

Assessment of the actual hand position on the steering wheel for drivers of passenger cars while driving

M. Hruška

Czech University of Life Sciences, Faculty of Engineering, Department of Technological Equipment of Building, Kamýcká 129, CZ165 21 Prague 6, Czech Republic

*Correspondence: jabko@tf.czu.cz

Abstract. This work deals with the assessment of the actual position of the hands on the steering wheel of drivers of passenger cars in specific driving modes. The findings are compared with the location that is generally considered to be optimal in terms of both active and passive safety, and the long-term effects on the health of the driver. The research described in this work was carried out on a sample of randomly selected drivers in the Czech Republic. For all of the measurements, one identical neutral passenger middle-class vehicle, with which none of the test subjects had previous experience, was selected. The reason for this research was to model a normal situation where the driver controls a vehicle with his hands on the steering wheel in a position that is only the result of his or her own intuition and the subjective sense of the driver's comfort. On the basis of a statistical evaluation of the obtained data, it was found that the introductory hypothesis, which states that a significant part of the tested sample of drivers holds the steering wheel in an unsuitable manner, can be confirmed. This fact negatively impacts not only on the reduction of active and passive safety, but also affects the health of drivers who drive a large amount of kilometres annually. The results of this work can be used in the design of cabs and modern passenger car systems that will be able to motivate the driver to hold the steering wheel in an optimal way. This will directly affect road safety and positively influence the health of drivers.

Key words: driver, posture, hands, steering wheel, age, gender.

INTRODUCTION

Today, the ergonomic design of passenger car cabins is a key part of the design process of a new vehicle (Wang et al., 2007; Bhise, 2012). An optimally ergonomically-designed driver's seat plays a major role particularly in the field of vehicle safety (Reed, 1998). Modern multifunctional steering wheels and hand rests provide a direct link between the driver and the machine, and the optimal design of these elements directly affects the driver's feelings and well-being, and thereby the safety of the vehicle's operation (Chang & Chen, 2016).

The position of the driver's hand on the steering wheel is important from several points of view, but these are in some ways contradictory. They include, for example, active safety requirements, subjective feelings of comfort, passive safety, and others. This work seeks to ascertain and evaluate the actual position of drivers' hands that they most often occupy during long, calm trips on major roads or motorways. The work compares the acquired data with values that are described as optimal (Hault-Dubrunelle et

al., 2010), and the differences obtained are assessed mainly from a physiological and medical point of view. The work is also concerned with the position of the grip on the load on specific muscle groups, in particular in the area of the lumbar spine.

A great deal of research focuses on measuring the position of the driver’s hand on the steering wheel (Schmidt et al., 2015), and such research is mostly focused on the impact of grip on passive safety and the subsequent type and extent of injury during an accident. This most often consists of measurements in laboratory conditions and on special measuring seats (Schiro et al., 2013). This work obtains accurate data from a real environment, where the monitored subject is not stressed by the laboratory environment and sits in the actual vehicle, and is therefore able to take up the position that is used in normal operation.

There is a relatively high degree of consensus among experts on the issue of optimum steering wheel grip values. The optimal value is generally specified, according to the analogue clock face with the position of the left hand on the nine, and the right hand on the three while the driver holds the steering wheel with both hands (Hault-Dubrulle et al., 2010; Schiro et al., 2013). The primary objective of this work is to find out how large a percentage of drivers from the tested sample do not observe these grip values, and what the most commonly used values actually are.

Some ergonomics studies (Hruška & Jindra, 2016) showed that there is a link between gender, as well as the age of the driver and his or her ability to control the vehicle and adjust its controls. The secondary objective of this work is therefore to verify the hypothesis that there is a correlation between age, gender, mileage driven and correct steering wheel grip.

MATERIALS AND METHODS

Participants

A total of 100 participants (39 women and 61 men) were obtained for the measurements, all of them from the university environment – students or graduates of technical or economic orientation. The age of the participants ranged from 18 to 65 years (the average age was 29 years). It was clearly required and verified that all of the participants had a driving license authorizing the driving of passenger cars. All of the participants were also in good health and had no restrictions in the locomotive apparatus.

Table 1. Number of tested persons and their parameters in relation to the measurements

	Amount	Age			Number of driven km (thousands of km)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
Men	61	30	19	65	192	5	800
Women	39	27	18	52	68	5	400
Total	100	29	18	65	144	5	800

Test environment

The test vehicle that was chosen was the Mercedes Benz C220d model series 2016, with standard interior features and steering on the left. The vehicle was equipped with modern longitudinally-adjustable seats with mechanical movement in the longitudinal direction and with the electronic positioning of the seat height, seat inclination and backrest inclination (Fig. 1). All of the tested persons marked the range of seat and

steering wheel position settings as sufficient. The features included a mechanically adjustable steering wheel with a classical cross-sectional arm (Fig. 1). The vehicle can be characterized as a standard mid-class sedan with a classical steering wheel design.

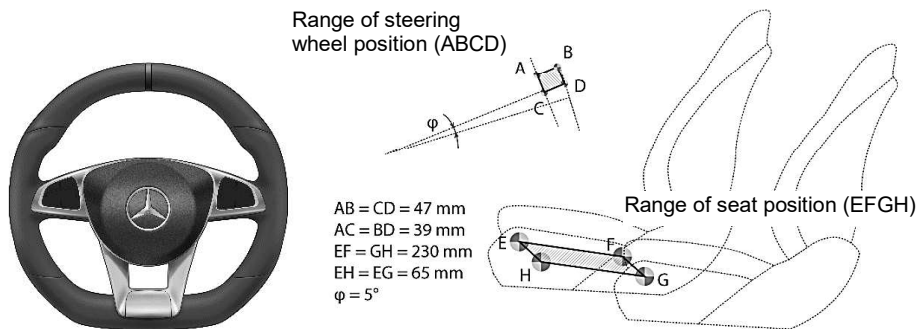


Figure 1. Seat and steering wheel position ranges, and the shape of the steering wheel in the test vehicle.

The vehicle was placed in a laboratory under constant light conditions at constant temperature and stable noise load so that all of participants in the experiment had the same external conditions (Fig. 2). During the measurements, the driver’s door was closed to allow the test subject to use the left arm rest.



Figure 2. Test subject in the measuring vehicle with hands in the optimal position L9-R3.

Data Collection Procedures

None of the tested persons had any previous experience with the test car, but all of the tested persons were using the same steering wheel concept that the test vehicle had at the time of the vehicle measurement. Each tested person was thoroughly trained and familiarized with the seat and steering wheel control systems before getting into the measuring vehicle. After getting into the test vehicle, each tested person was given enough time to test out and understand all of the functions necessary to control the seat and steering wheel position. Prior to the measurement, each tested person was asked whether he or she considered his position in the vehicle to be comfortable and whether this position was as near as possible to the position they normally occupy in a vehicle.

The test subjects were also asked to grip the steering wheel in the way in which they were used to and in a truly relaxed position during usual traffic on a major road outside a city. The position of the hands was subsequently coded as L1-L12 or R1-R12, or a combination of both positions, when the steering wheel was gripped by both hands (Fig. 3). However, in practice, because other values were not measured, the left hand values were measured only on the left part of the L7-L12 sphere, and for the right hand on the right part of the R1-R6 sphere.

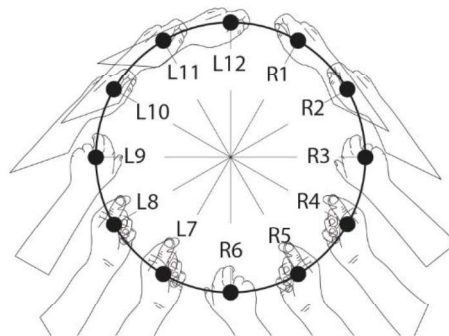


Figure 3. Scheme of the positions of individual grips according to the analogue clock face.

The active data collection described above, where the test subject is directly in the vehicle and is able try out the investigated hand position on the steering wheel, was evaluated as the better than the normal questionnaire method. As part of the aforementioned measurements, during the primary collection of statistical data (age, mileage driven, etc.), the tested persons were also asked about the position of the hands on the steering wheel. However, after getting into the vehicle, nearly 70% of the tested persons corrected or clarified this data, in particular due to the effect of mechanical memory, where the test subjects better realized the position in which they ordinarily drive. For the reasons described above, only the data obtained directly by measurements in the vehicle are therefore used for statistical evaluation.

RESULTS AND DISCUSSION

The results obtained during the measurements were statistically processed and evaluated using pivot tables, the Pearson's chi-squared test and the Anova method. The percentage representation of individual positions obtained from the measured data, regardless of whether the steering wheel is held in one hand or both, are shown in Table 2 and Fig. 4. The data shows that some of the steering wheel grip positions, such as position R3, differ substantially for both genders, whereas the opposite position, L9, indicates roughly the same results for both genders. These differences are explained below based on demonstrated right or left hand preferences depending on gender.

Table 2. The resulting values of grip percentage representation in individual positions

Item	L7	L8	L9	L10	L11	L12	R1	R2	R3	R4	R5	R6
Both genders	14.9%	5.3%	43.6%	26.6%	6.4%	3.2%	1.7%	27.1%	54.2%	5.1%	10.2%	1.7%
Women	12.8%	0.0%	48.7%	38.5%	0.0%	0.0%	0.0%	11.0%	16.0%	0.0%	2.0%	0.0%
Men	16.4%	9.1%	40.0%	18.2%	10.9%	5.5%	3.3%	16.7%	53.3%	10.0%	13.3%	3.3%

Interesting are the differences in the upper positions L11, L12 and R1, where women do not use these positions at all. This fact can be explained mainly by lower values of anthropometric data in women compared to the same parameters in men. Another possible explanation is the need to use more steering forces on the steering wheel at these positions, given the longer lever, which may be less comfortable for women (Tilley, 2002).

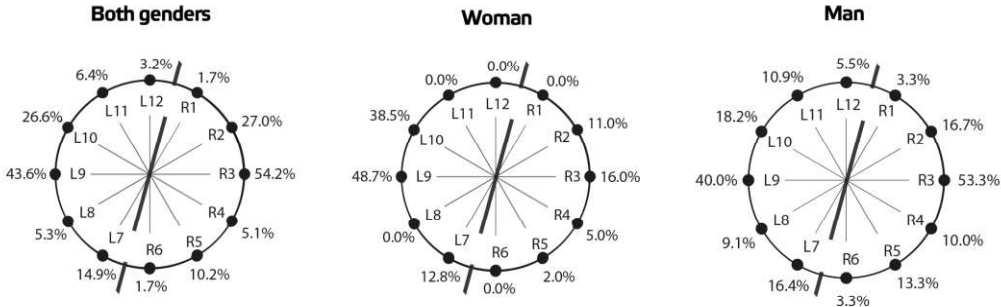


Figure 4. Schematic depiction of the resulting grip percentage representation values in individual positions.

Note: The values in percentages are calculated separately for the left and right hand.

The percentage representation of the steering wheel grip method using only the left or right hand, or both hands at once, and depending on gender, is shown in Table 3. Here, it is evident that women prefer to hold the steering wheel with both hands, which is also confirmed below by Pearson’s chi-squared test (Table 4).

If women hold a steering wheel with one hand, they significantly prefer the left hand, and they do not use the right hand at all when steering. Even in the case of men, it is evident that when driving with only one hand, they use the left hand. This can be explained by the fact that all of the test subjects exclusively drive cars with steering on the left and the shift lever is on the right side of the car. This may lead to the preferred use of the left hand for steering while the driver is restrained by the right hand on the central armrest and the right hand is placed on the gear lever. In this respect, it would be interesting to supplement the results presented in this work with further follow-up research that would identify the same data for persons using only vehicles with the steering on the right side. This would make it possible to specify this influence more closely.

Table 3. Method of holding the steering wheel depending on gender

	Left hand only	Right hand only	Both hands
Both genders	41.0%	6.0%	53.0%
Women	25.6%	0.0%	74.4%
Men	50.82%	9.84%	39.34%

Table 4. Data evaluation using a Pearson’s chi-squared test

Degrees of freedom	X ²	Critical value	Cramer’s V	Significance level
1	11.7	3.84	0.342	0.05

In order to confirm the hypotheses defined above, it was necessary to subject the measured results to a statistical analysis. Pearson's chi-squared dependency test was used in order to test the dependency between the gender of the tested persons and the optimal value of the spontaneously chosen angle.

Table 5 shows the input data for evaluating the statistical significance of how the steering wheel is held depending on the gender of the tested persons. As the default source for further statistical processing, a pivot table (Table 5) with two degrees of freedom was used, distinguishing separate grips with left and right hand. Because the number of subjects who steered using only the right hand was insufficient, it was necessary to reduce the degree of freedom and merge the subjects with those who steered with any one hand and those who steered with both hands. Using Pearson's chi-squared dependence test, the value of X^2 (11.71) was calculated, which is significantly higher than the critical value (3.84), confirming the primary input hypothesis that the method of holding the steering wheel is dependent on gender.

The rate of grip dependency on gender was further verified by Cramer's V (0.342). Based on the calculated values, the dependence of the grip on the steering wheel on gender can be considered significant. The explanation of the difference in gripping a steering wheel between women and men can be sought out in particular in the different settings of the relative position of the steering wheel and the top of the body for each gender. As was ascertained in other research (Hruška & Jindra, 2016), women have a tendency to sit closer to the steering wheel and to have more bent and relaxed hands. This is due to differences in the anthropometric parameters of men and women (Tilley 2002; Wang et al., 2007), but also in the psychological level, as women tend to approach driving more responsibly (Bergdahl, 2005) and try to observe the generally recommended position of L9R3, even at the cost of lower subjective comfort.

Tables 6, 7 and 8 show the most frequently represented combinations when the test subject holds the steering wheel with both hands. It can be seen that in this case, the results for both men and women are very similar, and the differences occur mainly in the frequency of individual combinations. When steering with both hands, most of the subjects mainly use the L9R3 or L10R2 position, which is strongly represented mainly by women.

The Mann Whitney U test statistical method at a significance level of 0.05 was used to assess secondary hypotheses that assess the dependence of the way a steering wheel is gripped on experience (driven mileage) and age.

Table 5. Input data for statistical evaluation of the dependence of steering wheel grip on gender

	Left only	Right only	Both hands	Sum
men	31	6	24	61
women	10	0	29	39
both genders	41	6	53	100

Table 6. The most represented combinations of hand position without gender differences

	L7	L8	L9	L10	L11
R1	0	0	0	0	1
R2	0	0	1	15	0
R3	0	0	30	0	0
R4	1	0	0	0	0
R5	4	1	0	0	0

Table 7. The most represented combinations of hand positions for women

	L7	L8	L9	L10	L11
R1	0	0	0	0	0
R2	0	0	0	11	0
R3	0	0	16	0	0
R4	0	0	0	0	0
R5	2	0	0	0	0

Table 8. The most represented combinations of hand positions for men

	L7	L8	L9	L10	L11
R1	0	0	0	0	1
R2	0	0	1	4	0
R3	0	0	14	0	0
R4	1	0	0	0	0
R5	2	1	0	0	0

The *p-value*, calculated by the Mann-Whitney test, which determines the order of the respondents by mileage divided by the way the steering wheel is held, is 0.001. Since this value is less than the chosen significance level of 0.05, it can be confirmed that the method of holding the steering wheel is related to mileage. Drivers who have a higher mileage drive more often with one hand (Table 9).

The *p-value*, calculated by the Mann-Whitney test for the age-based respondents, divided by the way the steering wheel is held, is 0.068. Since this value is higher than the chosen significance level of 0.05, it can be said that the steering angle of the steering wheel is not statistically significant with the age of the respondents (Table 10).

Table 9. Dependence of steering wheel grip method on the number of driven km using the Mann Whitney U test method

Steering wheel grip	Number of subjects	Average km	<i>p-value</i>
One hand	47	177.6	0.001
both hands	53	113.3	

Table 10. Dependence of steering wheel grip method on the age of subjects using the Mann Whitney U test method

Steering wheel grip	Number of subjects	Average age	<i>p-value</i>
One hand	47	30.2	0.068
both hands	53	28.1	

The above results must also be interpreted from the point of view of the effects on the health of the driver, in particular for professional drivers or for drivers who travel long distances; it is for these drivers that the aforementioned data is essential as a factor that has a long-term effect on their health condition.

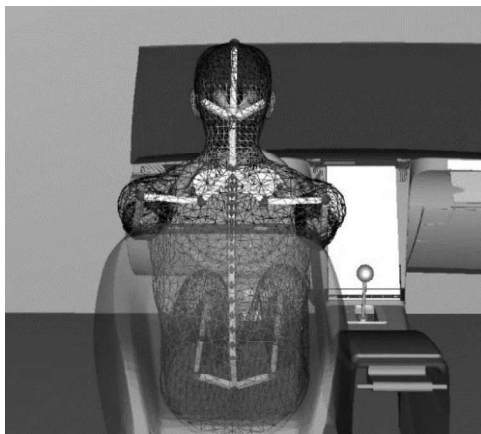


Figure 5. Driver gripping the steering wheel in position L9R3.

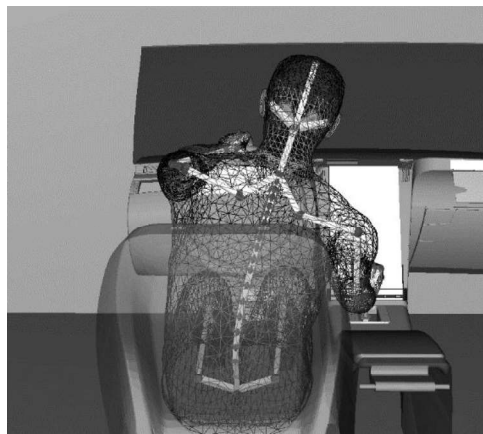


Figure 6. Driver gripping the steering wheel in position L12.

While observing test subjects during the measurements, it became clear that every subject who does not grip the steering wheel with both hands, will necessarily be subject to a certain degree of rotation of the upper half of the body. If we assess the aforementioned steering wheel grip position from the viewpoint of the impact on the health of the driver, it should be noted, that the worst steering wheel grip positions are L11, L12 and R1. In order to simply evaluate of these positions, the Tecnomatix Jack program was used, in which the L9R3 (Fig. 5) and the L12 (Fig. 6) positions were simulated for a 95 percentile man in a general middle class sedan. In Figs 5 and 6, it is quite clear that in drivers who only grip the steering wheel with the left hand in the least suitable position, L12, there is significant lateroflexia with significant muscle strain, in particular *m. quadratus lumborum*, *m. obliquus externus abdominis*, *m. obliquus internus abdominis* and *m. erector spinae*. Long-term driving in such a position can lead to pain in the lumbar spine and, in extreme cases, to permanent damage to the postural system (Véle, 1995; Havlíčková, 1999). In contrast, the driver in Fig. 5, who holds the steering wheel with both hands in the L9R3 position, is sitting upright and the load on the muscle groups in the lumbar spine is uniform in this case. As can be seen from the above results (Table 2), the above described inappropriate positions are occupied exclusively by men, and it can therefore be stated that the influence of the inappropriate position of the steering wheel grip on health condition will be significantly greater for men than for women.

CONCLUSIONS

In this work, a large amount of valuable primary data was obtained from a relatively homogeneous group of respondents, which may be statistically interesting in terms of possible comparisons with other statistics that could be obtained from respondents with other parameters such as different education, age, etc. By dividing the data by means of pivot tables, it was found that when driving, a statistically significant group of respondents gripped the steering wheel in a way that cannot be labelled as optimal on the basis of the selected comparative parameters.

This finding could be used for the further development of passenger car cabins, where the modelling of the interior could create conditions wherein the driver is not forced to find a subjectively comfortable grip of the steering wheel which, however, cannot be described as optimal for the above reasons (Hault-Dubrulle et al., 2010; Schiro et al., 2013,). This would eliminate the human factor, which is imperfect in these cases of subjective judgment.

On the basis of the above results, it can be further stated that the primary hypothesis mentioned in the introduction of the thesis has been fully confirmed. There are statistically significant differences in how men and women grip the steering wheel when driving in calm traffic outside cities. The explanation of this phenomenon can be seen in the generally more responsible approach of women to driving a car (Vágnerová, 2007), but also in the fact that men are able to relax more freely in the vehicle and occupy an instinctively relaxed position (Wilson, 1999, Bergdahl, 2005).

The secondary hypotheses, specified in the introduction to this work, were partially demonstrated, only in the case of the dependence on the method of holding the steering wheel on mileage. In the case of dependence on holding the steering wheel on

respondent's ages, some dependence was found, but it cannot be considered valid due to insufficient statistical evidence.

The results presented in this paper could serve as a basis for further research that could help to further refine the aforementioned findings. The data and hypotheses presented in this paper could serve as ancillary factors in the design of vehicles with regard to potential customer target groups.

The contribution of this work can also be seen in the number of test subjects and gender factor involvement. Another benefit of this work is the provision of valid data for further follow-up research in which the above results could be clarified or supplemented by data obtained from field investigations or, for example, from environments where vehicles with the steering on the right prevail, thereby excluding or confirming some other hypotheses which came from this research.

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