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Original scientific paper

Using Different Methods to Assess the Discomfort during Car Driving

David Ravnik[1,2], Stanislav Otáhal[1] and Metoda Dodič Fikfak[3]

[1] Department of Anatomy and Biomechanics, Faculty of Physical Education and Sport, Charles University of Prague, Prague, Czech Republic
[2] Rehabilitation center dr. David Ravnik, Kranj, Slovenia
[3] University Clinical Centre, Clinical Institute of Occupational, Traffic and Sports Medicine, Ljubljana, Slovenia

A B S T R A C T

This study investigated the discomfort caused by car driving. Discomfort estimates were achieved by self-administered questionnaire, measured by different testing methods, and through the goniometry of principal angles. Data from a total of 200 non-professional drivers who fulfilled the questionnaire was analysed. 118 subjects were analysed by goniometry and 30 drivers were assessed using the OWAS (Ovaco Working Posture Analysis), RULA (Rapid Upper Limb Assessment), and CORLETT tests. The aim of this paper was to assess the appearance of the discomfort and to find some correlations between drivers' postures. Results suggest that different levels of discomfort are perceived in different body regions when driving cars. Differences appear mostly between the genders concerning the discomfort. With the questionnaire and the different estimation techniques, it is possible to identify 'at risk' drivers and ensure urgent attention when necessary. It can be concluded that the questionnare and the CORLETT test are good in predicting location of discomfort. TheBorg CR10 scale is good indicator of the level of the discomfort, while OWAS and RULA can appraise the body posture to predict discomfort appearance. According to the goniometry data, the drivers posture could be one of the contributing factors in appearing of discomfort.

***Key words**: discomfort, driver, car, posture, assessment*

Introduction

The concepts of comfort and discomfort during car driving are under debate. There is no widely accepted definition, although it is beyond dispute that comfort and discomfort are feelings that are subjective in nature. In general comfort is defined as a conscious well-being. Discomfort has to be validated from five standpoints: intensity, quality, body location, where's felt, and its appearance over time[1].

Several subjective assessment methods have been developed to measure human responses ranking from mild discomfort to pain[2,3]. Among car drivers, the most commonly used method of discomfort evaluation has been the self-administered questionnaire. An example of the findings is provided by Myers and Schierhout[4], who suggested the validity of self-reported questionnaires when applied to large test groups. One of the most frequently encountered self-reported questionnaires is the Standardised Nordic Questionnaire[5]. Another widespread questionnaire is the Questionnaire Body part Discomfort Scale from Corlett and Bishop[2]. A lot of different modifications have been made[6,7].

Several researchers have suggested possible factors which affect human discomfort during the driving task. Personal factors identified by the scientific research include: body dimensions[8], age[9], gender[10], driving experience[7], and biochemistry & metabolism[11]. Factors related to the driving environment include: the possibilities for seat adjustment[12], the driving posture[13], the pressure distributions and body anthropology[6], progression of muscle fatigue[7], the duration of the driving[7], the forces exchanged with the vehicle[14], postural shifts[15], and the possible presence of vibration[3]. El Falou et al.[7] admitted that under the regarding accessible methodology listed above, it is difficult to evaluate driver's discomfort.

There are also several objective methods (e.g. posture analysis, pressure measurements, and electromyography

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– EMG) in use to assess sitting comfort or discomfort[16]. However, these methods are rarely used among car driving. Pressure distribution appears to be the objective measure with the clearest association with the subjective ratings[17]. For other variables, for instance, spinal profile or muscle activity, the reported associations are less clear and usually not statistically significant[17]. Opposite opinions include Gyi and Porter[18], who stated that levels of pressure in prediction of discomfort are unsatisfactory. In spite of measurements of Gyi and Porter[18] and Porter et al.[6], who could not find relationship between discomfort and values measured by pressures, they still hold an opinion that compressive data on contact interface of human to seat could be the prime agent in prediction of discomfort. Attempts to correlate postural angles and distances derived from the photographs with subjective judgments of physical discomfort reported on a questionnaire were unsuccessful[19]. It is assumed that the discomfort increases with mechanical load in joint areas[1]. Objective measurement that could be performed by EMG[1] disagree de Looze et al.[17]. Discomfort appearance does not require the presence of muscular fatigue[7]. According to Liao and Drury[15], one of well distinguishable signals of discomfort are shifts in posture. The feeling of subjective fatigue does not always correlate to objective measures of fatigue[20]. Fountain[21] compared the validity of results gained by the RULA (Rapid Upper Limb Assessment) with records gained from EMG and subjective evaluation of discomfort. Positions that were appreciated by RULA as high-risk for rise of musculoskeletal problems were at the same time those which were found by individuals to be the most uncomfortable. According to Yamazaki[22], the results of the relation between the characteristics of the surface deformation, anthropometry, sitting posture, and comfort perception showed that the comfort of each morphological fitting did not correspond to one special and single parameter from those physical factors, but was represented by a function with many parameters related to the deformation, posture, and body antropology.

The aim of the present study was to investigate validity of different methods in assessing discomfort during car driving among non-professional drivers and to assess the appearance of the discomfort in the locomotor system. The aim was also to: assess the driver's posture, find out some correlations with discomfort appearance, and to show that driving a car is becoming a social problem.

Methodology of Discomfort Survey

Questionnaire

200 randomly chosen persons were included in this study (Table 1), and all were non-professional drivers. A self-administered questionnaire was developed to investigate the discomfort appearance among these drivers. The questionnaire[23,24] investigated symptoms of musculoskeletal discomfort in different body regions, and was based on the Nordic design as used by Rehn et al.[25] and Giacomin and Screti[26]. The questionnaire consisted of four headings with 49 items. The headings included personal data, working factors, information about discomfort appearance, and driving habits.

TABLE 1
TWO TEST GROUPS BY GENDER, RESIDENCE AND AVERAGE AGE

Slovenia[23]	Czech Republic
N=118, M=50, F=68	N=82, M=35, F=47
Average age 30.2 years SD 11.4 years	Average age 31.7 years SD 10.6 years

N – number of subjects, F – female, M – male, SD – standard deviation

OWAS, corlett, borg cr 10, and rula tests

For the driver's evaluations, the Owas, Corlett & Borg CR10, and Rula tests were administered. Ten people for each test (30 people together) were randomly chosen from the group of 200 people to drive for three hours. During these observed time, they had 15 minutes to pause and rest. Driving was conducted in the field and drivers were guided in maintaining comparable speeds and driving maneuvers.

OWAS – ovaco working posture analysis

OWAS is a method for the evaluation of postural load during work. It is based on a simple and systematic classification of work postures combined with observations of work tasks, and the authors used a modification of OWAS made by Sušnik[27]. The driver's posture was observed in systematic time intervals (every 3 minutes). Observations were written in a special form with small lines and the data was first analysed manually, and secondly, by a computer program (WinOWAS from the Tampere University of Technology). Classification of working postures was focused on:

- posture pattern of thoracolumbal spine – 4 items (1.1 – straight standing, 1.2 – flexed posture more than 15°, 1.3 – straight standing with torsion or deviation of the spine for more than 30° and 1.4 – flexed posture for more than 30°);
- posture patterns of upper extremities – 4 items (2.1 – both upper arms are at the torso, 2.2 – one or both upper arms are in abduction under the shoulder level, 2.3 – one upper arm is over the shoulder level, and 2.4 – both upper arms are over the shoulder level);
- posture patterns of hands – 3 items (3.1 – soft or firm grip, 3.2 – typing, and 3.3 – other activities of the lower arms);
- patterns of posture and moving of lower extremities – 9 items (4.1 – sitting, 4.2 – standing, 4.3 – standing on one leg, 4.4 – flexion in all joints of the leg, 4.5 – kneeling, 4.6 – walking, 4.7 – sitting on the floor, 4.8 – lying and 4.9 – crawling);
- patterns of posture and incline of head – 5 items (5.1 – neutral position, 5.2 – flexion over 30°, 5.3 – lateral

flexion over 30°, 5.4 – extension over 30°, and 5.5 – rotation over 45°);

- the extent of external force, which we have to solve with muscle force – 3 items (6.1 – 10-99N, 6.2 – 100-199N, and 6.3 – more than 200N).

Corlett – subjective technique for discomfort estimation and borg cr 10 scale

The body part discomfort scale[2] is the subjective evaluation technique which can be used to assess the degree of comfort that a person experiences. Subjects were asked about the location where they feel the most intensive discomfort, and for assistance, a body part scale was shown. The most sensitive parts were marked first. The affected parts were written into the form of Corlett and Bishop[2] and modified by Begovic[28]. Locations used by Corlett were: the neck, shoulders, upper arm, lower arm, upper back, middle back, lower back, buttocks, left thigh, right thigh, left calf, and right calf. Discomfort was ranked from 01 to 12. Rank 01 has the location with the maximal discomfort, rank 02, next one, and so on. Drivers were asked for discomfort every 10 minutes. At the same time, the level of the discomfort was assessed also by Borg CR10 scale[29] shown in table 2. Borg CR 10 is a category ratio scale with values from 1 to 10. There is no upper limit to the scale and participants can use fractions to describe level of exertion. Numbers from 0 to 11,12… are points, expressed in working unit [pt] = points.

RULA – ergonomic technique for discomfort estimation

The Rapid Upper Limb Assessment (RULA) was developed by McAtamney and Corlett[30]. This ergonomic technique evaluates individuals' exposures to postures, forces, and muscle activities that have been shown to contribute to repetitive strain injuries. Use of this ergonomic evaluation approach results in a risk score between one and seven for the left and right side of the body, where higher scores signify greater levels of apparent risk. A low RULA score does not guarantee that the environment is free of ergonomic hazards and a high score does not assure that a severe problem exists. The driver's posture is assessed every ten minutes. A score of one or two indicates that posture is acceptable if it is not maintained or repeated for long periods, a score of three or four indicates that further investigation is needed and changes may be required, a score of five or six indicates investigation and changes are required soon, and a score of seven or more indicates investigation and changes are required immediately.

Goniometry

Digital images of all 118 participants from Slovenia were taken in a driving position in their own car without changing their seats, and also in a car (Volkswagen Golf IV), where they have to adjust the seat. The camera used was an Olympus C-350 ZOOM. Images were treated with computer program, OBR for MS DOS, where angles of knee, hip, back seat, and neck were measured. In the saggital plane, the distance from the occipit to head restraint was measured. The head position was made with a graphical analysis of the angles and distances (Figure 1). Anatomical points of the bulbus oculi, lips, meatus acusticus externus, cartilago thyriodea, and acromion were used. The angle between the lines of acromion and meatus acusticus externus, and middle of the angle between lips and bulbus oculi and meatus acusticus externus was used to determine the correct position of the neck and head.

Statistical methods

The results were statistically analyzed (average, standard deviation, Spearman's coefficient of correlation, and the pair t-test) and $p<0.05$ was accepted as the minimum of significance. In the results chapter, the data was shown where the results were statistically significant. The computer program used for statistical analysis was SPSS 12.0. Data from Owas observations was written in a special form with small lines and then was analysed, first manually, and secondly, by use of computer program (WinOWAS). The results of the Corlett test was written in a special form and the values of ranks were calculated. RULA results were made by the computer program on web side, http://www.ergonomics.co.uk. The images of goniometry were treated first manually, then with program OBR for MS DOS. This study was done in year 2003 through 2006.

Results

Results of questionnaire

Data analysis from the questionnaire showed that discomfort in locomotor system during driving represented 77.8%, mainly due to spinal discomfort (Table 3). The only significant difference in discomfort between Slovene and Czech drivers was found in the shoulder area (p<

TABLE 2
BORG CR10 SCALE FROM NULL TO THE ABSOLUTE MAXIMUM[26,29]

Grade [pt]	0	0.3	0.5	1	1.5	2	2.5	3	4	5	6	7	8	9	10	11,12…
Verbal	Null		Extremely weak	Very weak		Weak		Moderate		Strong		Very strong			Extremely strong	Absolute maximum

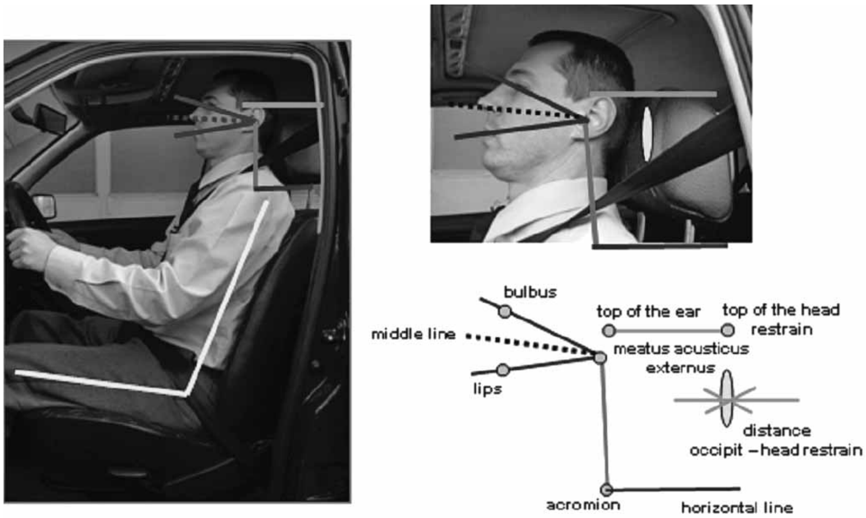

Fig. 1. Antropometrical angles of the driver (basic photos belong to Police of Slovenia).

TABLE 3
DISCOMFORT DURING DRIVING BY LOCATION AND DRIVERS' DOMICILE

Drivers / Discomfort	All (N=200)	Slovenian drivers (N=118)	Czech drivers (N=82)	p value
General discomfort	77.8%	75%	79%	ns
Neck discomfort	38.3%	37%	40%	ns
Shoulders discomfort	14.9%	10%	22%	<0.05
Thoracic spine discomfort	19.4%	18.6%	20.5%	ns
Lumbar spine discomfort	38.8%	35.6%	43.3%	ns
Legs discomfort	25.5%	28%	22%	ns

N – number of subjects, ns – not significant, p – the probability value

0.05). Discomfort was found in different forms from uneasiness to pain.

Discomfort appeared in one or more body parts at the same time. Differences in appearance of the discomfort and in localisation between genders were statistically significant in the cervical and lumbar spine regions (Table 4). More women than men reported discomfort while driving. Table 4 presents the shares of discomfort appearance during driving by genders. According to the questionnaire, more women than men also reported discomfort in the locomotor system. Discomfort was noticed from 83% to 88% of women ($p<0.001$).

According to the questionnaire, vibrations were recognised very subjectively. There were no statistically

TABLE 4
DISCOMFORT AMONG DRIVERS BYGENDER AND SUBJECTS' DOMICILE

Gender & domicile	Male (SLO) (N=50)	Female (SLO) (N=68)	p value	Male (CZ) (N=35)	Female (CZ) (N=47)	p value
Discomfort						
General discomfort	56%	88%	<0.001	50%	83%	<0.001
Neck	28%	44%	<0.05	33%	47%	<0.05
Shoulders	8%	12%	ns	15%	23%	ns
Thoracic spine	16%	20%	ns	18%	20%	ns
Lumbar spine	20%	47%	<0.005	22%	53%	<0.01
Legs	28%	29%	ns	23%	27%	ns

N – number of subjects, SLO – Slovenia, CZ – Czech Republic, ns – not significant, p – the probability value significant differences between genders in vibration perception but women frequenty described vibrations as »disturbing« ($p<0.05$). In Slovenian group of drivers, almost 10% of subjects were disturbed by vibrations, meanwhile, bad roads interfered 73% of subjects in Slovenian group ($p<0.05$) and almost 90% of subjects in Czech group ($p<0.001$). The consequences of vibration exposure and bad seat adjustments were not familiar to 85% of test subjects ($p<0.05$). According to the questionnaire, 98% of Slovenian drivers and 91% of Czech drivers used seat belts. During trips longer than 2 hours, 83% of subjects did not stop. During driving, 64% of subjects frequently changed their posture. All of the Slovenian subjects[23] assumed that they had their seat adjusted correctly.

Results of OWAS, CORLETT, BORG CR 10 and RULA tests

Table 5 exhibits the calculated portion (the share of the specific position according to trial) of a specific posture during OWAS assessment. Possible steps are shown if there is need to intervene. Word formation »yes, now« means the position can cause damage now and there is need to interfere immediately. Word formation »yes, time« means the position can cause damage if the subject will persist in such position for some time and there is need to interfere soon. Formation »more tests« means that more tests are needed to be taken. The symbol »?« means that position is ergonomical and safe. The results of Owas showed that the posture of the spine wasn't ergonomical and could cause damage. Problems that can turn into damage can appear in some time in the shoulder area, in prolonged sitting postures, and according to the external forces.

A graphical presentation of the OWAS analysis of the back region, where steps are needed to be taken now, is shown in figure 2. The results from the portions of the positions are shown in black. Other paterns indicate: horizontal lines (no need to take steps), small squeres (steps are needed to be taken in foreseeable time), and white points on the gray background (steps are needed to be taken now). Postures are on the x-axis and portions of the specific position are on y-axis.

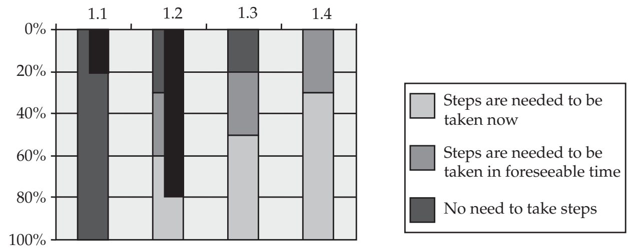

Fig. 2. Results according OWAS – back (1.1 – straight standing, 1.2 – flexed posture more than 15 degrees, 1.3 – straight standing with torsion or deviation of the spine for more than 30 degrees, 1.4 – flexed posture more than 30 degrees)

The results of the CORLETT method gave us the data about the location of the discomfort appearance and how it changed after the break in long term driving. Discomfort was ranked from 01 to 12.

Table 6 displays the results of the CORLETT method observation during the driving of one female subject. The most intensive discomfort has the first rank, the second most intensive has the second rank, etc. Rank 01 is the location with the maximal discomfort, rank 02 is the next one, and so on. Rank 01 is worth 12 points, rank 02 is worth 11 points, and so forth. Numbers from 1 to 12 are points expressed in working unit [pt] = points. Numbers in the cells represent the location of discomfort: 1=neck, 2=shoulders, 3=upper arm, 4=lower arm, 5=upper

TABLE 5
RESULTS OF OWAS IN THE GROUP OF 10 OBSERVED DRIVERS

Position	Portions of position $Pe = \frac{\sum FPe \cdot 100}{\sum Fs} \ldots \%$	Intervention to be taken
1.1 straight standing	20±2.87	?
1.2 flexed posture more than 15°	80±9.72	yes, now
2.1 both upper arms are at the torso	69±7.85	?
2.2 one or both upper arms are in abduction under the shoulder level	31±3.61	yes, time
3.1 soft or firm grip	85±5.05	more tests
3.3 other activities of the lower arms	15±2.7	?
4.1 sitting	100±0	yes, time
5.1 neutral position of the head	100±0	?
5.5 rotation of the head over 45°	4±1.27	?
6,1 external force 10-99N	75±3.35	yes, time

TABLE 6
RESULTS OF CORLETT METHOD (Female, age of 32, Slovenian)

Rank	Discom-fort (pt)	Time (hr)																		
		9:00	9:10	9:20	9:30	9:40	9:50	10:00	10:10	10:20	10:30	10:40	10:50	11:00	11:10	11:20	11:30	11:40	11:50	12:00
1	12			1	1	1	1	1	7	7	1	7			1	1	1	5	5	5
2	11					7	7	7	1	1	7					5	7	1	1	7
3	10							5	5	5	5						5	7	7	1
4	9										2								2	2
5	8																			8
6	7																			
7	6																			
8	4																			
9	3																			
10	2																			
11	1																			
12	0																			
	Total (pt)	0	0	12	12	23	23	33	33	33	42	12	0	0	12	23	33	33	42	50

hr – hour, pt – points

back, 6=middle back, 7=lower back, 8=buttocks, 9=left thigh, 10=right thigh, 11=left calf, 12=right calf. Observations illustrated in table 6 showed that at 9:20, the driver had a neck discomfort estimated with 12 points, at 9:40 had neck discomfort estimated with 12 points and low back discomfort estimated with 11 points. According to Table 6, the discomfort spread from the neck at 9:20, to the neck and lower back at 9:40, and to the neck, lower back, and the upper back at 10:00. It is constant until 10:20, then spread to the shoulders at 10:30. After the break, the subject did not feel any discomfort until 11:10, where she again described neck discomfort. The discomfort increased to the end of the trial drive. Table 7 shows a summation of the points in specific region in all of the ten test subjects. The value means the summation of points of discomfort for a specific area in working unit [pt] = points.

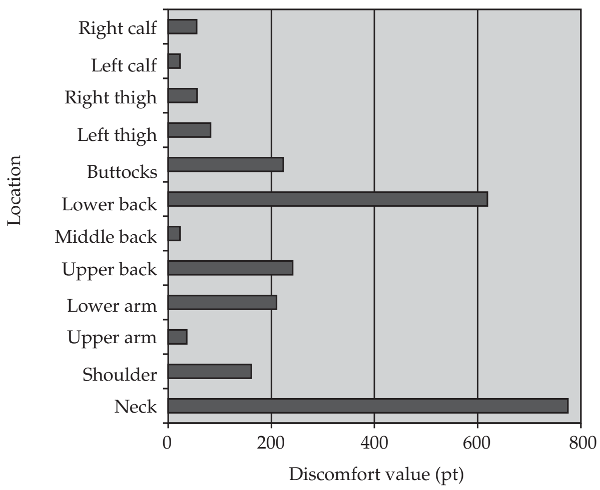

Fig. 3. Estimated degree of discomfort and its location.

Figure 3 shows that, according to intensity, the locations where discomfort appearance was increased during car driving were the spinal area, the shoulders, the lower arm, and the buttocks.

Table 8 and figure 4 display the summation of discomfort during three hours of driving. At 10:40, drivers had a fifteen minutes break.

Discomfort appeared for the first time approximately after 20 minutes of driving and increased rapidly until a stop at a rest house for 15 minutes. After the break, discomfort increased over time and was at maximum at the end of trial drive (three hours).

The discomfort rating according to BorgCR10 scale is present in table 9 and graphically in figure 5.

The average results received by RULA were between 6–7 on the left side and 6–7 to the right side of the driver's body (Table 10).

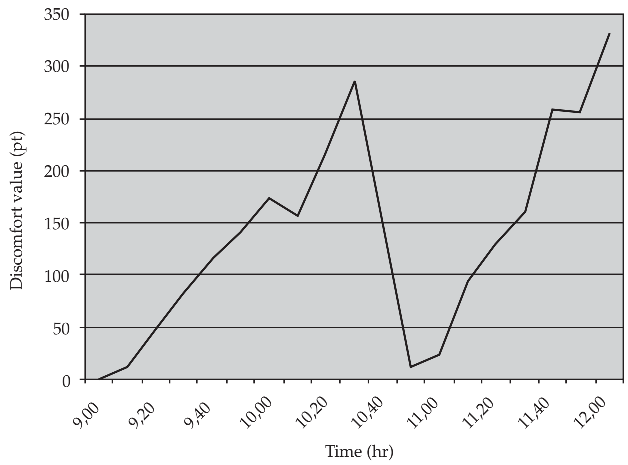

Fig. 4. Discomfort value during 3 hour driving.

TABLE 7
DISCOMFOR LEVEL DUE TO LOCATION

Location	1	2	3	4	5	6	7	8	9	10	11	12
Value (pt)	775	161	36	210	241	23	619	223	82	56	23	55

TABLE 8
DISCOMFORT VALUE IN TIME

Time (hr)	9:00	9:10	9:20	9:30	9:40	9:50	10:00	10:10	10:20	10:30	10:40	10:50	11:00	11:10	11:20	11:30	11:40	11:50	12:00
Value (pt)	0	12	48	83	116	141	173	158	216	287	153	12	24	94	129	160	259	256	332

TABLE 9
DISCOMFORT AMONG DRIVERS BY GENDER ACCORDING TO BORG CR10 SCALE

	Neck [pt]	SD	Thoracic spine [pt]	SD	Lumbar spine [pt]	SD	Shoulders [pt]	SD	Legs [pt]	SD
Male	1.9	0.2	1.8	0.1	1.8	0.2	1.2	0.2	0.9	0.1
Female	2.6	0.3	2.4	0.2	2.1	0.2	1.4	0.2	1.1	0.1

N=200, pt – points, SD – standard deviation.

TABLE 10
RESULTS OF RULA

Number of person	1	2	3	4	5	6	7	8	9	10
Body side	L	R	L	R	L	R	L	R	L	R
L	R	L	R	L	R	L	R	L	R	
Scores	6	6	7	7	6	7	7	7	6	6
	6	6	6	6	7	6	6	7	6	7

L – left side, R – right side

Results (according to RULA) showed that left and right side of the driver's body were burdened almost the same, with the values being between 6 and 7. A score of five or six indicates that further investigation was needed and that changes were required soon. A score of seven or more indicates that investigation and changes were required immediately.

Results of goniometry

The distance between the occiput and head restraint was, on average, 7.7 cm (SD±3.8 cm). The larger the sitting angle of the back of the seat was (average 104°, SD±9.5°), the greater was the distance between occipit and head restraint (Spearman's coefficient of correlation, $r=0.8$, $p<0.001$). The angle of the back of the seat in subjects' own cars was on average 101° (SD±7.9°). In the vehicle (Volkswagen Golf IV), where they had to adjust the seat individually before the ride, was on average 94° (SD±6.4°). Subjects adjusted the seat in the new car individually by smaller angles than in their own cars ($t=3.41$, $p<0.01$). The example of the angle measurement is shown on figure 6. Discomfort appeared in 60% subjects in the neck area, where the back of the seat's angle was adjusted between 110° and 120°. In this range, the angle of the neck-head complex was not ergonomical ($p<0.05$). Less discomfort was noticed (and later discomfort appearance) was found in the group of subjects who had the proper seating adjustment. The same results were also noticed in the group of subjects who were familiar in techniques of correct entrance and exit of the

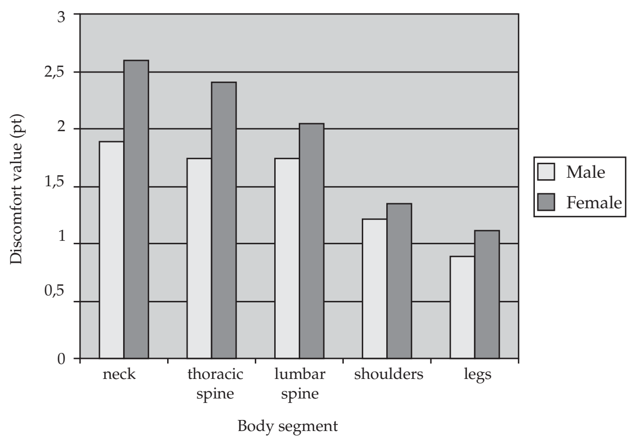

Fig. 5. Discomfort among drivers by gender according to BorgCR10 scale (N=200).

Fig. 6. Example of angle measurement (The yellow circle represent the distance from the occipit to the head restrain. See also Figure 1).

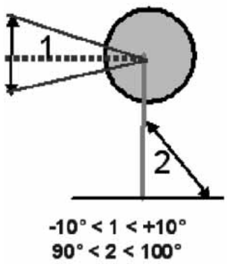

Fig. 7. Ergonomical position of the head during driving – anatomical markers of head can be seen on the figure 1 (minimal ergonomical angle value is written on the left side of the number of the joint and maximal ergonomical angle on the right side. 1 – angle of the middle line between the meatus acusticus externus and lips line and meatus acusticus externus and eyes line, 2 – angle between the horizontal line and line from acromion to meatus acusticus externus).

car and also in the group where subjects were more physically active and stopped more often ($t= –6.1$, $p<0.001$). The angle of their neck was between 90° and 100° measured from the back ($p<0.05$). According to the results, the optimal ergonomic position of the head for least discomfort should be as is shown on figure 7. Discomfort was less noticed in that range of motion.

Discussion

There is no single posture that can be comfortably maintained for long periods of time. Any prolonged posture will lead to static loading of the muscles and joint tissues, and can consequently cause discomfort. A lot of people drive long distances daily to and from work and many of them do not or even cannot adjust their car seat. The correct adjustment of the seat can decrease the burdening of the locomotor system. According to the questionnaire, more women than men reported experiencing discomfort of the locomotor system during driving ($p< 0.001$). Among the bus drivers[31], it was found that 57% of subjects have a problem in the spine area and the portio of discomfort appearance in spine area among rally drivers[24] was 60%. The portion of discomfort appearing in the spine area in the observed group of non-professional drivers[23] was 71%. Time spent driving had the most rapid and the most influencial appearance of subjective awareness of discomfort[23]. If we consider the discomfort landmark for the discomfort appearance among drivers at 10%, then all driving longer than one hour should be considered as highly critical in the comfort aspect. The slowest influence on the appearance of subjective awareness of discomfort is sitting time in daily life, where 50% of our group had symptoms of discomfort after 6 hours in comparation with 2.5 hours of driving.[23]

Drivers were found to adapt to changes in the vehicle's geometry primarily by changes in limb posture, whereas torso posture remained relatively constant[32]. The back of the seat shall take the angle of 100 degree[33]. According to Ravnik[23] 60% of those (who felt discomfort in the neck) had the position of the back of the seat between 110° and 120°. Subjects in seats with the backrest inclinations of 110° to 130° and with concomitant lumbar support had the lowest disc pressures and the lowest EMG activity from spinal muscles. There is a need to pay attention because this position can provoke a forward head position which can be a reason for the discomfort appearing in neck region. Although almost all of the subjects in the test group thought that their seat is correctly adjusted, the distance between occiput and head restraint was, on average, 7.7 cm (SD±3.8 cm). The research on whiplash indicates that the greater the gap between the head and the headrest, the greater likelihood of injury[34]. If someone is sitting on a correctly adjusted seat, there may still be a problem because the spine is being fixed in one position for a longer period of time. With prolonged sitting, a correct ergonomic posture is not enough and a constant change in posture is necessary. The spine is made for movement. It is recommended that during longer trips, drivers should stop often and move around as much as possible. According to the results of the questionnaire, 83% of drivers were not stopping often when driving longer distances, while 64% of drivers frequently changed their position during driving. Fenety and Walker[35] found out that movement on the seat in a period of two hours of testing increased. Also, the seat should not be neglected because the seat is important in how much energy will be transmitted to the human body[11]. There are recommended seats on the market which are able to absorb vibration frequencies in the range between 1 to 20 Hz[33]. Vibration exposure initiates changes in the muscle behaviour and therefore renders the back region to be more susceptible to damage.

The cause of the difference between subjects' domicile could be the servo steering wheel (power steering). In subjects from Slovenia, servo steering wheels were present in 68% of the cars, and in Czech test group, in 46% of the cars. According to Lawrence and Siegmund[34], the major contributors of neck discomfort while driving are insufficient headroom and inadequate seat positioning. Forward head posture, which is very common between drivers, can affect important postural joins such as as the atlanto-occipital joint, the cervical spine, the scapulothoracic joint, and the glenohumeral joint[36]. Direct and associated pain, discomfort, and dysfunction in the above joints can be directly attributed to the effects of forward head posture. This position causes additional stress to the muscles. In this case, the vertebral joints and disks are placed under additional physiological loads. According to Christman[36], for every 2.5 cm, the head moves forward from neutral, an additional 6.8 to 13.6 kg of tension is placed on the supporting neck muscles. Results show that the angle of the back seat, and consequently, the spine where the activity of the muscles is minimal, causes the forward head position.

From the literature review, it is clear that discomfort in car driving depends on many applied factors and there is no one valid test for its determination. The main problem could be from the fact that discomfort is a subjective experience and is therefore very individually recognised and is always dependant on the subjective statements of the person. There are also poorly described relationships between the subjective sensation of discomfort and the objective records. According to results of the CORLETT method, breaks and time spent outside the car can decrease the symptoms of the discomfort. Discomfort increased with the time spent driving. The history of the exposure and the condition of the driver's body may be important. There must be an exposure line where symptoms can be determined to be reversible or irreversible. For now, there are only standards, but the literature review found some deficiencies. Standards are based more on psychosocial factors as the subjective discomfort feeling rather than the effect of the driving and associated factors on the human body. The results confirm that different regions of the human body experience different levels of discomfort due to the driving activity among non-professional drivers. The regions associated with the highest levels of mean, self-reported discomfort were (according to the Borg CR10 scale): the neck, the thoracic spine, and the lumbal spine. According to the CORLETT test and questionnaire, most of the discomfort was noted in the neck and lumbar spine area. According to results of the research, the data may indicate that the whole spine (different levels of neck, thoracic spine, and lumbal spine) is more at risk in the appearing of discomfort. Research among non-professional drivers is still rare at this time. Almost all research is specialized among professional drivers.

The purpose of the article is also to elaborate on the procedure of the driver's risk assessments. This procedure was also later tested among rally drivers[24]. There are three suggested stages (A–C). The following stages, A–C, could be developed during the human's involvement in the 'Discomfort and Vibrations during driving' to assess the risk of physical symptoms associated with driving. Stage A is the Initial Risk Assessment (questionnaire) for all drivers. Stage B is the Detailed Risk Assessment (interview) for drivers with a high exposure to driving (more than 4 hours per day) and/or are already experiencing driving related discomfort. Stage C could be Urgent Action for drivers with severe discomfort or reoccurring pain, with a medical history of back or neck injury, drivers with an inappropriate car, high driving exposure, or other risk factors. Information from the Initial and Detailed Risk Assessments (A and B) should be considered as part of an integrated approach involving, where necessary: additional training, medical input, reduced exposure to driving, a change of car, a change of daily tasks, a change of lifestyle, or specialist advice (e.g. medical doctor, ergonomist, physiotherapist, psychologist, biomedical enginner, etc.).

Conclusions

It can be concluded, that the questionnare and the CORLETT test are good in location prediction of discomfort, and the Borg CR10 scale is good indicator of the level of the discomfort. Meanwhile, the OWAS and the RULA tests are good at appraising the body's posture to predict discomfort appearance. Using a healthy posture is like holding a defense shield against future problems in the locomotor system. It is of urgent need to train drivers of the necessity of developing measures to reduce or avoid problems in the selection of an individual's car with respect to comfort and postural criteria. Discomfort and pain can be prevented. There should not be a separation between discomfort removal and the prevention of damage to one's health. It is concluded that the recommendations for drivers phrased in terms of »static angles and distances« are currently unsubstantiated and, thus, are not yet ready to be codified as formal standards. The human's natural behaviour is to change their body posture often. The seated posture is determined by both the design of the seat and the task being performed. Vibrations (in combination with sitting) cause discomfort to appear earlier than compaired to sitting alone. People are less aware of the vibrations which can cause harm. According to research, people are more likely to change their position often during driving rather than stopping more often and being physically active. Discomfort during driving mostly appears in the spinal region and in leg and shoulder region, which can be also caused by the discomfort in the spinal region. After exposure to vibration over the whole body, the muscles are fatigued and the discs compressed, making them less capable of absorbing and distributing load. It is reasonable to recommend the avoidance of heavy lifting immediately after the driving. Car driving has a non-disputed influence on human perception. Vehicular vibrations and the task of driving a car causes discomfort in the locomotor system to appear faster than in other forms of sitting. Correct car seat adjustment, awareness of posture and vibrations, using the correct techniques of entering and exiting a vehicle and, most importantly, frequent rests and physical activity, can contribute in maintaining the driver's health. The health of drivers is an important issue in public health, occupational health, transport policy, and also in employment conditions. There has not been a concerted assault on those factors that cause poor health and this is an area of neglect that needs urgent attention. Measures to protect and improve the health of drivers should be pursued in a way that maximises gains to all sectors of society.

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D. Ravnik

Rehabilitation center, dr. David Ravnik s.p., Ulica Tuga Vidmarja 10, 4000 Kranj, Slovenia
e-mail: david.ravnik@gmail.com

UPOTREBA RAZLIČITIH METODA PROCJENE NELAGODE TIJEKOM VOŽNJE AUTOMOBILOM

SAŽETAK

Ova studija istraživala je nelagodu uzrokovanu vožnjom automobila. Procjena nelagode postignuta je individualnim upitnikom, mjerena različitim metodama testiranja, te goniometrijom osnovnih kutova. Analizirani su podaci od ukupno 200 neprofesionalnih vozača koji su ispunili upitnik. 118 subjekata analizirani su pomoću goniometrije, a 30 vozača procijenjeni su pomoću OWAS (Ovaco Working Posture Analysis), RULA (Rapid Upper Limb Assessment), te CORLETT testova. Svrha ovog rada je proučavanje pojave nelagode i pronalaženja korelacija između položaja vozača. Rezultati su pokazali da se različite razine nelagode javljaju u različitim dijelovima tijela tijekom vožnje automobila. Razlike u nelagodi se najčešće javljaju među spolovima. Pomoću upitnika te različitih tehnika procjene, moguće je identificirati »rizične« vozače te osigurati hitnu pažnju kada je to potrebno. Može se zaključiti da su upitnik i *CORLETT* test dobri u predviđanju mjesta nelagode. Borgova *CR10* ljestvica je dobar pokazatelj razine nelagode, dok *OWAS* i *RULA* mogu procijeniti položaj tijela za predviđanje pojave nelagode. Prema goniometrijskim podacima, položaj vozačeva tijela može biti jedan od faktora koji doprinosi pojavi nelagode.