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BIOMECHANICAL RATIONALE OF THE DRIVER'S WORKING POSTURE BEHIND THE WHEEL OF A CAR

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ABSTRACT

An important element of active road safety is the correct working posture of the driver behind the wheel, which ensures a reduction in the number of driving errors, delays the onset of fatigue, and prevents driver injury in emergency situations.

The purpose of the study is the biomechanical justification of the individual safe working posture of the driver. To achieve the goal, video recording of the working posture behind the wheel of the world's best rally drivers was used; electromyography on a simulator of the main muscles involved in steering the wheel; a pedagogical experiment involving qualified drivers who repeatedly passed the slalom course in different working postures behind the wheel of a production car; methods of mathematical statistics.

It was found that the winners of the World Rally Championship sit behind the wheel with the seatback tilted back minimally and with their arms bent at right angles at the elbows, holding the steering wheel. The results of a pedagogical experiment with drivers who repeatedly drove a slalom course in a production car in different working positions, as well as electromyography of the muscles involved in turning the steering wheel, confirmed that the described position behind the wheel of the world championship leaders provides the highest steering accuracy and speed, the ability to apply the greatest force to hold and turn the steering wheel in emergency situations, as well as reducing fatigue during a long trip.

Therefore, to reduce the number of road accidents, drivers can be recommended the working posture described above.

It is expected that the implementation of the developed practical recommendations will allow to increase the level of active road safety.

Keywords: *car, driver, comfort, safety, fatigue, steering wheel, working posture, car rallies*

Introduction

The requirement to ensure human health and safety at all levels of its activity requires a detailed study of the phenomena that occur during movement and accidents

of the "driver-vehicle-road-environment" (DVRE) systems (Rybak et al., 2018). As experts claim Rybak, 2013, the importance of the subjective factor – the driver – in this system undoubtedly outweighs the importance of objective factors. Therefore, improving his workplace is an important scientific and practical task.

According to UNESCO, among the causes of human mortality in peacetime, road accidents (RA) rank third in the world after malignant tumors and cardiovascular diseases. Road traffic accidents continue to remain one of the leading causes of mortality and a direct economic burden worldwide (World Health Organization [WHO] (2023). The WHO Global Report on Road Safety 2023 details the scale of road traffic deaths and progress in improving laws, policies and actions to reduce them worldwide. It reviews progress made between 2010 and 2021 and sets a baseline for the United Nations road safety targets and actions for 2021–2030, which aim to halve road traffic deaths and injuries by 2030. While road traffic deaths fell to 1.19 million per year between 2010 and 2021, and efforts to improve road safety are paying off, the cost of mobility remains too high, and urgent action is needed to halve road traffic deaths and injuries by 2030. Unless urgent action is taken, WHO estimates that road traffic accidents will become the seventh leading cause of civilian death by 2030. Today, 90 percent of road traffic accidents occur in low- and middle-income countries, which have not yet benefited from the stricter vehicle standards and effective road safety laws established in high-income countries.

A number of modern scientific studies are devoted to the analysis of the causes of road accidents Bucsuházy et al., 2020; Inah et al., 2025; Hill & Boyle, 2006; Shakil et al., 2023. One of them is the incorrect working posture of drivers behind the wheel. Modern methods are used to study it Bingley et al., 2005; Carlsson et al., 2016; Chen et al., 2016; Reed et al., 2000; Zhao et al., 2018; widely using posture modeling Fehren et al., 2003; HaultDubrulle et al., 2011; Östh et al., 2014. The working posture behind the wheel is associated with driver fatigue, which is often the cause of accidents Grujicic et al., 2010; Michida et al., 2001; Park et al., 2002.

Much attention of researchers is directed to studying changes in the working posture of drivers immediately before an accident Ejima et al., 2008; Gao et al., 2016; Hetier et al., 2005; Khattak et al., 2024, as well as the relationship between the posture of drivers and passengers in vehicles and the severity of injuries they receive as a result of a road accident (Doecke et al., 2020; HaultDubrulle et al., 2011; Hou et al., 2020; Katsuhara et al., 2017; Leledakis et al., 2021; Schaefer et al., 2021.

The results obtained by the above-mentioned scientists clearly confirm the feasibility of reducing the impact on road accidents of the weakest link in the human-machine-road-environment system, which is the driver (Rybak et al., 2019), by improving his working posture while driving.

In recent years, a number of publications have been published on recommendations for correct posture while driving (PhysioMed (n.d.). *Correct sitting posture*; Uti res (n.d.). *Driving posture tips and stretches for a long trip*; Evercare Protection. (n.d.). *6 maneras de asegurar una postura correcta al volante*; Frotcom. (2021, November). *7 sencillos consejos para una buena postura al volante*; Lipe, 2023). However, these recommendations

are usually subjective and fragmentary in nature, as they are not supported by scientific research results and are based on traditional approaches and personal experience; the authors of these recommendations are not indicated, etc. Therefore, the problem of improving the ergonomic working posture of the driver behind the wheel, which would ensure precise control of the vehicle for a long time without fatigue, the successful implementation of all anti-accident actions to prevent accidents or reduce their severity (active safety elements), as well as reducing injuries in the event that an accident is inevitable (passive safety). Such a posture should also allow the driver to act with the necessary effort on the steering wheel and brake pedal in the event of an unexpected failure of the power steering and brakes (for example, when the corresponding drive belt is damaged, a hose bursts, the engine of a car with automatic transmission stalls, etc.) – in situations that almost 100% cause serious accidents.

The study of such an important element of vehicle control as steering is devoted to the work of the authors Atkinson et al., 2002; Previati et al., 2024; Walton & Thomas, 2005, who found that drivers often provide torque with one hand, and do not create it with both hands, applying force to the steering wheel in opposite directions. It was also found that gripping the steering wheel with the hands by its lower part creates a significant risk of injury to the upper limb during airbag deployment. However, participation in steering wheel rotation of various functional muscle groups of the driver, the magnitude of torques created on the steering wheel and the accuracy of steering wheel turns in different working postures have not been studied enough and require further study.

The aim of the scientists Siqueira Labrego ey al. (2025) was to determine the optimal posture of a person while sitting and standing based on a questionnaire of 544 Greek physiotherapists, who chose the optimal sitting posture from seven options proposed by the researchers, and from five options for standing, justifying their choice. The topic of the study itself was considered important or very important by 93.9% of the respondents. Of these, 97.5% chose three different sitting postures as optimal. Despite the lack of complete consensus, the most frequently chosen postures were certain variations of vertical lordotic sitting, in contrast to stooped spine curves or forward head postures, which were almost never chosen as optimal. The survey participants used similar arguments to justify their choice – natural spinal curves, muscle activation. It turned out that the optimal position for the curvature of the thoracolumbar and lumbar spine, as well as the level of comfort, is the best one with the backrest tilted at an angle between 0° and 15°. The results obtained by the authors Korakakis et al. (2019) confirm previous data regarding the optimality of vertical lordotic sitting postures and can be recommended when modeling the working posture behind the wheel.

All the studies described above (except Katsuhara et al., 2017) concern the working posture behind the wheel and its influence on the accident rate on the roads of civilian and professional drivers of different categories who drive different vehicles in different conditions. The working posture behind the wheel of the best drivers in the world, such as rally racers – participants in world championships – has not been studied enough, although the parameters of their working posture behind the wheel of sports cars, which

ensures accurate, efficient, long-term and error-free driving, and also allows you to avoid (or significantly reduce the severity of) injuries in emergency situations, can be successfully used to develop practical recommendations for civilian drivers, including drivers of special, rescue, operational and military vehicles.

Incorrect driver posture behind the wheel leads to rapid fatigue and decreased concentration caused by the need to constantly hold your own body. Compliance of the parameters of the driver's working posture with his anthropometric characteristics ensures alignment and support of the head, neck, arms, back, buttocks and legs, helps reduce static and dynamic mechanical loads and overloads and fatigue, and also significantly reduces the risk of injury in emergency, extreme and emergency situations. Ergonomic "seating" allows the driver to receive more complete and detailed information about the movement of the car, determines the accuracy of work with the controls, increasing active road safety (Rybak et al., 2018; Rybak, 2013).

Therefore, the purpose of the study was chosen to substantiate and improve recommendations for individualizing a safe working posture behind the wheel.

Methodology

To achieve the goal of our research, a number of experimental methods were used. The study of the driver's muscle biocurrents during steering wheel rotation was carried out using the multi-channel functional complex "Neuro-MVP8" in laboratory conditions on a passenger car simulator designed by us Rybak O. & Rybak L (2012) with the involvement of the master of sports in automobile sports Yu.R. (age – 35 years, experience in car racing – over 20 years), who gave written consent to voluntary participation in the experiment, in which the research protocol was described in detail. After a 15-minute warm-up on the simulator (simulating the passage of high-speed sections of the Rally of Finland – gravel roads with many turns and elevation changes) for 30 minutes using skin electrodes – during the simulation of the passage of the following routes of high-speed sections on the simulator – the electrical activity of the muscles of those functional muscle groups that can participate in steering was recorded.

The biocurrents of the studied muscles were recorded by applying the surface electrodes "Skintakt" an interelectrode distance of 2 cm to the zones of their motor points with. The electrodes were placed along the fibers or in the center of the the greatest contouring of the muscle. Recording and processing of signals was carried out using a personal computer.

In order to experimentally verify the feasibility of the recommendations we developed regarding the individualization of the working posture behind the wheel to improve the steering process, the exercise of passing the element of the automobile slalom "snake with a variable step between chips" on a production car was chosen, the result of which directly depends on the efficiency of steering. Ten driving instructors from the Lviv driving school – the center for improving driving skills (persons aged 28–34 years, with driving experience of over 10 years and experience as a driving instructor of over 5 years)

were involved in the pedagogical experiment. All persons involved in the pedagogical experiment gave written consent to voluntary participation in it, in which the research protocol was described in detail.

The protocols of both experimental studies were approved by the ethics committee of the Ivan Boberskij Lviv State University of Physical Culture. They were conducted in accordance with the moral and ethical requirements and measures according to the Declaration of Helsinki on human research and the ethical standards proposed by experts (Harriss & Atkinson, 2009).

Instructors involved in the pedagogical experiment took turns driving the same production car "Škoda Fabia III" with an engine capacity of 1400 cm3 and passed the "snake with variable pitch" track shown in Fig. 1 – an element of automobile slalom. To exclude the influence on the result of the drivers' reaction, the start was given from the place after the starter's signal and turning on the stopwatch from the photoelectric pair located at a distance of 0.2 m from the starting line, when its beam crossed the front bumper of the car. The finish was performed "in motion", the arrival time was recorded by the stopwatch with an accuracy of 0.01 s at the moment of operation of the same photoelectric pair. Time of day – from 13:00 to 14:45, the track was dry and clean, air temperature + 23°C, cloudy and no direct sunlight. The first race of the experiment participants took place in the "average" (a) landing, the second – in the "close" (b), and the third – in the "far" landing (c) – as in Fig. 2. After the described part of the experiment, each driver established an individual working posture according to our recommendations, and then ran the slalom course for the fourth time.

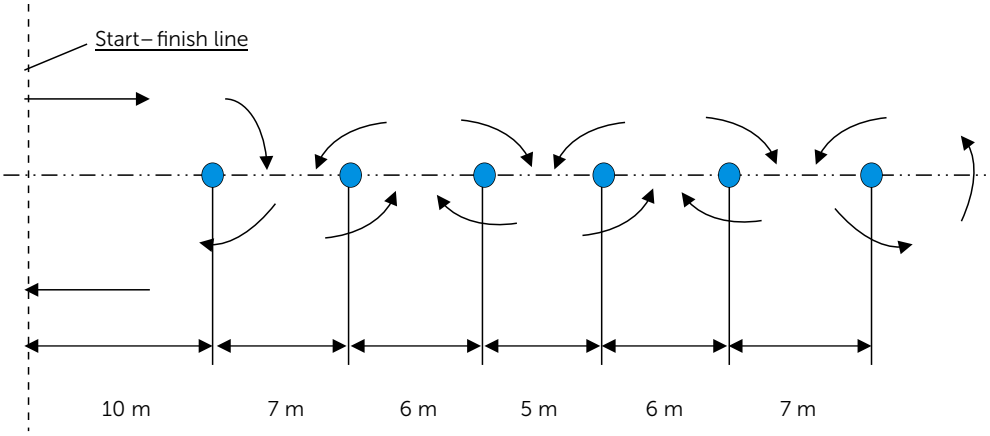

Figure 1 Slalom course used for the experiment

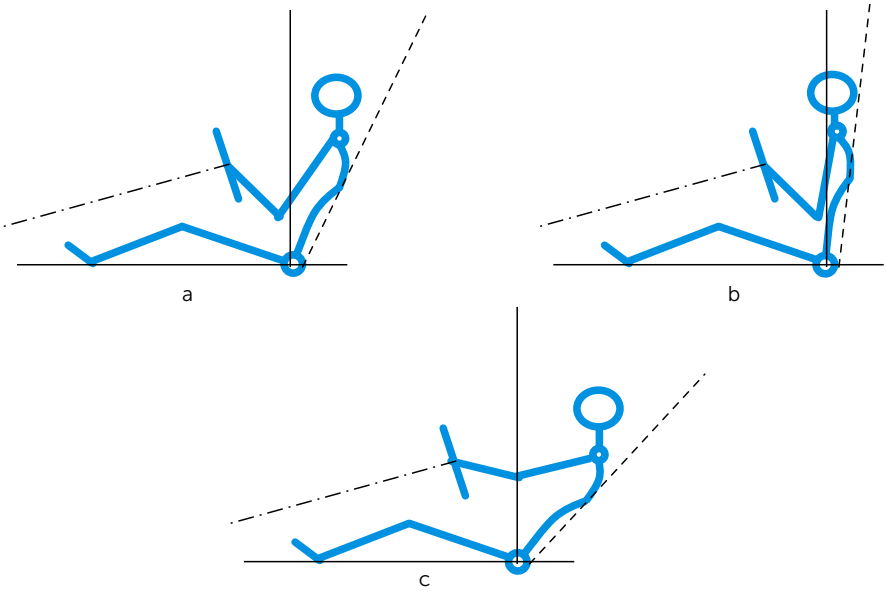

Figure 2 "Average" (a), "close" (b) and "far" (c) landing in a car

Results

The results of timing all races that were part of the pedagogical experiment with the participation of ten driver-instructors, who took turns passing the route of the "snake with variable step" automobile slalom exercise in a production car in four different working positions, are summarized in Table 1.

The conducted electromyographic study made it possible to establish which functional muscle groups (hereinafter referred to as FMG) of the driver are involved in turning the steering wheel to the right and left. During its turn to the right (clockwise from the driver's side), electrical activity was detected in the flexors and abductors of the right shoulder, pronators and extensors of the right forearm (the flexors of the fingers of the right hand and the muscles of the shoulder girdle perform the holding work), as well as the extensors and adductors of the left shoulder and supinators and flexors of the left forearm. When turning the steering wheel to the left (counterclockwise), the same FMGs are active, but in the left and right hands, respectively.

Table 1 Total duration of the route of the "snake with variable step" exercise from the automobile slalom program in "medium", "close", "far" and individual optimal landings by the drivers involved in the experiment ($M \pm s$)

Drivers' landing type	«medium»	«close»	«far»	Individual optimum.	*F*	*P*
Average duration of the route, *s*	23.15 ± 3.33	24.13 ± 2.56	24.30 ± 2.93	21.20 ± 3.66	9.082*	0.000

*$p < 0.001$

Discussion

The previously mentioned recommendations for correct working posture while driving suggest a significant (up to 40°) tilt of the seat back, which contradicts the results of the study Korakakis et al. (2019 and Siqueira Labrego et al. (2025), holding the steering wheel almost straightened in the elbow joints (angle 130–150°) with arms extended forward and acting on the pedals with legs bent in the knee joints to an angle of 120–150° (Fig. 3).

In contrast, the results of our study of the working posture behind the wheel of the best drivers of the planet – winners of the World Rally Championship Kuvaldina et al. (2014) and Vynogradskyi et al. (2014), revealed that the parameters of their "landing" differ significantly from those shown in Fig. 3. At the same time, individual differences in the parameters determined by the mentioned scientists turned out to be statistically insignificant. In addition, all of them are calculated in angular units and do not depend on the total sizes or proportions of the body parts of specific drivers. Thus, athletes sit almost vertically – the inclination of the seat back is less than 5°, arms are bent at the elbow joints within a right angle, shoulders are lowered much lower, and the minimal horizontal inclination of the lower part of the seat allows you to act on the pedals with more straightened legs (Fig. 4).

The differences found between the parameters of the drivers' working posture recommended in the literature and the parameters of the driving posture of the world's strongest rally athletes require biomechanical analysis and comparison in order to assess their ergonomic efficiency.

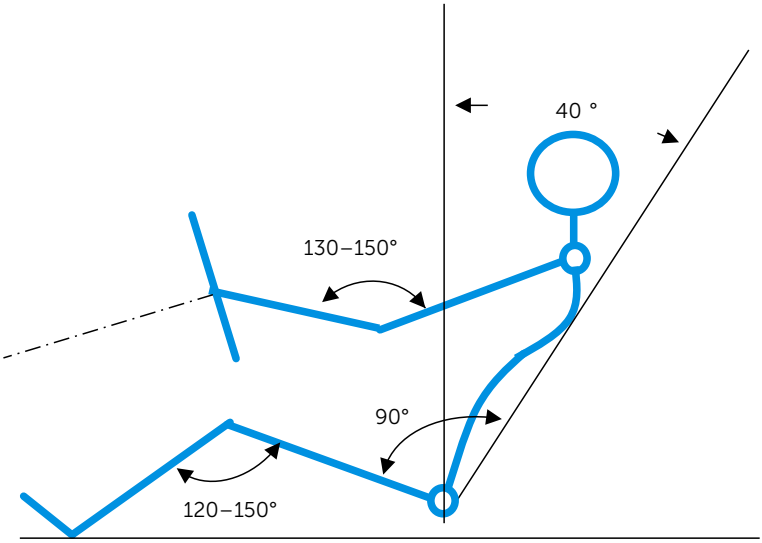

Figure 3 Averaged parameters of the working posture behind the wheel, recommended in the special literature

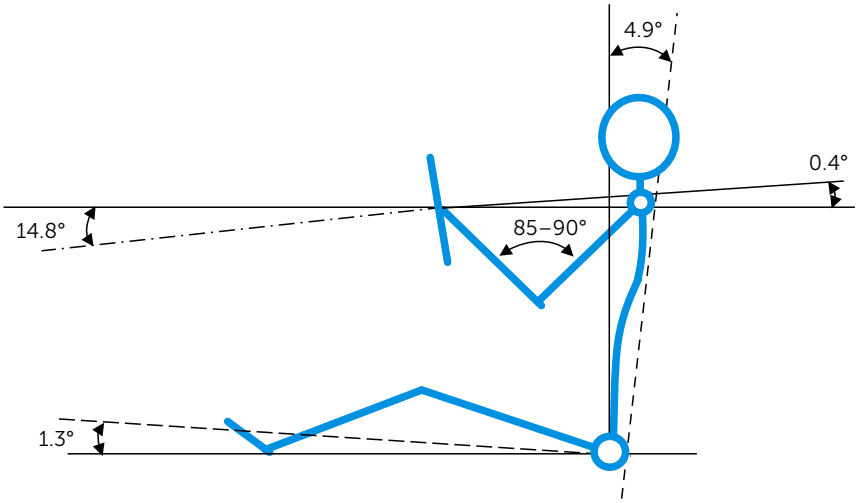

Figure 4 "Landing" parameters of the world's leading rally athletes

The posture recommended in the special literature (Fig. 3) is primarily characterized by pronounced thoracic kyphosis and lumbar lordosis, caused by a significant tilt of the seat back backward and the driver's attempt to reach the steering wheel, located far in front, with straightened arms. Due to the small lever of action of traction forces the functional muscle groups (FMG) of the shoulder flexors and forearm, caused by large angles in the shoulder and elbow joints, they cannot provide the proper effort to hold and rotate the steering wheel in emergency situations (hitting an obstacle, entering a rut, failure of the power steering, etc.). The driver is forced to keep his arms stretched forward in a horizontal position, which leads to increased tone of the corresponding FMG and rapid fatigue. To facilitate keeping his hands in this position, he begins to lean his hands on the steering wheel, which leads to increased load and fatigue of the FMG of the finger flexors, increased reaction time and reduced steering accuracy. Such a working posture causes increased tone of the FMG of the spine extensors, as well as hip flexors, calf extensors and foot flexors. Drivers, trying to ensure a comfortable body position in the cabin of civilian cars, first move the seat back to ensure that the legs are straightened for ease of operation with the pedals. Then they comfortably tilt the backrest back, but not being able to reach the steering wheel located close to the instrument panel, are forced to turn the seat forward, which leads to excessive bending of the legs and forces the muscles of the lower legs and thighs to be involved in working with the pedals, reducing the accuracy of regular working efforts and the magnitude of the maximum effort on the brake pedal in emergency situations (especially in the event of a brake booster failure). This causes accelerated fatigue of the corresponding FMG and a decrease in the accuracy of working with the pedals, which negatively affects active road safety.

The working posture behind the wheel of the world's leading athletes with an almost vertical inclination of the seat back, almost straightened legs and bent arms at the elbow

joints, holding the steering wheel located high and close to the shoulder joints, the axis of which is tilted up to 15° from the vertical downwards (Fig. 4) is characterized by reduced thoracic kyphosis and lumbar lordosis, as well as increased tone of the FMG of the cervical spine extensors, shoulder flexors and forearms. Their mutual arrangement provides a greater magnitude of the shoulder of application of the traction forces of these FMG, necessary for ensuring effective steering, working and emergency steering, and also significantly facilitates holding the hands in front of the body. This reduces the magnitude of the traction forces of the specified FMG, increases steering accuracy and reduces fatigue and the number of errors in driving a vehicle. This posture allows you to increase the tone and reduce the load on the FMG of the spine extensors, as well as the hip flexors, shin extensors and foot flexors of the more straightened leg, thanks to which the driver is able to press the corresponding pedals more accurately, and if necessary, much harder.

The results of electromyography of the driver's FMGs during turning the steering wheel in both directions in different working positions made it possible to substantiate its optimal location in terms of height, length and inclination of the steering wheel axis relative to the centers of the driver's shoulder joints, which allows applying precise and fast efforts to it both during the main and compensatory steering or understeering (Rybak, 2013), as well as maximum efforts during course maintenance of the car's movement when the front wheel hits the rut, the tire is damaged or the power steering fails.

The obtained data allow us to conclude that the "front" and "rear" landings do not allow the driver to maximize his potential in terms of steering, since the position of the steering wheel relative to the main anatomical points of their body does not allow the muscles of the corresponding FMG to provide the appropriate speed, strength and accuracy of contraction in these positions, including creating obstacles to intermuscular coordination. In contrast, the "average" landing, which is usually used in everyday practical driving by the drivers involved in the pedagogical experiment, and even more so its modification using the practical recommendations developed by us, made it possible to achieve a statistically significant difference in the time of performing the specified exercise, which requires perfect steering.

This position on a production car can only be achieved using certified spacers of different lengths between the steering wheel and the steering column. First of all, the seat base is installed more horizontally, then its distance to the pedals is adjusted according to the length of the legs. The seat back is set at an angle of up to 5° relative to the vertical, and then the steering wheel tilt and the height of the spacer between the standard steering wheel center mount and its new location are selected based on the length of the arms. The only parameter that cannot be set on a production car is a more horizontal steering wheel axis, the tilt of which is provided only by the design of modern sports cars.

Conclusions

Generally accepted traditional recommendations regarding the correct working posture behind the wheel of a car are biomechanically and ergonomically insufficiently substantiated. At the same time, the parameters of the "seating" of the world's leading rally athletes, analyzed by us from the standpoint of ergonomic biomechanics, really make it possible to reduce the load on the main FMG of drivers while driving vehicles, increase the accuracy of steering actions, reduce the number of errors and postpone the onset of fatigue in time, which causes their rapid growth and the potential occurrence of emergency situations, thereby increasing the level of active road safety. In addition, the parameters of the working posture behind the wheel that we recommend make it possible to avoid or significantly reduce the severity of driver injuries in emergency situations. Therefore, they can be recommended not only for athletes and drivers of special vehicles, but also for professional drivers and amateur motorists.

REFERENCES

Rybak, O., Rybak, L., & Vynogradskyi, B. (2018, 8 червня). *Zapobieganie zawodowym obciążeniom na organizm kierowcy samochodu*. Utrzymka XXI wieku w naukach o zdrowiu i kulturze fizycznej: materiały Międzynar. konf. nauk. (c. 363–390). Jelenia Góra, Польща: Karkonoska Państwowa Szkoła Wyższa w Jeleniej Górze.

Rybak, O. Yu. (2013). *Safety of competitive activity in automobile sports: monograph* [монографія]. Lviv: LDUFK (in Ukrainian).

World Health Organization [WHO]. (2023). *Global Status Report on Road Safety*. World Health Organization. https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/global-status-report-on-road-safety-2023

Inah, O. I., Ofem, M. I., Abam, F. I., Effiom, S. O., & Jimmy, O. O. (2025). Trend and causative factors of road traffic crashes in Nigeria: A Six Sigma (DMAIC) approach. *Journal of Road Safety, 36*(1), 53–65. https://doi.org/10.33492/JRS-D-25-1-2460893

Shakil, A., Md, A. H., Sayan, K. R., Bhuiyan, M. M. I., & Sabuj, S. R. (2023). A study on road accident prediction and contributing factors using explainable machine learning models: analysis and performance. *Transportation Research Interdisciplinary Perspectives, 19*, Article 100814. https://doi.org/10.1016/j.trip.2023.100814

Bucsuházy, K., Matuchová, E., Zůvala, R., Moravcová, P., Kostíková, M., & Mikulec, R. (2020). Human factors contributing to the road traffic accident occurrence. *Transportation Research Procedia, 45*, 555–561. https://doi.org/10.1016/j.trpro.2020.03.057

Hill, J. D., & Boyle, L. N. (2006). The safety implications of vehicle seat adjustments. *Journal of Safety Research, 37*(2), 187–193. https://doi.org/10.1016/j.jsr.2006.01.003

Bingley, L., Morris, R., & Cross, G. (2005). Determination of real world occupant postures by photo studies to aid smart restraint development. In *Proceedings: International Technical Conference on the Enhanced Safety of Vehicles* (Vol. 2005, pp. 15p–15p). National Highway Traffic Safety Administration. http://www-nrd.nhtsa.dot.gov/pdf/nrd-01/esv/esv19/05-0319-W.pdf

Zhao, M., Beurier, G., Wang, H., & Wang, X. (2018). Invehicle driver postural monitoring using a depth camera Kinect. *SAE Technical Paper* 2018010505. https://doi.org/10.4271/2018-01-0505

Chen, J., Jiang, B., Song, S., Wang, H., & Wang, X. (2016). Invehicle driving posture reconstruction from 3D scanning data using a 3D digital human modeling tool. *SAE Technical Paper* 2016011357. https://doi.org/10.4271/2016-01-1357

Reed, M., Lehto, M., & Schneider, L. (2000). Methods for laboratory investigation of truck and bus driver postures. *SAE Technical Paper* 2000013405. https://doi.org/10.4271/2000-01-3405

Carlsson, A., Pipkorn, L., Kullgren, A., & Svensson, M. (2016). Realworld adjustments of driver seat and head restraint in Saab 93 vehicles. *Traffic Injury Prevention, 18*(4), 398–405. https://doi.org/10.1080/15389588.2016.1217522

HaultDubrulle, A., Robache, F., Pacaux, M. P., & Morvan, H. (2011). Determination of preimpact occupant postures and analysis of consequences on injury outcome. Part I: A driving simulator study. *Accident Analysis and Prevention, 43*(1), 66–74. https://doi.org/10.1016/j.aap.2010.07.012

Östh, J., Eliasson, E., Happee, R., & Brolin, K. (2014). A method to model anticipatory postural control in driver braking events. *Gait & Posture, 40*(4), 664–669. https://doi.org/10.1016/j.gaitpost.2014.07.021

Fehren, M., Thunnissen, J., & Nicol, K. (2003). Influence of package factors on driver's posture and conclusions for posture assessment and modeling. *SAE Technical Paper* 2003012224. https://doi.org/10.4271/2003-01-2224

Michida, N., Okiyama, H., Nishikawa, K., & Nouzawa, T. (2001). A study of drivers' fatigue mechanisms during longhour driving. *SAE Technical Paper* 2001010381. https://doi.org/10.4271/2001-01-0381

Park, S., Kim, S., Kim, C., & Kwon, K. (2002). A study on the assessment of driver's fatigue. *SAE Technical Paper* 2002010784. https://doi.org/10.4271/2002-01-0784

Rossi, R., & Pascolo, P. B. (2015). Longterm retention of a divided attention psychomotor test combining choice reaction test and postural balance test: A preliminary study. *Accident Analysis and Prevention, 82*, 126–133. https://doi.org/10.1016/j.aap.2015.05.010

Grujicic, M., Pandurangan, B., Xie, X., Gramopadhye, A. K., Wagner, D., & Ozen, M. (2010). Musculoskeletal computational analysis of the influence of carseat design/adjustments on longdistance driving fatigue. *International Journal of Industrial Ergonomics, 40*(3), 345–355. https://doi.org/10.1016/j.ergon.2010.01.002

Hetier, M., Wang, X., Robache, F., Autuori, B., & Morvan, H. (2005). Experimental investigation and modeling of driver's frontal precrash postural anticipation. *SAE Technical Paper* 2005012684. https://doi.org/10.4271/2005-01-2684

Gao, Z., Li, C., Hu, H., Chen, C., Zhao, H., & Yu, H. (2016). Study of muscle activation of driver's lower extremity at the collision moment. *SAE Technical Paper* 2016011487. https://doi.org/10.4271/2016-01-1487

Khattak, Z. H., Li, W., Karnowski, T., & Khattak, A. J. (2024). The role of driver head pose dynamics and instantaneous driving in safety critical events: Application of computer vision in naturalistic driving. *Accident Analysis and Prevention, 200*, Article 107545. https://doi.org/10.1016/j.aap.2024.107545

Ejima, S., Zama, Y., Satou, F., Holcombe, S., Ono, K., Kaneoka, K., & Shiina, I. (2008). Prediction of the physical motion of the human body based on muscle activity during preimpact braking. In *Proceedings of the International IRCOBI Conference on the Biomechanics of Injury* (pp. 163–175). IRCOBI.

Katsuhara, T., Takahira, Y., Hayashi, S., Kitagawa, Y., & Yasuki, T. (2017). Analysis of driver kinematics and lower thoracic spine injury in World Endurance Championship race cars during frontal impacts. *SAE International Journal of Transportation Safety, 5*(1), 120–132. https://doi.org/10.4271/2017-01-1432

Doecke, S. D., Baldock, M. R. J., Kloeden, C. N., & Dutschke, J. K. (2020). Impact speed and the risk of serious injury in vehicle crashes. *Accident Analysis and Prevention, 144*, Article 105629. https://doi.org/10.1016/j.aap.2020.105629

Leledakis, A., Östh, J., Davidsson, J., & Jakobsson, L. (2021). The influence of car passengers' sitting postures in intersection crashes. *Accident Analysis and Prevention, 157*, Article 106170. https://doi.org/10.1016/j.aap.2021.106170

Schaefer, L. C., Junge, M., Vörös, I., Koçaslan, K., & Becker, U. (2021). Odds ratios for reclined seating positions in realworld crashes. *Accident Analysis and Prevention, 161*, Article 106357. https://doi.org/10.1016/j.aap.2021.106357

Hou, L., Peng, Y., & Sun, D. (2020). Neck injury mechanisms in train collisions: Dynamic analysis and data mining of the driver impact injury. *Accident Analysis and Prevention, 146*, Article 105725. https://doi.org/10.1016/j.aap.2020.105725

HaultDubrulle, A., Robache, F., Pacaux, M. P., & Morvan, H. (2011). Determination of preimpact occupant postures and analysis of consequences on injury outcome. Part I: A driving simulator study. *Accident Analysis and Prevention, 43*(1), 66–74. https://doi.org/10.1016/j.aap.2010.07.012

Rybak, O. Yu., Atoyan, A. K., & Feldman, O. M. (2019). Application of motor sports experience in reducing road accidents. *Visnyk Prykarpatskoho universytetu. Seriia: Fizychna kultura, (31)*, 124–135 (in Ukrainian). https://doi.org/10.15330/fcult.31.124-135

PhysioMed. (n.d.). *Correct sitting posture: Driving – PhysioMed in touch with the way you work* [PDF]. Retrieved from https://www.physiomed.co.uk/uploads/guide/file/21/Physiomed_Sitting_Guide_-_Driving_Digital.pdf

Uti res. (n.d.). *Driving posture tips and stretches for a long trip*. Retrieved from https://www.utires.com/articles/driving-posture/

Lipe, M. A. (2023). No pain behind the wheel! The importance of driver ergonomics. *Brightmile Blog*. Retrieved from https://www.brightmile.io/blog/no-pain-behind-the-wheel-the-importance-of-driver-ergonomics/

Frotcom. (2021, November). *7 sencillos consejos para una buena postura al volante* [Blog post]. Retrieved from https://www.frotcom.com/es-ES/blog/2021/11/7-sencillos-consejos-para-una-buena-postura-al-volante

Evercare Protection. (n.d.). *6 maneras de asegurar una postura correcta al volante* [Blog post]. Retrieved from https://evercareprotection.com/6-ways-to-ensure-proper-posture-behind-the-wheel/

Walton, D., & Thomas, J. A. (2005). Naturalistic observations of driver hand positions. *Transportation Research Part F: Traffic Psychology and Behaviour, 8*(3), 229–238. https://doi.org/10.1016/j.trf.2005.04.010

Previati, G., Mastinu, G., & Gobbi, M. (2024). Driver–steering wheel interaction during cornering. *SAE International Journal of Vehicle Dynamics, Stability, and NVH, 8*(3), 427–442. https://doi.org/10.4271/10-08-03-0024

Atkinson, P., Hariharan, P., MariGowda, S., Telehowski, P., Martin, S., Van Hoof, J., Bir, C., & Atkinson, T. (2002). An underhand steering wheel grasp produces significant injury risk to the upper extremity during airbag deployment. *Annual Proceedings of the Association for the Advancement of Automotive Medicine, 46*, 45–62. https://pubmed.ncbi.nlm.nih.gov/12361499/

Siqueira Labrego, A. C., Mendes Esperedião, A. C., Gonçalves Oliveira, C. D., de Melo do Espirito Santo, C., & Araujo, R. C. (2025). The effect of three different angles of the working seat on lumbar spine curvatures and comfort: An observational study. *Journal of Bodywork and Movement Therapies, 42*, 838–845. https://doi.org/10.1016/j.jbmt.2025.02.005

Korakakis, V., O'Sullivan, K., O'Sullivan, P. B., Evagelinou, V., Sotiralis, Y., Sideris, A., Sakellariou, K., Karanasios, S., & Giakas, G. (2019). Physiotherapist perceptions of optimal sitting and standing posture. *Musculoskeletal Science & Practice, 39*, 24–31. https://doi.org/10.1016/j.msksp.2018.11.004

Rybak, O. Yu., & Rybak, L. I. (2012). *Simulator for special transcript training of rally crews* [Patent Ukraine No. 74186; MPK G09V 9/02]. Bulletin No. 20 (in Ukrainian).

Harriss, D. J., & Atkinson, G. (2009). International Journal of Sports Medicine – ethical standards in sport and exercise science research. *International Journal of Sports Medicine, 30*(10), 701–702. https://doi.org/10.1055/s-0029-1237378

Vynogradskyi, B., Muzyka, F., & Rybak, L. (2014). Kinematic model of the working posture of rally athletes. *Visnyk Chernihivskoho natsionalnoho pedahohichnoho universytetu. Seriia: Pedahohichni nauky. Fizychne vykhovannia ta sport, 118*, 31–34 (in Ukrainian). https://repository.ldufk.edu.ua/items/fb0e98f8-5cc2-4682-97fa-fd3910c3647b

Kuvaldina, O., Martyn, V., & Rybak, O. (2015). Justification of the parameters of the seating position behind the wheel of a modern sports car. *Moloda sportyvna nauka Ukrainy: zb. nauk. pr. z haluzi fiz. vykhovannia, sportu i zdorovia liudyny / za zah. red. Ye. Prystupy, 19*(т. 1), 202–207 (in Ukrainian).