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THE EFFECTS OF MECHANICAL VIBRATION ON THE UPPER BODY POSTURE

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Abstract: **The study aimed to effects of mechanical vibration on the upper body posture and to investigate by use of questionnaire the prevalence of discomfor in locomotor system and its risk factors among drivers. 200 persons were included in this study. All were non professional drivers. Persons were chosen accidentally. A self administered questionnaire was developed and applied to investigate the level of discomfort experienced in the human body. The objective of the questionnaire was to gather body discomfort data in a quick and efficient manner. Data from the questionnaire and digital images of 118 subjects were used. According to risulte this study 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, consequently, can cause discomfort. A lot of people drive long distances daily to and from work and many of them don't or even can't adjust their car seat.**

Key words: **Mechanical vibration, Upper body, Ergonomic**

I. 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 or emotions that are subjective in nature. If we want to describe discomfort enough, we have to validate it from four standpoints: intensity, quality, body location, where's felt and its behaviour in time (time diagram) [1].

Several subjective assessment methods have been developed to measure human responses ranking from mild discomfort to pain [2], [3]. When the discomfort is caused by the objective measure with the clearest association with the subjective ratings [4]. For other variables, regarding spinal not statistically significant [4]. Opposite opinion have Gyi and Porter (1999), who wrote that levels of pressure in prediction of discomfort are unsatisfactory. In spite of measurements of [19], [20], who could not find relationship between discomfort and values measured by pressures, they automobile driving, the most commonly used method of evaluation has been the self-reported questionnaire. An example of the findings is provided by Myers and Schierhout (1996) who suggested the validity of self-reported questionnaires when applied to large test groups. Of the self-reported questionnaires, one of the most frequently encountered examples is the Standardised Nordic Questionnaire [5]. Most widespread questionnaire is Questionnaire Body part Discomfort Scale from Corlett and Bishop (1976). A lot of modifications were 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], smoking [11] and body chemistry [12]. Factors related to the driving environment include: the possibilities for seat adjustment [16], the driving posture [13], the pressure distributions and body architecture [15], progression of muscle fatigue [7], the duration of the driving [14], the forces exchanged with the vehicle [17], postural shifts [20] and the possible presence of vibration [3]. El Falou et al (2003) admitted that under the regarding accessible methodology is difficult to evaluate driver's discomfort.

There are also several objective methods (e.g. posture analysis, pressure measurements, electromyography - EMG) in use to assess sitting comfort or discomfort [18] during car driving. Pressure distribution appears to be

profile or muscle activity for instance, the reported associations are less clear and usually still think, that compressive data on contact interface of man – seat could be the prime agent in prediction of discomfort [6].

II. METHODOLOGY OF DISCOMFORT SURVEY

Questionnaire

200 persons were included in this study (table 1). All were non professional drivers. Persons were chosen accidentally. A self administered questionnaire was developed and applied to investigate the level of discomfort experienced in the human body. The objective of the questionnaire was to gather body discomfort data in a quick and efficient manner. Data from the questionnaire and digital images of 118

subjects were used. Discomfort was measured subjectively with the questionnaire. The self administered questionnaire [21] investigated whole body symptoms of musculoskeletal discomfort. It was loosely based on the Nordic design as used by Rehn et al. (2004) and Giacomin and Screti (2004). The questionnaire consisted of 4 heading with 49 items. This study was done from year 2013 to 2015. Data from Digital images of posture in car were used only from subjects from Slovenia. The first heading of questionnaire included personal data as gender, age, height, weight, BMI, sport activity, smoking and habits, second heading included working factors as education, job, time table, working time, years at work, gait, stress at work, working environment and bordering. The third heading included discomfort as frequency, localization intensity , associated symptoms, history and association with driving. The fourth heading included driving habits as kind of car, accidents, equipment, seat, time driving, driving licence, kilometres per year, vibrations, gait, rests, belt and head restrain. The results have been statistically analyzed (average, standard deviation, hi square test, Pearson's coefficient of correlation, pair t-test) and p < 0,05 was accepted as the minimum of significance. Computer program for statistical analysis was SPSS 12,0.

Slovenia [21]	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

Table 1. Test groups (N-number of subjects, F-female, M-male, SD-standard deviation).

III. OVACO Working Posture Analysis - OWAS

OWAS is a method for the evaluation of postural load during work. The OWAS method is based on a simple and systematic classification of work postures combined with observations of work tasks. We used modification of OWAS made by Sušnik (1987). OWAS was made on 10 drivers, who were driving for 3 hours. Subject's posture was observed in systematic time intervals (every 3 minutes). Observings were written in special form with small lines or by use of computer program WinOWAS from Tampere University of Technology. Classification of working postures was focused on [27], [28]:

- 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°, 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, 6.3 – more than 200N).

IV. Subjective technique for discomfort estimation - CORLETT

The body part discomfort scale [2] is the subjective evaluation technique which can be used to assess the degree of comfort that a person using a technical aid experiences. It may seem easy to take this scale for granted because it is internationally recognized and universally practiced. In contrast to traditional comfort surveys, they espoused the measures of discomfort. Subjects were being observed during car driving. We ask the subjects where they feel the most of discomfort or pain and for help we show them a body part scale. The most sensitive parts are first marked. The affected parts are written into the form (Corlett and Bishop (1976) modified by Begovic (2005). Rank 01 has the location with the maximal discomfort or pain, rank 02 next one and so on. We can ask the subject in specific time intervals. Observation according to CORLETT test was made on 10 persons and was modified from 12 pointed rank to 16 pointed rank (9 labelled and 7 unlabeled) as used in Borg CR10 scale [25]. Numbers from 0 to 11,12… are points expressed in working unit [pt] = points:

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

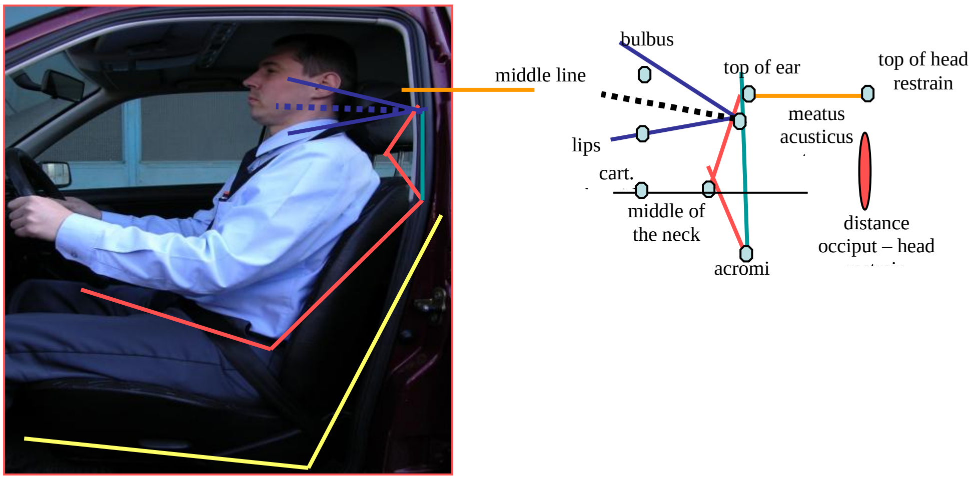
Table 2. Borg CR10 scale (Borg, 1998, Giacomin, Screti, 2004)

V. Ergonomic technique for discomfort estimation - RULA

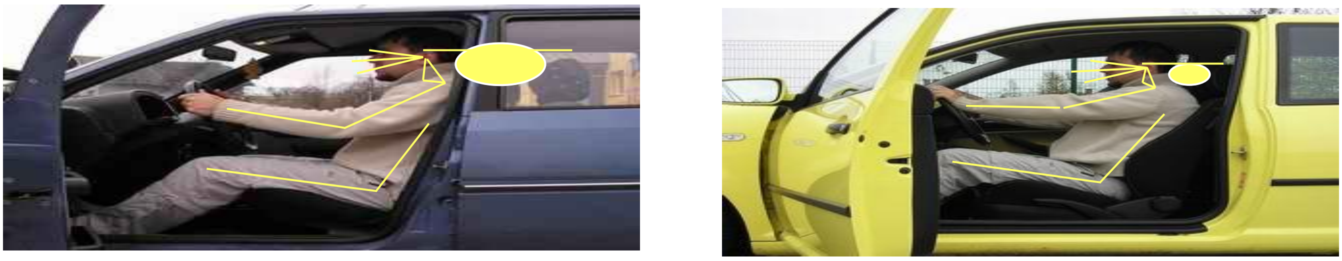
The Rapid Upper Limb Assessment (RULA) was developed by McAtamney and Corlett (1993) of the University of Nottingham's Institute of Occupational Ergonomics. This ergonomic technique evaluates individuals' exposures to postures, forces and muscle activities that have been shown to contribute to repetitive strain injuries. Use of this ergonomic evaluation approach results in a risk score between one and seven, where higher scores signify greater levels of apparent risk. A low RULA score does not guarantee that the workplace is free of ergonomic hazards and a high score does not assure that a severe problem exists. Rula can be worked out manually or by computer. It was developed to detect work postures or risk factors that deserve further attention. 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 further investigation is needed and changes may be required. A score of five or six indicates investigation and changes are required soon. A score of seven or more indicates investigation and changes are required immediately.

VI. Goniometry of posture

Photographs of the 118 participants from Slovenia were taken in a driving position in their own car without changing their seats (25% Renault, 10% Fiat, 9% Citroen, 7% Škoda and Opel, other cars were in minority) and secondly in a car Volkswagen Golf IV, where they have to adjust the seat. We used camera Olympus C-350 ZOOM and Mustek MVVR-100. Images were treated with program OBR for MS DOS, where angles of ankle, knee, hip, back seat, neck, elbow, shoulder and wrist were measured. In saggital plane the distances from occiput to head restrain, from the top of the head to the roof of the car and from xyphoid to the steering wheel were measured. For the head position we made a graphical analysis of the angles and lines. We use anatomical points (bulbus oculi, lips, meatus acusticus externus, cartilago thyriodea and acromion). 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.



Picture 1. Angles of the driver



Picture 2. Example of angle measurement

VII. RESULTS

Discomfort in locomotor system during driving represents 77,8%, specifically in the spine. Discomfort is found in different forms, beginning with uneasiness and continuing into the pain. Distinctions in appearance of the discomfort and differences in localisation of the phenomena between genders were statistically proven in the cervical spine and lumbar spine regions. Women perceived discomfort subjectively more often than men. People are not aware of vibrations which cause discomfort in interaction, within the sitting position and even less of the consequences which crop up afterwards.

N=200	All together	Slovenia	Czech Republic	Diff. between nations
Accidents	52,5%	51%	55%	ns
Problems	30,6%	29%	33%	ns
Discomfort	77,8%	75%	79%	ns
Neck	38,3%	37%	40%	ns
Shoulders	14,9%	10%	22%	($p<0.05$)
Thoracic spine	19,4%	18,6%	20,5%	ns
Lumbar spine	38,8%	35,6%	43,3%	ns
Legs	25,5%	28%	22%	ns
Spine (all together)	72,1%	71%	73,5%	ns

Table 3.Discomfort appearance among drivers separated by nations (N – number of subjects, ns - non statistical, p - the probability value)

52,5% of the subjects were involved in car accidents, but the problems in the locomotor system appear in 30,6% not dependently on driving. Discomfort appears in one or more body parts at the same time. The discomfort in the spine area appeared in 72,1% according to all areas. Table 4 presents shares of discomfort appearance during driving

N=200	Male (SLO)	Female (SLO)	Diff. between genders	Male (CZ)	Female (CZ)	Diff. between genders
Discomfort	56%	88%	($p<0.001$)	50%	83%	($p<0.001$)
Neck	28%	44%	($p<0.05$)	33%	47%	($p<0.05$)
Shoulders	8%	12%	ns	15%	23%	ns
Thoracic spine	16%	20%	ns	18%	20%	ns
Lumbar spine	20%	47%	($p<0.005$)	22%	53%	($p<0.01$)
Legs	28%	29%	ns	23%	27%	ns

Table 4. Discomfort appearance among drivers separated by genders and nations (N – number of subjects, SLO – Slovenia, CZ – Czech Republic, ns - non statistical, p - the probability value).

The discomfort rating according to BorgCR10 scale is present in figure 1. Only statistical difference between nations was found in discomfort in the shoulders area ($p<0.05$) (table 3.). Table 4 presents an appearance of discomfort separated by gender

	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

Table 5. Comparison of discomfort rated between genders according to BorgCR10 scale (N=200) (SD - standard deviation).

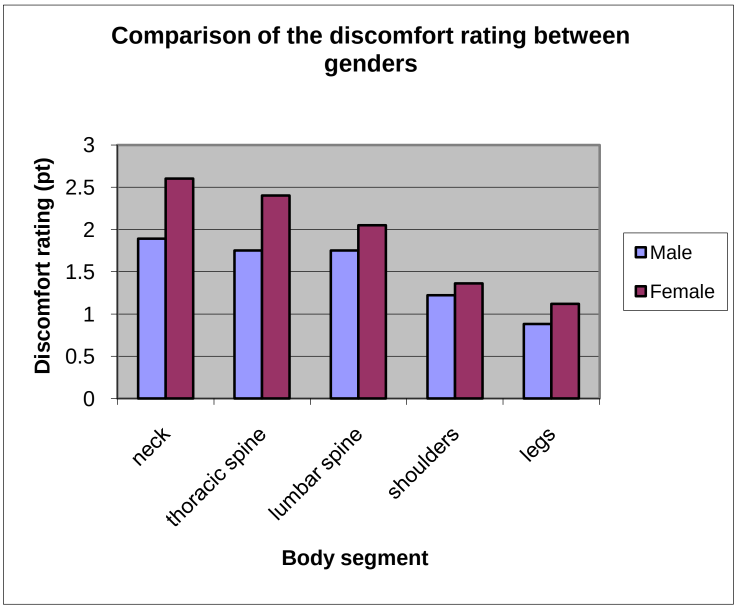
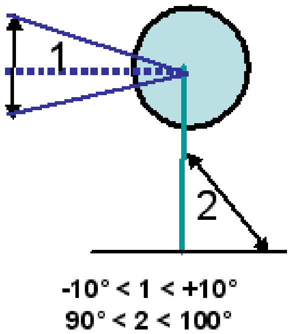


Figure 1. Comparison of the discomfort rating between genders. The discomfort rating according to BorgCR10 scale separated by genders is present in table 5 (N=200).

Vibrations are recognised very subjectively. There are no statistically differences in sex between vibration perception. In Slovenia almost 10% of subjects are disturbed by vibrations, meanwhile bad roads interfered 73% of subjects in Slovenia (p<0,05) and almost 90% of subjects in Czech Republic (p<0,001). Vibrations disturb women more than men (p<0,05). The results and consequences of vibrations influencing the human body and the bad seat adjustments were not familiar to 85% of test subjects (p<0,05).
Seat belts used according to the questionnaire 98% (SLO) and 91% (CZ) of subjects. During longer trips 83% of subjects did not stop regularly. During the driving 64% of subjects changing their posture. All of the Slovenian subjects [21] assumed that they have their seat adjust correctly. The distance between the occiput and head restrain was in average 7,7cm (SD ± 3,8cm). Bigger the angle of the back of the hair was (average 104°, SD ± 9,5°), greater was the distance between occiput and head restrain (Spearman's coefficient of correlation, r=0,8, p<0,001). Adjustment of the angle of the back of the seat in subjects own cars was in average 101° (SD ± 7,9°). In the vehicle Volkswagen Golf IV, where they have to adjust the seat individually before the ride was in average 94° (SD ± 6,4°). Subjects adjusted the seat in the new car individually by a smaller angles than in their own cars (t=3,41, p<0,01). Discomfort appeared in 60% in the neck area where the back of the seat's angle was adjusted between 110° and 120°. In that range also the angle of the neck-head complex is not being ergonomical (p<0,05). Less discomfort was noticed and later discomfort appearance was found in the group of subjects, who have good seating adjustment, and in the group of subjects who knew the techniques of correct entrance and exit of the 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 degrees measured from the back (p<0,05). According to the results of our research the ergonomical position of the head should be as is shown on picture 3.



Picture 3. Ergonomical position of the head during driving. Anatomical markers of head can be seen on the picture 2 (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.).

According to OWAS an observation was made on 10 drivers who were driving for 3 hours. Average results of 50 observations per person are present in the table and in graphical presentations. Table 6 presents the calculated portion (share of specific position according to trial) and lasting (time of specific position) of specific posture during trial with OWAS assessment. Possible steps show if there is need to intervene in. "yes, now" – the position can cause damage now, so it is need to interfere immediately, "yes, time" - the position can cause damage if the subject persisting for some time, so it is need to interfere soon, "more tests" – more test are need to be taken, "□" the position is ergonomical and safe.

POSITION	PORTIONS OF POSITION	LASTING OF POSITION	POSIBBLE STEPS
	$p = \frac{\sum Fp \cdot 100}{\sum Fs} ...\%$	$t_p = \frac{150 \cdot p(\%)}{100} = ...\text{min}$	
1.1	20 ± 2,87	30	?
1.2	80 ± 9,72	120	yes, now
1.3	0	0	?
2.1	69 ± 7,85	103,5	?
2.2	31 ± 3,61	46,5	yes, time
2.3	0	0	?
3.1	85 ± 5,05	127,5	more tests
3.2	0	0	?
3.3	15 ± 2,7	22,5	?
4.1	100 ± 0	150	yes, time
4.2	0	0	?
4.3	0	0	?
4.6	0	0	?
5.1	100 ± 0	150	?
5.2	0	0	?
5.3	0	0	?
5.5	4 ± 1,27	6	?
6,1	75 ± 3,35	112,5	yes, time

Table 6. Results of OWAS (p - share of specific body position, tp - time of lasting of specific position, ∑Fp - amount of lines of specific position, ∑Fs - amount of lines in group)

Graphical presentation of an average results according to the OWAS analysis of back region where steps are need to be taken now is shown on figure 2. Results of portions of positions are shown with blue colour. Other colours show: no need to take steps – green colour, steps are needed to be taken in foreseeable time – yellow colour, steps are needed to be taken now – red colour. There are postures on axis “x” and there are portions of specific position on axis “y”.

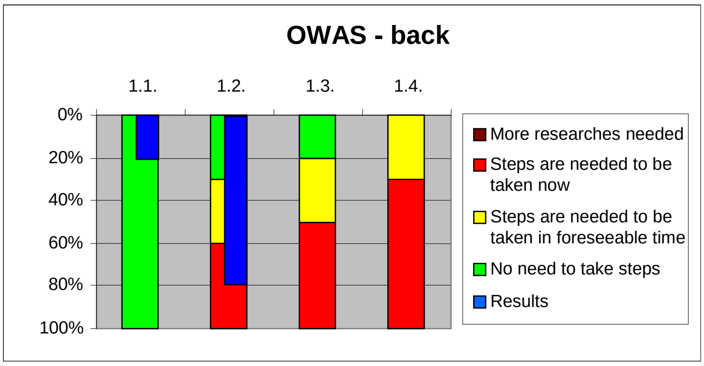


Figure 2. Results according OWAS –back.

CORLETT method gave us the data about location of the discomfort appearance and also how it changes after the rest during long term driving. Observation was made on 10 persons. All of them were driving a car for 3 hours. Results were written into the form. Numbers from 1 to 16 are points expressed in working unit [pt] = points:

		Time [hr]																		
Rank	Pain [pt]	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	16			1	1	1	1	1	7	7	1	7			1	1	1	5	5	5
2	15					7	7	7	1	1	7					5	7	1	1	7
3	14							5	5	5	5						5	7	7	1
4	13										2								2	2
5	12																			8
6	11																			
7	10																			
8	9																			
9	8																			
10	7																			
11	6																			
12	5																			
13	4																			
14	3																			
15	2																			
16	1																			
	Total [pt]	0	0	16	16	31	31	45	45	45	58	16	0	0	16	31	45	45	58	70

Table 7. Example from one subject (Female, age of 32, Slovenian)

Table 7 shows the results of the CORLETT method observation during driving. The most felt discomfort has first rank, the second most felt the second rank etc. Numbers in the frames are the numbers of the location (1 – neck, 2 – shoulders, 3 – upper arm, 4 – lower arm, 5 – upper back, 6 – middle back, 7 – lower back, 8 – buttocks, 9 – left thigh, 10 – right thigh, 11 – left calf, 12 – right calf). Table 8 shows summation of the pain points in specific region. Grade numbers are points expressed in working unit [pt] = points
:

Location	1	2	3	4	5	6	7	8	9	10	11	12
Grade [pt]	218	39	0	0	133	0	165	12	0	0	0	0

Table 8. Discomfort versus location.

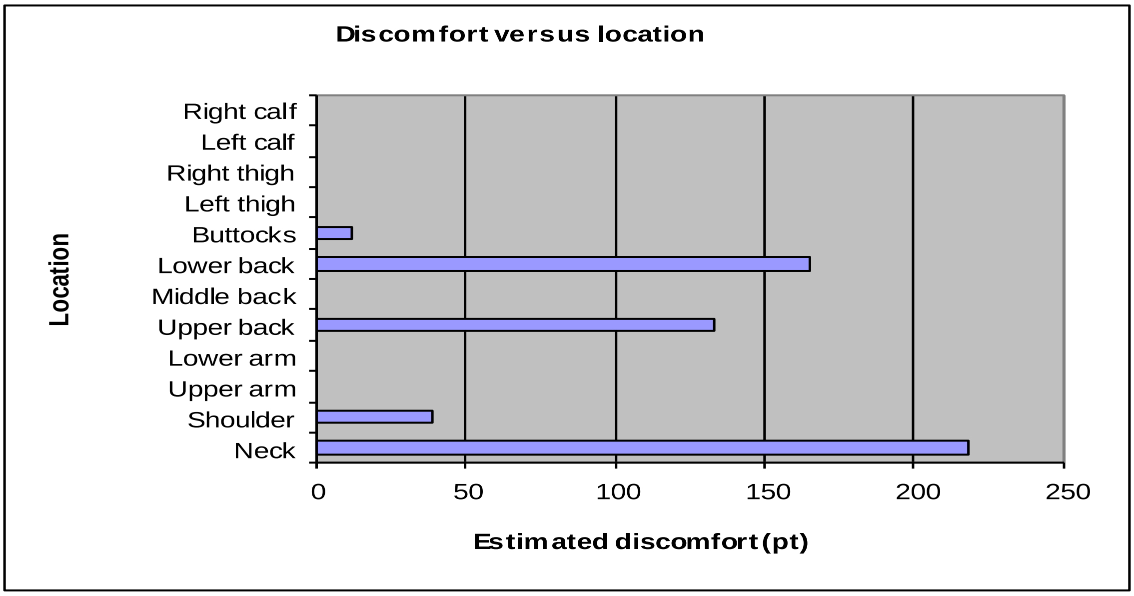


Figure 3. Discomfort versus location.

Figure 3 shows, that in our female subject, the most problematic locations during car driving were: neck, shoulders, upper part of the spine, lower part of the spine and buttocks. Figure 4 is also the graphical form of table 9

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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
Grade (pt)	0	0	16	16	31	31	45	45	45	58	16	0	0	16	31	45	45	58	70

Table 9. Discomfort in time.

Table 9 shows the summation of discomfort felt during driving. Grade means the summation of the appeared discomfort in whole body at specific time in [pt]. Time 10.40 is coloured grey because of the time of the break.

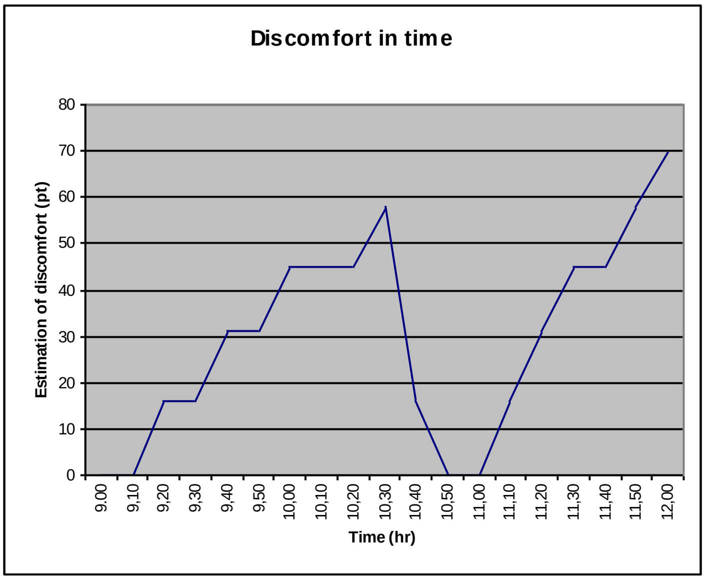

Figure 4. Discomfort in time.

From figure 4 it is obvious, that discomfort for the first time appeared after 20 minutes of driving and increases all to the stop at rest house for 15 minutes. After the break the discomfort again increased in time and was at maximum at the end of our trial drive (3 hours).

10 people accomplished the form of RULA on the computer. The results received by RULA were between 6-7 to left side and 6-7 to the right side of the driver's body (table 10) on page http://www.ergonomics.co.uk/Rula/Ergo/index.html.

No. 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

Table 10. Results by RULA (L – left side, R – right side).

A score of five or six indicates investigation and changes are required soon. A score of seven or more indicates investigation and changes are required immediately.

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, consequently, can cause discomfort. A lot of people drive long distances daily to and from work and many of them don't or even can't adjust their car seat. The correct adjustment of the seat can decrease the burdening of the locomotor system. According to the questionnaire, the results of female drivers were found to be more sensitive to discomfort in locomotor system during driving. Discomfort was noticed in 88% of women who fulfilled the questionnaire ($p<0,001$). Statistically an important difference in localization of discomfort was found in neck and lumbar area. Among the bus drivers (Netterstrom, Knud, 1989) it was found, that 57% of subjects have a problem in the spine area. The portion of discomfort appearing in the spine area in our group of subjects, where all were non professional drivers, was 72,1 %. Time spent driving, has the fastest influence on the appearance of subjective awareness of discomfort [21]. If we consider the discomfort landmark for the discomfort appearance among drivers at 10%, all driving longer than one hour shall be considered as critical in the confort 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 compare of about 2,5 hours of driving.

Drivers were found to adapt to changes in the vehicle geometry primarily by changes in limb posture, whereas torso posture remained relatively constant [22]. The back of the seat shall take the angle of 100° (Hedge 2003). 60% of those, who felt the discomfort in the neck, have the position of the back of the seat between 110° and 120° [21]. Subjects in seats with backrest inclinations of 110 to 130 degrees, with concomitant lumbar support, have the lowest disc pressures and lowest electromyography recordings from spinal muscles and also this position reduces forward translated head postures [16]. There is a need to pay attention, because such position shouldn't provoke forward head position. According to Ravnik (2005) that can be a reason for appearance of discomfort in neck region, where although almost all the subjects of the test group thought that their seat is correctly adjusted, but the distance between occiput and head restrain 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 the injury [23]. If someone is sitting on a correctly adjusted seat, it could still be problematic, because the spine is being fixed in one position for a longer period of time. The spine is made for movement. It is than recommended that during longer trips we need to stop often and move our bodies as much as possible. According to our research during longer trips 83% of drivers were not stopping often while 64% of drivers frequently change their position during driving. It seems we prefer to gym in our cars than stop and rest at stations. Fenety and Walker (2002) found out that movements on seat in a period of two hours of test increased every 2,5 cm the head moves forward of neutral, an additional 6,8 to 13,6 kg of tension is placed on the supporting neck muscles.

It is important that all risk assessments are reviewed regularly and up-dated as soon as possible, for example, on receipt of a new or different car or a change of tasks. We suggest 3 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 Initial Risk Assessment (questionnaire) for all drivers. Stage B is Detailed Risk Assessment (interview) for drivers with a high exposure to driving (more than 4 hours per day) and/or already experiencing driving related discomfort. Stage C could be Urgent Action for drivers with severe discomfort or already pain or a medical history of back or neck injury, with an inappropriate car, high driving exposure or other risk factor. 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; change of daily tasks; a change of lifestyle or specialist advice (e.g. medical doctor, ergonomist, physiotherapist, psychologist).

REALIZATION OF THE HYPOTHESIS AND RESEARCH QUESTIONS

1. Discomfort at car driving depends on many applied factors, and there is no one valid test for its inquest.

This hypothesis was proven:

(„moving" on seat). Due to that, we shouldn't neglect the seat, also because the seat is important in how much energy will be transmitted to the human body [12]. There are recommended seats, which are able to absorb vibration frequencies in the range between 1 to 20 Hz [24].

A forward head position and elevated shoulders have been implicated in the development or discomfort among drivers. The cause of the difference between nations could be in portion of the servo steering wheel (power steering). Between subjects from Slovenia, servo steering wheel was present in 68% and in Czech test group in 46%. According to Lawrence and Siegmund (2000) 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 as atlanto-occipital joint, cervical spine, scapulothoracic joint and glenohumeral joint [26]. Direct and associated pain, discomfort and dysfunction in the above joints can be directly attributed to the effects of forward head posture. When the muscles are placed under additional stress, the vertebral joints and disks are placed under additional physiological loads. According to Christman (2000) for

From the literature review and our results it is clear, that discomfort at car driving depends on many applied factors, and there is no one valid test for its inquest. The main problem could be the fact, that discomfort is subjective experience and is therefore very individually recognised and always depends on the subjective statements of the person. There are also a poorly described relationships between the subjective sensation of discomfort and the objective records.

2. Different regions of the human body experience different levels of the discomfort due to the driving.

This hypothesis was proven:

The results confirm the hypothesis 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 Borg CR10 scale, neck, thoracic spine and lumbal spine while according to questionnaire and CORLETT mostly the discomfort was noted in neck and lumbar spine area.

3. Discomfort from a subjective experience is hard to object, always depending on the subjective statements of the person. There is a poorly described relationship between the subjective sensation of the discomfort and the objective record.

This hypothesis was proven:

Different authors used methods of subjective questionnaires. Often another measurement of other quantity is used, independent on statement of individual that then relate to discomfort and try to find some relation. For example pressure distribution, progression of the muscle fatigue, driving performance, body posture, vibrations. There was not found clear relation between objective measurements and sensation of the discomfort.

4. Vibrations together with incorrect posture and bad driving habits can cause problems in the locomotor system – »Synergistic Driver Effect« or »Vibration Driver's Disease«. Vibration Driver's Disease can be a reversible state.

This hypothesis was proven:

The discomfort appearance among drivers could be classified as »Synergistic Driver Effect« or »Vibration Driver's Disease«. Synergistic because the fact that vibrations together with incorrect posture and bad driving habits can cause problems in the locomotor system during driving and disease because the definition of Health according to WHO (Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity) doesn't include drivers with discomfort. Vibration Driver's Disease can be a reversible state. According to results of the CORLETT method, breaks and time spent outside the car can decrease the symptoms of the discomfort. We believe that history of the exposure is very important and also the body condition. There must be a exposure line, where symptoms can be reversible or irreversible. For now we have only standards, but literature review found deficients.

5. Have whole-body vibration exposure and discomfort appearance been measured in any studies among non professional drivers?

Researches among non professional drives are in this time still rare. Allmost all researches are specialized in the professional drivers' problematics.

6. Do the existing exposure standards for whole-body vibration provide threshold levels for vibration-induced changes that reflect current knowledge? Does vibration exposure to drivers' present a health risk according to current exposure standards?

Answer on these two questions could be bipolar as yes and no. In the case of non professional drivers exposure it could be assumed that standards are mainly suitable, but in the case of professional drivers literature review found deficients.

7. Are any body regions more at risk in appearing the discomfort?

According to results of our research, the conclusion could be that the whole spine (different levels of neck, thoracic spine and lumbal spine) is more at risk in appearing the discomfort.

8. Are existing data sufficient enough to determine any relationship between the driver's vibration exposure, shape and function of neck and head complex and possible health effects?

No. There is a need for more detailed investigations.

9. How can discomfort be predicted and how can it be objectively and subjectively recognised?

A lot of attempts were made for discomfort prediction. It has not been made procedure for discomfort prediction yet with clear evidences. Discomfort description should be made from different standpoints.

CONCLUSIONS

Using healthy posture is like holding a defence shield against future problems in the locomotor system. It is an urgent need for the training of drivers in the importance of developing measures to reduce or avoid problems, for example, the selection of an individual's car with respect to comfort and postural criteria. Discomfort and pain can be prevented. It is concluded that recommendations for drivers are 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 being's natural behaviour is to change posture often. The seated posture is determined by both the design of the seat and the task to be performed. Vibrations in combination with sitting cause that discomfort to appear earlier that sitting alone. The vibrations which are dangerous we are less aware of. According to our research, people change their position during driving rather than stopping more often and being physically active. Discomfort during driving mostly appears in the spine region and in leg and shoulder region, which can be also caused by the discomfort in the spine region. After exposure to the whole body vibration the muscles are fatigued and the discs compressed, less capable of absorbing and distributing load. It would seem reasonable to recommend the avoidance of heavy lifting immediately after vibration exposure. Car driving has nondisputed influence on human perception. Vibrations and driving the car, causing that discomfort in the locomotor system appear faster than other forms of sitting. Women were found to be more sensitive concerning discomfort. Correct car seat adjustment, awareness of posture and vibrations, using the correct entrance and exit of the vehicle and most importantly all frequent rests and moving can contribute in maintaining our health. The health of drivers is an important issue in public health, occupational health, transport policy and 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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