PERIODICUM BIOLOGORUM
VOL. 112, No 1, 51–54, 2010

UDC 57:61
CODEN PDBIAD
ISSN 0031-5362

Original scientific paper

Impact of anthropometric measurements on ergonomic driver posture and safety

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Key words: ergonomic bodily posture, passenger safety, anthropometric measurements, airbags, safety belts, car seat covers

Received October 15, 2009.

Abstract

Basic properties of vehicle interior are described. Car seat design, upholstery fabrics and passenger safety have been particularly emphasized. Textile fabrics as products providing comfort, safety and esthetics of the vehicle interior were dealt with. Safety belts, airbags and car seat covers were specially pointed out. Specific problems related to the safety of passengers, whose anthropometric measurements deviate from the average ones, were addressed.

INTRODUCTION

Performing everyday jobs qualitatively and efficiently is unthinkable without any kind of vehicle. In most cases these vehicles are motor car, motor bicycle, bicycle, train, bus, ship, airplane etc. As a consequence of industry development, very fast, aesthetically attractive and cost-effective cars have been developed. Thus, almost everyone can buy a car relatively easily. Due to a large number of motor vehicles and passengers in traffic, frequent road accidents occur with a tragic outcome. The most frequent cause is too high speed and fatigue. Inexperienced young drivers in fast cars do not have any feeling of dangers on roads. Besides, incorrect sitting, unadjusted car seats, non-use of safety belt and use of motor vehicles without airbags are a frequent cause of severe car accidents. Ergonomically well designed car seats, comfort, and spaciousness of the environment reduce passenger fatigue which is especially important for the driver. This paper will pay considerable attention to the driver, consequences of a car accident because of ergonomically incorrect bodily posture and non-use of safety belts and airbags.

Concerning difference in a drivers' anthropometric measurements, it is sometimes a problem to adjust the car seats and safety belts. This problem arises in the deployment of the airbag if the driver's body deviates from average anthropometric measurements so that the driver's head slips outside of the airbag. It happens if the driver is exceptionally tall or short. The seat can be mostly adjusted by pulling it for-/backwards. Thus, the correct position of the legs can be adjusted. The seat height is not adjustable, and a short driver has a lower head position and a tall driver a higher one. The short driver is in an unenviable position, not only because of a poor field of vision, but also because of the possibility that the safety belts and airbags do not operate efficiently, as the body can be more easily released at the moment of a crash and get injured.

THEORETICAL SECTION

Motor vehicle interior

The role and presence of textile in motor vehicles is of paramount importance. When taking a look into the motor vehicle interior, textile is first noticed. It is one of the reasons why one decides on buying a car. Design, performance and efficiency are the key parameters essential for the built-in textile to fulfill its tasks. The fabrics used belong to the group of technical textiles having high strength, elasticity, porosity, resistance to abrasion, flammability, sunlight and other properties necessary for this purpose. Exceptional importance is attributed to fabrics used for airbags. Passenger safety depends on their properties and cut forms when there is a car accident. These fabrics should have specific properties such as: minimum air permeability, especially high strength which is achieved through raw material composition, processing, construction parameters and high quality joined places. In addition to interior design fabrics and airbags, fabrics for safety belts are also of great importance. These woven narrow fabrics are made specifically and belong to the group of fabrics woven on narrow fabric weaving machines. They feature high strength, stability obtained by a specially selected yarn with high densities achieved. Besides safety role of textile, design, comfort in driving and their adaptability to interior design play a significant role. These requirements are not only met by fabric, but also by knitted fabrics and nonwovens. By combining these three types of surface materials the motor vehicle interior is equipped. The greatest share goes to nonwoven fabric since it is the most cost-effective and used for covering all parts in the interior car section coming into contact with the body. In this section, woven and knitted fabrics as multilayered products prevail. The outer layer is very strong, but elastic woven or knitted fabric followed by polyurethane foam and the back side is a thin knitted or woven fabric. The first layer, which represents the front side of the fabric, plays a predominant role in comfort and performance. Textile products have one more indispensable task in cars; these are different filters and sieves produced in a special way that strictly meet world standards. These are mostly nonwoven or woven fabrics *(1–6)*.

Role of ergonomics and anthropometry in motor vehicles

Ergonomics belongs to young interdisciplinary scientific fields although it has been known since ancient times. Psychophysical fatigue is an occurrence which is very harmful when performing a specific task. Human body and psyche become fatigued not only by moving, but also by prolonged resting. Fatigue represents a hazard which can cause disastrous consequences in the workplace and environment. Fatigue is especially hazardous when driving a car or any other motor vehicle. Traffic accidents often occur in which the cause of the traffic accident cannot be determined, e.g. a car swerved into the other lane and collided with another car. Accidents are probably caused by fatigue of the driver driving for a prolonged period since the body is motionless, sitting in a comfortable car seat. After some time concentration diminishes, and drowsiness occurs of which the driver is unaware. Truck driving prescribes resting after a certain number of kilometers, thus reducing possible accidents. But passenger car driving with high speeds where high concentration is necessary does not foresee prescribed norms for taking a rest after driving and sitting in the car. This causes car crashes with cars from the opposite direction or car swerving off the road. Consequences of such accidents may be disastrous. Ergonomically unsuitable car seat or the driver's workplace giver rise to psychophysical fatigue. Since the driver's seat is adjusted to average anthropometric measurements of the human body, all persons who do not fit these measurements have certain difficulties when driving a car. Shorter drivers with shorter limbs do not only have problems reaching controls, but also in the field of vision (*7*). Taller drivers feel lack of space and reduced field of vision. These problems are reduced by correcting the seat shift, but the problem cannot be solved to the fullest. In addition, protective equipment such as airbags and safety belts cannot protect the driver with those anthropometric measures that deviate from the average ones. The consequence is mostly a partial counterbalance of the head impact against the airbag because inertia force in the upper body is not targeted at the air bag center so that the body slides by alpha angle (Figure 1). Likewise, a body with smaller or greater proportions than the average ones slides more easily above or beneath the safety belt by a certain shift which can be represented as b, g and d angles according to Figure 1. These problems can be solved only partially by integration of an airbag into the seat beneath the leg, ergonomically better designed seat and the possibility of shifting the seat into the position more suitable for the driver. A solution can be expected when the driver's workplace is adjusted to anthropometric measurements of the driver who operates the motor vehicle or such sensors are developed which could adapt the driver's seat to his/her anthropometric measurements *(8, 10)*.

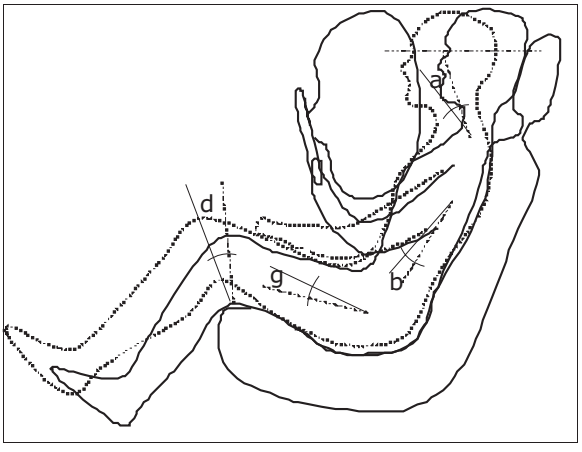

Figure 1. *Shift of the driver's body at the moment of collision.*

Figure 1 shows body shift at the moment of a direct car crash. Due to inertia the body shifts forward. The driver's head hits against the airbag which has already been deployed, compensating the impact with a relatively soft body which does not have adverse consequences for head impact *(10)*. However due to a rapid head movement the spine may be injured, and dangerous body injuries may happen. If the driver has greater anthropometric measurement, the head will hit against the upper part of the airbag, whereby its movement will be greater and alpha angle will be greater, as well. Likewise, there is a danger that the head slips off the airbag, especially if the body is in incorrect posture at the moment of collision. If the driver deviates from the average anthropometric measurements to lower values, there is a risk that the airbag deployment hurts him. At the moment of collision the whole body torso shifts forward and separates from the seat at a beta angle. By shifting the torso the knees and the upper part of the leg shift by a δ angle and γ angle. This body shift may be even greater if the safety belts do not function effectively, if the seat is not designed ergonomically and as adjustable and if there is no airbag in the seat which will lift the front part of the seat at the moment of collision. The consequences of torso and extremity shift are injuries caused by an impact against hard car parts and frequent bruises *(11–14)*.

EXPERIMENTAL SECTION

Three female persons of different body heights (155, 165 and 175 cm) and three male persons of different body heights (175, 185 and 195 cm) (Table 1; Figures 2, 3) were tested. Anthropometric measurements of persons in the driver's seat and surrounding measures were made within the car. Anthropometric measurements were made in the driver's position according to Figure 2. The figure

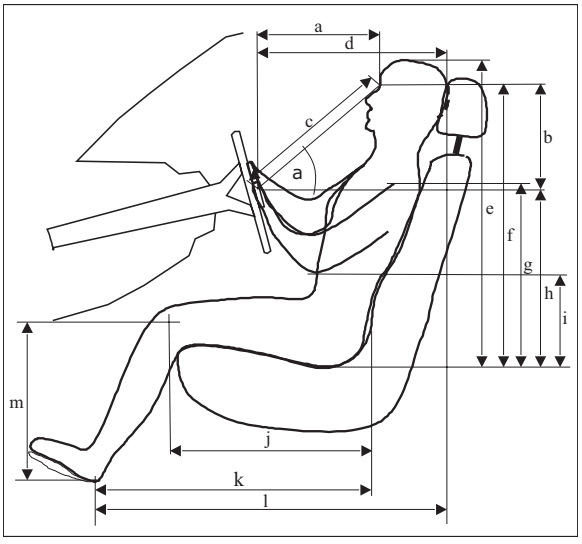

Figure 2. *Driver's anthropometric measurements in the car.*

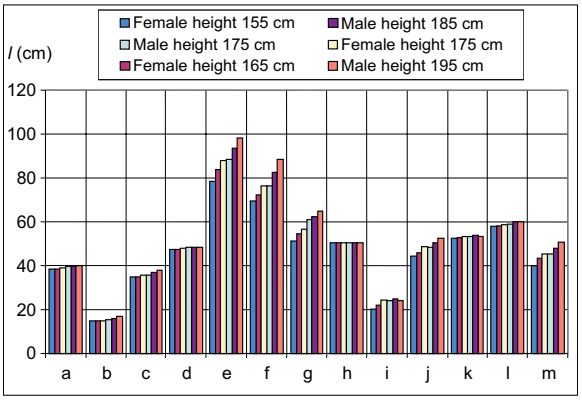

Figure 3. *Anthropometric measurements.*

TABLE 1

Anthropometric measurements of males and females according to body heights.

Sizes according to Fig. 1	Anthropometric measurements in females (cm)			Anthropometric measurements in males (cm)			Average (cm)
	Body height (cm)						
	155	165	175	175	185	195	175
a	38.4	38.3	38.7	39.4	39.7	39.8	39.1
b	14.8	14.8	15.0	15.2	15.7	16.9	15.4
c	34.6	34.8	35.3	35.3	36.6	38.1	35.8
d	47.4	47.5	47.7	48.2	48.4	48.4	47.9
e	78.2	83.7	88.0	88.3	93.7	98.1	88.3
f	69.1	72.2	76.1	76.3	82.6	88.4	77.5
g	51.3	54.4	56.6	60.9	62.4	64.9	58.4
h	50.5	50.5	50.5	50.5	50.5	50.5	50.5
i	20.4	21.7	24.3	24.0	24.7	24.0	23.2
j	44.0	45.7	48.8	48.1	50.3	52.5	48.2
k	52.4	52.6	53.2	53.3	53.5	53.4	53.1
l	57.7	58.1	58.5	58.8	59.6	59.8	58.8
m	39.9	43.2	45.5	45.4	47.8	50.7	45.4

shows that there is only one anthropometric measurement constant, which is h, meaning that most of them change with a change in driver's anthropometric measurements. The basic measurement, on which the airbag effectiveness is dependent, is an alpha angle which closes the triangle between the eyes and the place from which the airbag hops out.

DISCUSSION

Ergonomic seat position and driver's anthropometric measurements are particularly important for driver safety, airbag and safety belt effectiveness (Figure 1). Short drivers (less than 155 cm) or tall drivers (more than 195 cm) face certain problems when driving a car, including: quicker fatigue, difficult driving conditions, the sense of a cramped space, or too distant controls. Adjustment of the driver's seat to driver's anthropometric measurements has not been solved to the full extent.

According to the measurement results obtained, a difference in driver's anthropometric measurements and surrounding measurements within the car may be found (Table 1, Figure 3).

Driver's body height affects anthropometric and surrounding measurements which are essential for safe car control. The shortest driver's height (155 cm in female drivers) means the lowest measurements according to Figure 2 and the highest measurements mean the greatest height (195 cm in male drivers). The result thereof is correlation of anthropometric measurements with height. Nevertheless, there are cases when anthropometric measurements of some body parts are higher in short persons and vice versa (Table 1, j and m). It often happens that anthropometric measurements in men and women are different in case of the same heights. Such case was confirmed in these measurements too where measurement (g) was higher in men, and measurement (j) in women of the same height (175 cm). According to these analyses it may be claimed that anthropometric measurements affect driver's body posture in the car and the efficiency of car safety devices. A driver with large anthropometric measurements requires a larger space to feel comfortable and safe when driving.

CONCLUSION

An appropriately and ergonomically designed car seat reduces driver's fatigue and provides safe traffic.

Proper body posture, use of safety belts and airbag effectiveness support safety and reduce injuries in case of a collision.

Anthropometric measurements of a driver and surrounding measurements of car controls affect traffic safety and driver's fatigue.

A driver shorter than average has an inappropriate field of vision. Risk of injuries is higher due to the ineffectiveness of safety belts and airbags.

Taller than average drivers feel cramped so that a risk of injuries due to the ineffectiveness of safety belts and airbags is increased, and in particular head and spine injuries can occur.

In the future it may be expected that the workplace is adjusted to anthropometric measurements of a driver by using sensors.

Acknowledgements: *The results shown in the paper were obtained in scientific programs: Advanced Technical Textiles and Processes, code: 117-0000000-1376 conducted with the support of the Ministry of Science, Education and Sports of the Republic of Croatia.*

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