600      | 5.200  |
| Standard Deviation      | 1.655   | 0.425  | 1.182   | 0.359  | 1.250      | 0.637  | 0.995      | 0.288  |
| Sample Variance         | 2.741   | 0.181  | 1.396   | 0.129  | 1.563      | 0.406  | 0.990      | 0.083  |
| Kurtosis                | -0.815  | -0.256 | 3.955   | -1.602 | -1.141     | 1.677  | 0.112      | -0.749 |
| Skewness                | 1.085   | -0.423 | 1.958   | -0.391 | 0.747      | -1.453 | 0.957      | -0.473 |
| Range                   | 4.000   | 1.400  | 4.000   | 0.900  | 3.100      | 2.100  | 3.000      | 0.900  |
| Minimum                 | 3.800   | 3.800  | 3.600   | 3.600  | 4.800      | 4.800  | 4.600      | 4.600  |
| Maximum                 | 7.800   | 5.200  | 7.600   | 4.500  | 7.900      | 6.900  | 7.600      | 5.500  |
| Sum                     | 56.800  | 49.900 | 50.600  | 45.200 | 66.500     | 68.500 | 61.900     | 56.000 |
| Count                   | 11.000  | 11.000 | 11.000  | 11.000 | 11.000     | 11.000 | 11.000     | 11.000 |
| Largest(1)              | 7.800   | 5.200  | 7.600   | 4.500  | 7.900      | 6.900  | 7.600      | 5.500  |
| Smallest(1)             | 3.800   | 3.800  | 3.600   | 3.600  | 4.800      | 4.800  | 4.600      | 4.600  |
| Confidence Level(95.0%) | 1.112   | 0.285  | 0.794   | 0.241  | 0.840      | 0.428  | 0.669      | 0.193  |

Applied software enables assessment of discomfort level for part of the human body, figure 7.

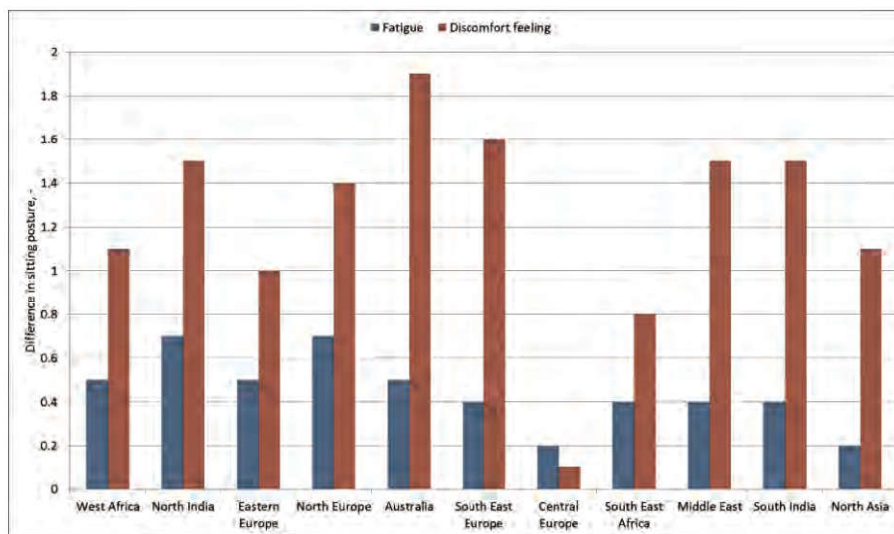
The neck is exposed to the highest level of fatigue and discomfort. Left and right legs, as well as left and right arm have the same level of discomfort and fatigue. Also, both legs is subjected to higher level of discomfort than arms.



**Table 5.** Correlation coefficients Descriptive statistics of discomfort values of 1% female and 99% male populations for seat backrest angle 105° in driving position (1) and resting position (2)

|        |                | Fatigue  |          | Discomfort |          |
|--------|----------------|----------|----------|------------|----------|
|        |                | (1)      | (2)      | (1)        | (2)      |
| Female | Height         | -0.41626 | -0.66435 | -0.36831   | -0.59346 |
|        | Sitting height | 0.088812 | -0.34878 | 0.092169   | -0.27216 |
| Male   | Height         | 0.760445 | 0.697349 | 0.539407   | 0.277367 |
|        | Sitting height | 0.453327 | 0.477271 | 0.166879   | 0.006908 |

Discomfort differences between sitting in driving position and resting position are presented in Figure 8 for 99% male population under 105° of seat back rest angle. Correlations between human body height and discomfort difference are small and there are no significant correlation for both population.

**Figure 8.** The difference in sitting posture respect to discomfort and fatigue for 99% male population in driving (1) and resting position (2) under 105° seat backrest angle

#### 4. CONCLUSIONS

The aim of this study was to determine the driver fatigue and discomfort in a different seating position. In this paper, digital human models of driver and passenger are used in order to assess the fatigue and discomfort. Also, discomfort of body parts, for two different sitting postures were analysed. Eleven different populations with anthropometric dimensions of 1% female and 99% male populations were used. Investigations were conducted by application of the software package Ramsis. The obtained results showed that all eleven populations have a permissible fatigue value below 5.5.

The most severe discomfort and fatigue are noticed in driving conditions under 105° seat backrest angle for both male and female population.

Application of Ramsis software is very suitable in vehicle design phase especially in the vehicle packaging. Obtained results are conducted for 1% female and 99% male population, which is tendency in vehicle design phase in order to enable usage of vehicle to wider population. Presented results an applied method enable discomfort and fatigue assessment and to save time in vehicle design.

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