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LABORATORY STUDY ABOUT PRESSURE DISTRIBUTION ON CAR SEATS WITH PEOPLE OF DIFFERENT ANTHROPOMETRIC FEATURES PARTICIPATION

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Summary

This article refers to actual problem of cars' travelling comfort.

In the first part of the article, an experiment was described in which particular attention was given to measuring system that is used in studying pressure distribution on the car seat bottom and backrest of the car seat. The structure of this system and usage possibilities, including basic parameters of its' work were also discussed.

In the second part, an analysis of the conducted study results was presented, with special consideration taken to dependence between particular values which characterize the pressure distribution on car seat bottom and basic anthropometric parameters of the human body.

Keywords: comfort, static comfort, travelling comfort, pressure distribution, car seat bottoms

1. Introduction

'Comfort' is a very subjective term. What one person may consider as comfortable, other one may perceive as uncomfortable.

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While speaking about comfort with connection to phenomena like vibrations or vibration and noise, we should think about comfort as:
- static which depends on seat bottom comfort,
- vibrational which besides seat bottom comfort, depends on vibration level which influence the driver or the passenger,
- acoustic which depends on acoustic influence on a vehicle user.

In order to meet static comfort (convenience) and vibrational comfort requirements, the car should be equipped with appropriately selected vehicle body, driver's cabin and seat suspension [14, 15, 16, 17]. The seat should have a possibility to be adjusted to individual dynamic and anthropometric features of drivers (passengers). 'Anthropometric features' term shall be understood as, among others, height, weight and measurable features of human body anatomy which distinguish especially spinal cord, etc.

Comfortable car seat shall provide:
- adopting correct posture,
- proper backrest from orthopedic perspective,
- appropriate pressure distribution on the seat bottom and backrest surfaces.

In literature, terms seat and seat bottom are used interchangeably as synonyms. In this article we will use the term seat, which include the seat bottom and the backrest.

Appropriate seat position shall minimalize encumbrance on spine, abdominal, pelvic and thighs muscles of the driver. Angles of the best comfort when sitting in the car are shown in the Figure 1. These angles were set on the assumption that there is only low tension of the muscles and the elimination of the pressure on the internal organs.

Maintaining appropriate angles: trunk – thighs, trunk – arm, arm – forearm etc. requires steplessly adjustable longitudinal, vertical and angle regulation of the seat bottom and backrest of the seat. Height regulation of the seat bottom is also crucial for providing good visibility because it helps to eliminate eyes' level differences between sitting people of different heights (Fig. 1a) [7]. In the Figure 1b average ranges of the angles values of the comfort recommended by DIN 33408 standard are presented [13].

Proper adjustment of the seat's shape to the person's body and appropriate flexibility of rack covering should provide appropriate unit pressure distribution on the seat bottom and the backrest of the seat. Unit pressures of the highest values should be accumulated around ischiadic tuber, hence this causes relieving of thighs, and that reduces the risk of limbs ischemia and feeling of discomfort [7]. Their values in ischiadic tuber position may reach 10-20kPa, and around it 8-15kPa.

This pressure is highly dependent on person's weight and his or her build. For instance in case of people with higher weight, higher peak pressures are registered. Body build characteristics, for instance high amount of fat around buttocks may cause more even distribution of the pressure and as a result these pressure can be lower than in case of slim people [6].

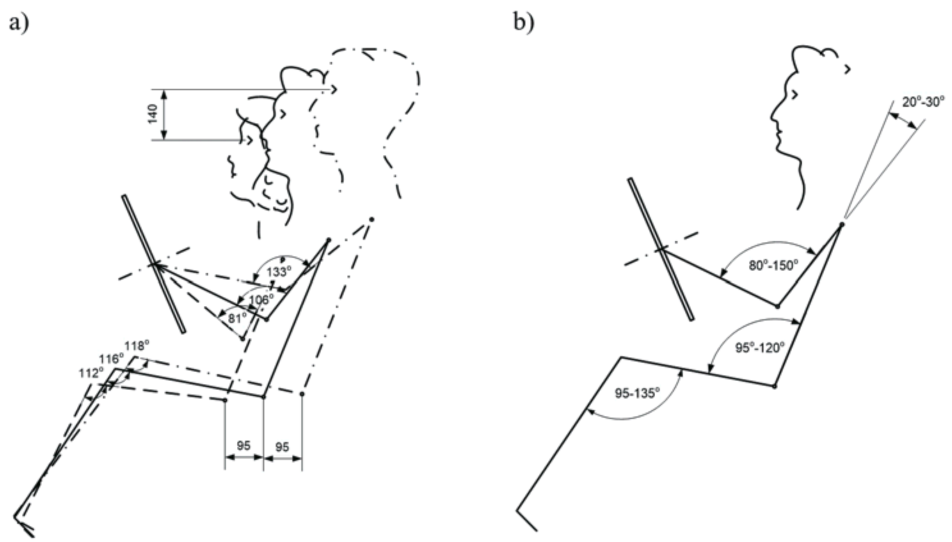

Fig. 1. Comfort angles for sitting position in a car:
a) for 50 centlie person and 5 centile female i 95 centile male [7],
b) comfort angle ranges recommended by DIN 33408 standard [13]

Body pressure on seat bottom's and backrest's surfaces creates local pressures, example of which is shown in Figure 2 [7]. These local pressures should not reach too high values, however, even distribution of them is also not recommended [7].

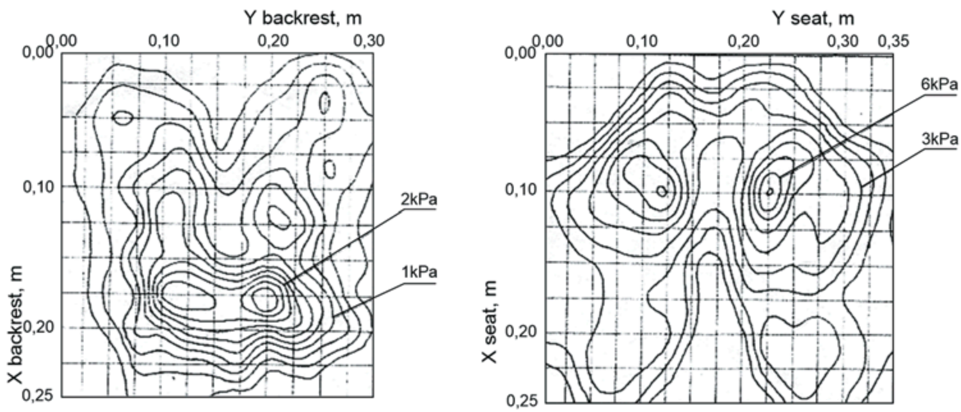

Fig. 2. The example of pressure distribution on: a – backrest, b – seat bottom, of the comfortable seat

Pressure on the backrest is significantly lower than this on the seat surface and from orthopedic point of view it is crucial for the spine, especially the lumbar vertebrae area, to be appropriately supported. The backrest of the seat should be properly adjusted to natural curvature of the spine.

In order to prevent lateral offset of the body during driving on rough surfaces, it is vital to appropriately adjust the shape of the whole seat. However, in the lower part of the backrest, around gravity center of the body, as well as on the rear part of the seat, there has to be provided lateral loose space. The upper part of the backrest should be constructed in such a way, that it provides freedom of movement for the arms during driving the vehicle.

The size and the nature of the contact surface between the body, the seat and the backrest has significant impact on static comfort assessment. [1, 2, 5, 8, 9]. In addition, for the driver, subjective optimal pressure distribution on the seat and the backrest of the seat is essential element for improving driving abilities.

Xuting Wu [10] has conducted comparative study of pressure distribution on two different kinds of vehicle seats (hard seat, soft seat). Six people took part in the research. Their sex has not been provided. The results has been shown in form of three-dimensional diagram. Andreoni [1] has used TEKSCAN system to register pressure distribution. Seven people took part in the study (six males and one female). During the study people adopted comfortable posture which has been registered with use of optoelectronic sensor.

Above mentioned studies became inspiration to conduct further studies on a larger number of people in order to find correlation between values characterizing pressure distribution on the seat bottom and anthropometric features of people.

2. Measurement devices – BPMS system

The study has been conducted with use of BPMS system (Fig. 3), which consists of following components:
- measurement module with USB interface to connect with the computer,
- software with sensors maps – map, i.e. library which allows to connect a particular sensor to the system,
- 5400N sensor (pressure sensing mat).

Basic parameters of measuring system are shown in the Table 1.

Table 1. BPMS measuring system parameters [11]

Name	Value
The accuracy of the system	10%
Linearity error	5%
Repeatability	3.5%
Hysteresis	4.5%
Response time	20 μs
Work temperature	from -9°C to 60°C

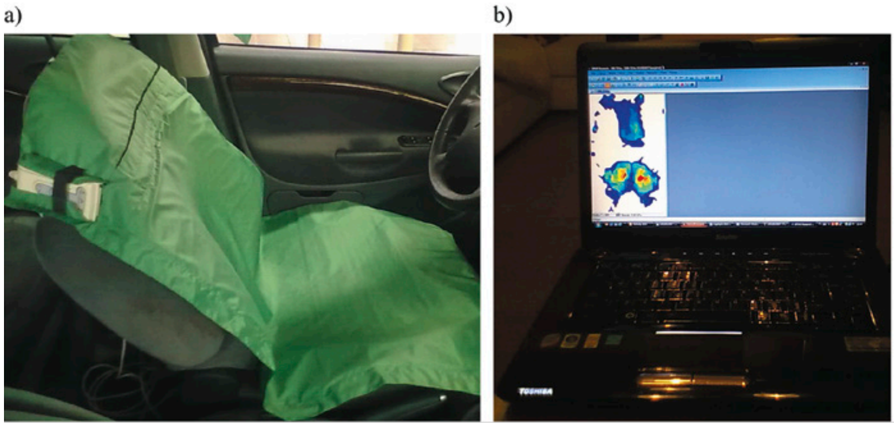

Fig. 3. Elements of measuring system: a) 5400N sensor (pressure sensing mat) placed on the seat with the Evolution Handle, b) PC with the software

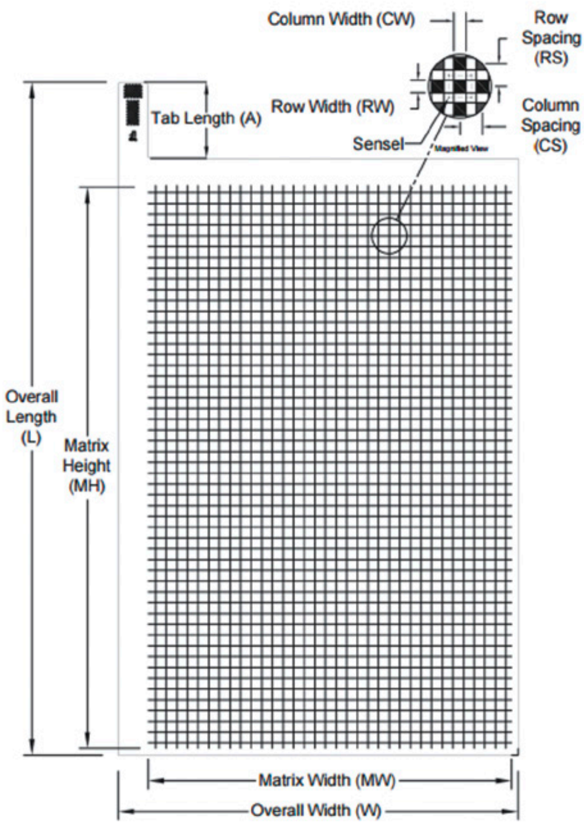

Fig. 4. Size of the pressure sensing mat model 5400N [12]

Tekscan™ pressure sensing mat (5400N model) (Fig. 4, Tab. 2) consists of, among others, 1768 sensors which use the change of electric resistance of the material as a result of acting mechanical power force. The data acquisition system connected with computer allows to obtain pressure maps of the surface of dimensions 578.1 mm x 883.9 mm in real time.

Table 2. Sizes and parameters of the pressure sensing mat [12]

Name	Value
Overall length (L), mm	1059.9
Matrix height (MH), mm	883.9
Overall width (W), mm	640.1
Matrix width (MW), mm	578.1
Number of measurement points	1768
Density of measurement points, measurement point/cm^2	0.3
Range of surface pressure, kPa	0-648
Thickness in the measurement area, mm	0.3

3. Research course

Both women and men, aged from 20 to 25 years old, participated in the carried out research. These persons were characterized by measuring anthropometric characteristics such as: height and weight. These characteristics enabled the establishment of the Body Mass Index (BMI) [3, 9, 11] for each of them as well as an indicator constituting a quotient of the weight and height.

BMI is an indicator used in medicine the value of which is calculated by dividing the body weight (m) given in kilograms by squared height (h) given in meters [3, 9, 11].

$$BMI = \frac{m}{h^2} \tag{1}$$

For grown-ups the BMI value may indicate: underweight, a correct weight, the first degree of obesity, the second degree of obesity or the third degree of obesity which is presented in table 3. The BMI values given in table 3 do not concern: persons under 18 years old, older persons, pregnant women and sportspeople. [11].

Table 3. Obesity indicator ranges

Status	BMI ranges, kg/m^2	
	Man	Woman
underweight	〈 20.7	〈 19.1
correct weight	20.7 - 26.4	19.1 - 25.8
first degree of obesity	26.5 - 27.8	25.9 - 27.3
second degree of obesity	27.9 - 31.1	27.4 - 32.3
third degree of obesity	〉 31.1	〉 32.3

The object of the research were seats of two types of cars. One of the tested seat was taken from a city car and the other one from a mid-size car.

During the experiment persons participating in the research adopted casual but comfortable postures while seating in the seats.

The BPMS measurement system used for the research registered force values in 1768 points and established:

- contact surface area of buttocks with the seat and of the back with the backrest,
- pressure distribution of the buttocks on the seat and of the back on the backrest (fig. 5),
- maximum pressure value imposed by the buttocks on the seat and by the back on the backrest [11].

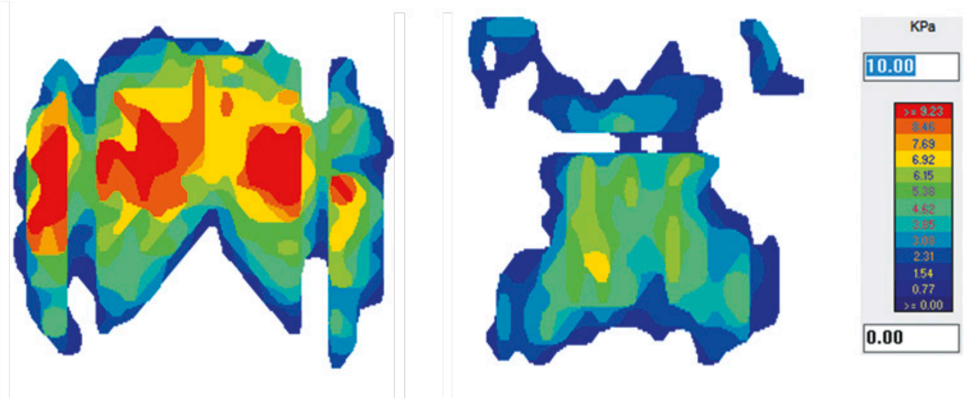

Fig. 5. Exemplary body pressure distribution registered on the car seat and the backrest

Pressure values, except for registered data, are presented in a graphic form; the "warmer" the color is, the bigger the pressure.

4. Research results analysis

The registered values characterizing the distribution of the pressure on the seat and on the backrest served to establish their correlation with the basic anthropometric characteristics of the persons participating in the research. The analyses results have been presented in a graphic form in figures 6 – 11.

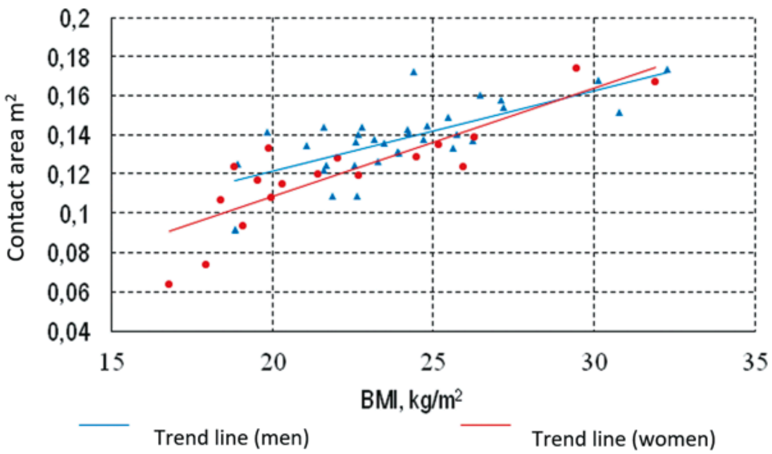

Fig. 6. Dependence between the size of the contact surface area of the buttocks with the seat and the BMI indicator of persons participating in the research for a city car

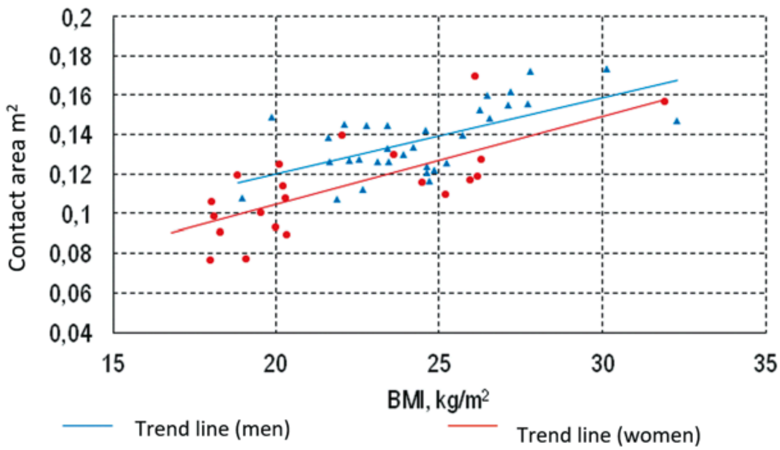

Fig. 7. Dependence between the size of the contact surface area of the buttocks with the seat and the BMI of persons participating in the research for a mid-size car

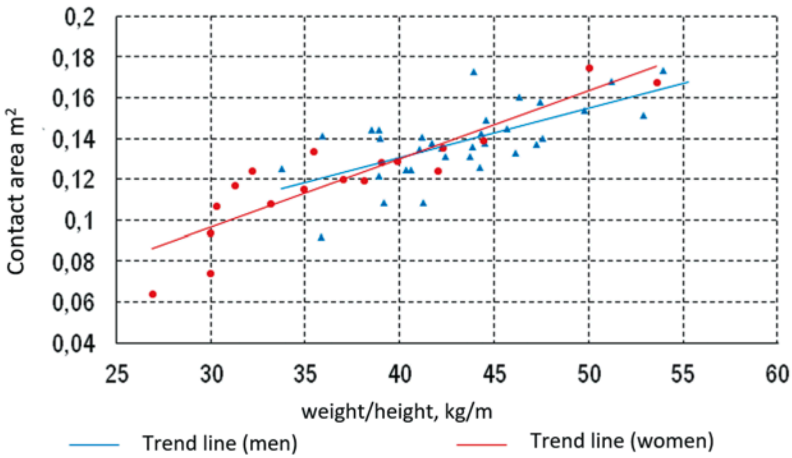

Fig. 8. Dependence between the contact surface area of the buttocks with the seat and the quotient of weight and height of persons participating in the research for a city car

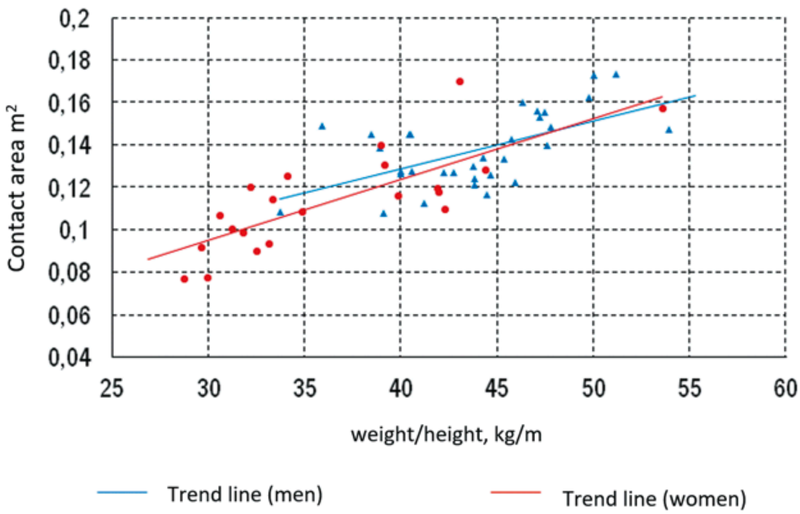

Fig. 9. Dependence between the contact surface area of the buttocks with the seat and the quotient of weight and height of persons participating in the research for a mid-size car

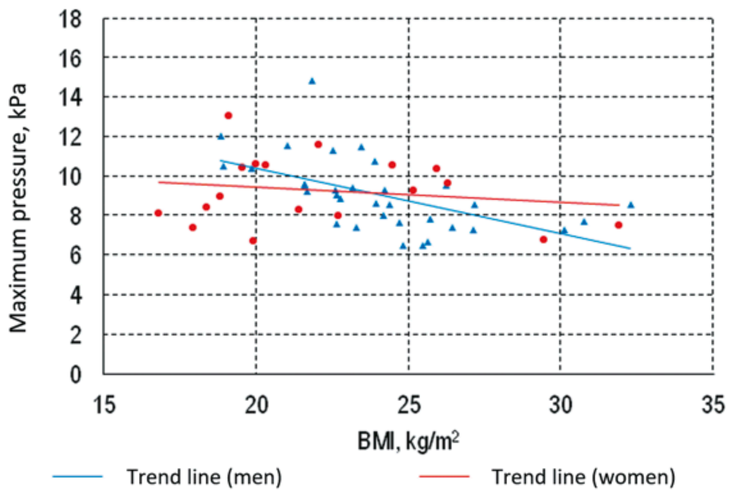

Fig. 10. Dependence between the maximum pressure imposed by the buttocks on the seat surface and the BMI indicator for persons participating in the research for a city car

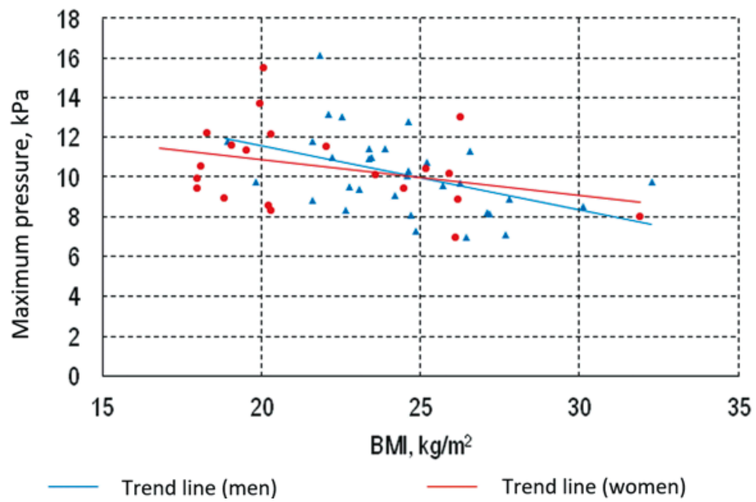

Fig. 11. Dependence between the maximum pressure imposed by the buttocks on the seat surface and the BMI of persons participating in the research for a mid-size car

The evaluation of the correlation and the existence of dependence between the registered values characterizing the pressure distribution on the seat (contact area of the buttocks with the seat, maximum pressure imposed by the buttocks on the seat) and indicators characterizing persons participating in the research (BMI, quotient of weight and height) has been carried out according to I. P. Guiford [4]. In the cases of sixteen correlation analyses high correlation has not been detected. In five analyzed cases high correlation has been detected and in seven cases – medium correlation has been detected (table 4).

In the remaining four cases the correlation was low and weak which is evaluated respectively as: dependence visible but of small "low correlation" and weak "almost unimportant".

Table 4. Compilation of correlation coefficients

Correlation coefficient		Indicator	
		BMI	weight/height
Contact area, mm^2	City car	0.72(♂)	0.62(♂)
		0.85(♀)	0.72(♀)
	Mid-size car	0.65(♂)	0.59(♂)
		0.89(♀)	0.78(♀)
Maximum pressure, kPa	City car	-0.56(♂)	-0.45(♂)
		-0.18(♀)	-0.33(♀)
	Mid-size car	-0.57(♂)	-0.46(♂)
		-0.24(♀)	-0.28(♀)

where:

- correlation coefficient below 0.2, weak correlation, dependence almost unimportant;
- correlation coefficient > 0.2 and ≤ 0.4, low correlation, dependence visible but small;
- correlation coefficient >0.4 and ≤ 0.7, medium correlation, dependence significant;
- correlation coefficient >0.7 and ≤ 0.9, high correlation, dependence significant;
- correlation coefficient >0.9 and ≤ 1.0, very high correlation, dependence certain.

5. Summary

The presented results comprise a part of research carried out within the scope of static comfort of car users.

On the basis of the gained results, prepared schemes and the evaluation of correlation the following conclusions have been made:

– the medium value of maximum pressures on the city car seat registered for all persons participating in the research equals 9.13 kPa and it turned out smaller by over 11% than the medium value of maximum pressures registered for the seat of the mid-size car;

– for women the medium value of maximum pressures registered in a city car and mid-size car equals 9.9 kPa and is higher by 2.5% than the medium value of maximum pressures registered for the same seats for men;

– the contact area of the buttocks with the seat is significantly influenced by the BMI indicator and the quotient of weight and height; the higher these indicators are, the bigger the contact area of buttocks with the seat;

- indicators established for men: weight/height BMI, have a significant influence on the maximum pressure of the buttocks on the seat; the higher these indicators are the bigger the contact area of the buttocks with the seat;
- in the case of women a visible influence on the maximum pressure of the buttocks on the seat have: the quotient of weight and height and BMI.

The familiarity of the pressure distribution on the seats can contribute to the optimization of car seats design and to an enhancement of mathematical test dummies models used to test car seats.

The results indicate a need of carrying out further tests with the use of a bigger number of cars of the same classes and persons in whom other anthropometric characteristics will be identified, such as for example the hip size.

The full text of the Article is available in Polish online on the website http://archiwummotoryzacji.pl.

Tekst artykułu w polskiej wersji językowej dostępny jest na stronie http://archiwummotoryzacji.pl.

References

[1] Andreoni G, Santambrogio G C, Rabuffetti M, Pedotti A. Method for the analysis of posture and interface pressure of car drivers. Applied Ergonomics 33. 2002: 511-522.

[2] Hinz B, Gericke L, Keitel J, Menzel G, Seidel H. Untersuchungen der Druckverteilungen an der Kontaktstelle Mensch-Sitz in Abhängigkeit von Sitzen, Haltungen und Körpermaßen. Z. Arbeitswissenschaft 54. 2002: 125- 188.

[3] Matusik P, Małecka-Tendera E, Nowak A. Metody stosowane w praktyce pediatrycznej do oceny stopnia odżywienia dzieci. Endokrynologia, Otyłość i Zaburzenia Przemiany Materii 2005; 1(2) /ang. Methods used in pediatrics practice for assssing the level of children nutrition. Endocrynology. Obesity and Metabolic Disorders./

[4] Mończak K. Technika planowania eksperymentu. /ang. Experimental technique planning/ WNT, Warszawa 1976.

[5] Reed M P, Saito M, Kakishima Y, Lee N S, Schneider LW. An investigation of driver discomfort and related seat design factors in extended-duration driving. Society of Automotive Engineers. 1991; 910117.

[6] Reed M. P, Schneider L W, Ricci L L. Survey of auto seat design recommendations for improved comfort (No. UMTRI-94-6). University of Michigan, Transportation Research Institute, 1994.

[7] Szelichowski S. Drgania a komfort fotela kierowcy. /ang. Vibrations and driver's seat confort./AUTO-Technika Motoryzacyjna 7'89.

[8] Thakurta K, Koester D, Bush N, Bachle S. Evaluating short and long term seating comfort. Society of Automotive Engineers. 1995; 910144.

[9] Tsigos C, Hainer V, Basdevant A, Finer N, Fried M, Mathus-Vliegen E, Micic D, Maislos M, Roman G, Schutz Y, Toplak H, Zahorska-Markiewicz B. Postępowanie w otyłości dorosłych: europejskie wytyczne dla praktyki klinicznej. /ang. Treatment in adult obesity: European Guidelines for clinical practice/ Translated by Zahorska-Markiewicz B. Via Medica, Gdańsk; ISSN 1734–3321.

[10] Wu X, Rakheja S, Boileau P-É. Study of human-seat interface pressure distribution under vertical vibration. Int. J. of Industrial Ergonomics 21. 1998: 433-449.

[11] Available from: www.poradnia.pl [cited 2016 Nov 2].

[12] Available from: www.tekscan.com [cited 2016 Nov 2].

[13] Zabłocki M, Sydor M. Ergonomy of the inside of a motorcar cabin used by a person with locomotive disability-a case study. Part I. Anthropometric analysis. Journal of KONES. 2009; 16, 559-566.

[14] Zuska A, Stańczyk T L. Analysis of the impact of selected anthropometric parameters on the propagation of vertical vibration in the body of a seated person (driver), JVE Journal of Vibroengineering. 2015; 17(7).

[15] Zuska A, Stańczyk T L. Application of anthropodynamic dummies for evaluating the impact of vehicle seat vibrations upon human body, Journal of Theoretical and Applied Mechanics, 2015; 54(4).

[16] Zuska A, Stańczyk T L. Przegląd antropodynamicznych modeli siedzącego człowieka pod kątem wykorzystania ich do badań komfortu wibracyjnego kierowcy /ang. Review of anthropo-dynamic models of the seated human with respect to investigations on driver's vibration comfort/. 2014; (3).

[17] Zuska A, Stańczyk T L. Review of anthropodynamic dummies used to evaluate the effect of vibrations on sitting human (vehicle driver). The Archives of Automotive Engineering – Archiwum Motoryzacji. 2014; 63(3): 65-74.