

# **Effects of Prolonged Sitting Posture on Neck and Shoulder Joints During Occupational Driving: Human Ergonomic Simulation Software**

**Aisha Ali Hasan Mohamed Dhaiban**

MSc. Student

Department of Industrial Engineering

Khalifa University, Abu Dhabi, United Arab Emirates

[100042637@ku.ac.ae](mailto:100042637@ku.ac.ae)

**Areej Mabrouk Abdrabo Bin Amro**

MSc. Student

Department of Industrial Engineering

Khalifa University, Abu Dhabi, United Arab Emirates

[100042689@ku.ac.ae](mailto:100042689@ku.ac.ae)

**Dr. Saed Amer**

Faculty Member

Industrial and Systems Engineering Department - Khalifa University

Abu Dhabi, United Arab Emirates

[Saed.Amer@ku.ac.ae](mailto:Saed.Amer@ku.ac.ae)

## **Abstract**

This study investigates the impact of prolonged driving posture for occupational drives on the upper back muscles. There have been limited papers in the literature that studies the upper body muscles hence this study focuses specifically on neck and shoulder muscles. A human simulation software called Jack software was used to measure the impact of the driving posture on these muscles. Three different trunk conditions relative to the angles were adopted as follows: extension, neutral and flexion. The trail incorporated four different postures to mimic the real driving experience including the neck muscle at the neutral position, neck lateral rotation to the left and neck extension. The results of this study reveal that the lowest discomfort levels of both neck and shoulders were measured at the trunk flexion position, thus it suggested that a proper headrest that would support the neck at 15 degrees' extension would help to reduce the strain on the joint.

## **Keywords**

Prolonged sitting posture, Occupational Driving, Jack Software, Torque force, Neck-shoulder Joint

## **1. Introduction**

According to the World Health Organization (WHO), musculoskeletal health is the performance of the locomotor system made up of muscles, bones, joints and adjacent connective tissues. There are numerous impairments that impact the musculoskeletal system and they are commonly characterized by pain, limited mobility and dexterity, which has a negative impact on society as it reduces human's ability to work and exercise. Apart from the fact that approximately 1.7 billion people live with various musculoskeletal conditions such as lower back pain, neck pain, fractures, rheumatoid arthritis, and etc., people with musculoskeletal conditions are at a higher risk to develop mental health issues (WHO 2022). In addition to the conditions mentioned previously, there is a subcategory that is covering work-related musculoskeletal disorders (WRMSDs). These can affect muscles, joints and tendons and in general, develop over time; these disorders can be either episodic or chronic, and also can result from an injury acquired in a work-related accident. Among the jobs that have the highest rates of WRMSDs are agriculture and forestry, construction, transport and storage (Goggins et al. 2022). Among the various musculoskeletal disorders and impairments, Lower

back pain (LBP) is a well-known common musculoskeletal disorder which is a serious occupational disease that has an 80 percent lifetime prevalence. Prevalence of LBP varies across populations, age groups and geographic areas, where 37% of low back pain globally attributes to occupational risk factors and increases in the lower overall health status regions (Yosef et al. 2019). Another common musculoskeletal is neck and shoulder pain, and during a study made in Tunisia, it was found that neck and shoulder pain affects adolescents (15-19 years old) where the occurrence of such musculoskeletal health issues reaches 43% (Ben Ayed et al. 2019). Another study in Japan was conducted to determine neck-shoulder stiffness/low back pain (NSS/LBP) comorbidity rate, as well as to compare the quality of life in individuals with comorbid NSS/LBP, and those with symptoms of NSS or LBP alone. As it was seen from the study done among 1122 subjects, NSS had a morbidity rate of 45.6%, while LBP had a slightly higher rate of 51.9% (Kumagai et al. 2021).

Another study was conducted among professional bus drivers to observe the risk of developing musculoskeletal pain and disability due to their working conditions. The study was conducted among 83 drivers, and it was found that the neck and the back were mostly affected with rates of 81.9% and 80.7% respectively. In general, occupational truck drivers have the highest work-related musculoskeletal disorders since drivers are vulnerable to various occupational trauma through challenging physical working conditions such as prolonged seating, noise, temperature fluctuations, awkward sitting positions and whole body vibrations (Kasemsan et al. 2021). Although the most common occupational hazards are considered to be prolonged sitting and awkward positions, a study was done on the impact of vertical seat-to-head vibration transmissibility and its impact, which showed that there is an increased discomfort when combining rotation and whole-body vibration exposure (WBV). The study was done over a small participants group and over 4 short 1-hour test sessions and yet the results showed that even such short periods of WBV cause higher levels of discomfort. Furthermore, without whole body vibrations, participants of the study had even higher levels of discomfort due to sitting at rotated postures as that caused increased muscle and joint fatigue and in turn may lead to occupational trauma if taken in a scenario of work setting (Goggins et al. 2022).

The objective of this study is to increase safety measurements of occupational vehicle drivers by minimizing complications of prolonged poor posture. Also, to provide a risk assessment technique to explore the different factors such as joint angle, joint force and joint moment/torque that causes adversities to the human body by different prolonged sitting postures. And, by the end of this study, we will investigate the standardized posture that is recommended by international standards to provide an ergonomic measure recommended to reduce the risk of prolonged sitting adversities.

## **2. Literature Review**

A study has been conducted to investigate and compare risk factors for musculoskeletal disorders among truck drivers in Canada. The results of the study showed that when comparing truck drivers to the general reference population of male workers, they have a higher occurrence of various musculoskeletal pains in the neck, back, and upper and lower limbs (Cardoso et al.2018). An evaluation has been done to determine fatigue, stress and vigilance levels among truck drivers with and without an ergonomic seat. The experiment was set up with a driving simulator that would replicate a 10-minute drive before and after a 90-minute highway driving task. After data collection, it was concluded that standard seat results in more pronounced muscular fatigue, and moreover, using an ergonomic seat elevates both physical and mental fatigue which in the long run decreases the possibility of accidents and occupational trauma such as LBP and NSS (Cardoso et al. 2019). Another investigation was done using an ergonomically-designed truck seat prototype, where the participants were performing two 2-hour driving simulations, while subjective discomfort was monitored in 15-minute increments along with an assessment of posture. As a result of the study, participants showed greater discomfort in the right side of the lower body as well as the neck while driving in the standard truck seat. Overall, findings show that regular truck seats may lead to the development of poor posture and discomfort, which in the long run can lead to injuries in the lower back and neck, meanwhile the ergonomic seat helps to improve posture and elevates discomfort (Cardoso et al. 2018). Yet, there are some limitations of the current papers in the literature that the identification of the road condition is not specified in most of the papers which can have a great impact on the postures obtained as unstable surfaces or road conditions contributes significantly to an increase in the muscle Tension in the upper extremities. Furthermore, limited studies have been performed targeting female participants, as only 5 papers that were found targeted the female population and the findings reveal that they have a higher risk of musculoskeletal disorders compared to men.

### 3. Objectives

Several Studies have shown the impact of long distance driving on the lower back part, with limited studies on the upper back part. So, this study would focus on the effect of prolonged sitting posture for industrial drivers on the neck and shoulder muscles, as this area will be fully active during the driving period as a result of the “9 and 3” hands technique. This study aims to increase the safety of industrial vehicle drivers by minimizing complications of prolonged poor posture by providing risk assessment technique to explore the different factors (Joint angle/force/etc) that cause adversities to the human body by different prolonged sitting postures, investigating the standardized posture that are recommended by the international standards and providing ergonomic measures that can reduce the risk of prolonged sitting adversities.

### 4. Methods

The proposed methodology approach used to test ergonomics during driving is through using human simulations in a virtual environment that mimics the actual act. The benefits of using this approach enable you to get a precise angle measurement of the desired motion and analysis tool that is able to acquire quantitative data. There are growing appeals toward the use of human simulations in the field. A group of researchers from Canada has performed a study to compare a driving simulator and real-road driving (Risto & Martens, 2014) The results of their study reveal that there’s no significant difference made between the real data and the data obtained from the simulator. This finding strongly supports the use of a simulator as a cost-effective and controllable approach to conducting studies.

#### 4.1 Jack Software

In this study, Jack software from Siemens Tecnomatix simulation was used. Jack software offers a variety of distinct tools for ergonomic analysis that are human-focus. It provides a different anthropometric database to customize the population to match the research aims. As reported in many studies that have used Jack software to perform ergonomic analysis, the results of both of these studies show promising results based on the ergonomic analysis performed by Jack simulation. As described, Siemens has developed Jack as part of the Tecnomatix Package which is designed for the purpose of establishing an understanding of the impact of human work tasks relevant to their environments. The following describes the feature Jack software provides:

Enables users to design the virtual environment as per their preferences, library packages that are pre-installed with the software can be also used for designing the virtual environment

Human posturing techniques that are user-friendly. Angles can be adjusted as per the research goal.

Task simulation Builder is one of the tools Jack has been used in this study where it enables you to instruct the human subject in your virtual environment to follow a certain task as per the trial of the study. This tool provides Human postures and motion that can generate an ergonomic report bases on the sequence.

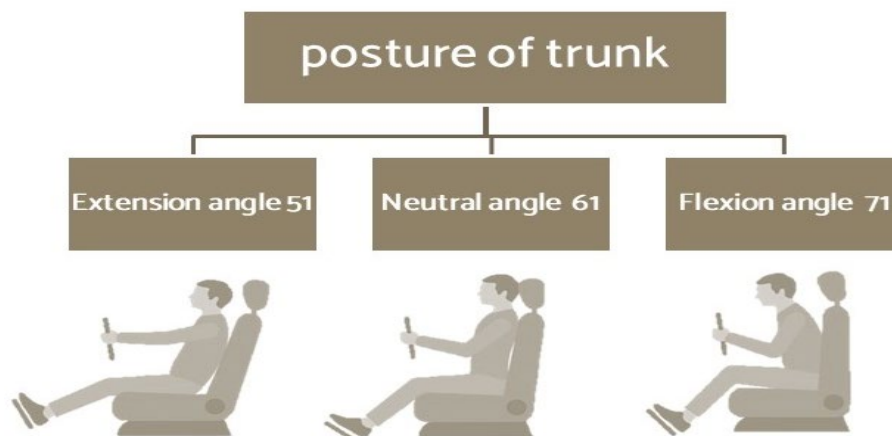


Figure 1. The three different trunk angle conditions adopted for the experimental design, 51°, 61° and 71° respectively).

## 5. Data Collection

The virtual environment included the human model in 3D in a driving posture with hands gripping the wheel as Figure 1 below shows. The duration of the simulation was 30 min (1800 seconds) in total. To understand the impact of the trunk angle on the neck and shoulder joint in the driving posture, the design was extended by adding three trials, one for each angle of the trunk. The first condition is the neutral condition where the trunk is at 61 degrees, the second condition is the trunk extension where the angle is at 51 degrees and the third condition is where the trunk angle is at 71 degrees. Figure 1 below summarizes the three conditions where each of these conditions was tested for 30 min to evaluate its effect on the neck and shoulder joints.

The trial then incorporated four different postures in the driver position to mimic the real driving experience. The Human subject modeled in this simulation held one of the four postures with varying angles of the trunk position and neck posture and they are described as follows:

- 1) **Posture 1:** Driving posture while looking forward neck at a neutral position.
- 2) **Posture 2:** Driving posture while turning left to check the side mirror with neck positioned to left lateral with a rotation at 45 degrees.
- 3) **Posture 3:** Driving posture while turning neck upward to check the rearview mirror with neck extension at 15 angle degrees.
- 4) **Posture 4:** Driving posture while looking forward neck at a neutral position.

The trial lasted for 30 mins and the order of postures starts from posture 1 to 4 in consecutive order for each condition of the trunk conditions mentioned above. Figure 2 below shows the order of the postures alongside the duration of the trial. The design of the seat in the simulation had the back where the human subject was resting on the chair back support in all the postures. Both of the Human models were kept on the steering wheel with the hand grip option in the task simulation builder and there was no arm set, as it was reported in most of the studies that most heavy vehicle equipment is missing these arm sets (Nazerian 2020).

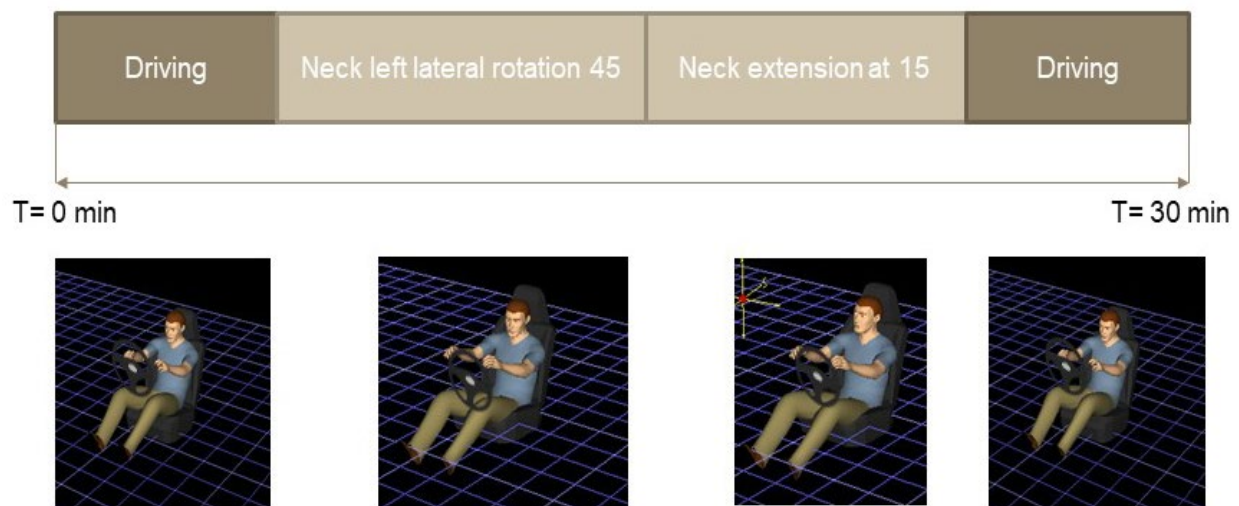


Figure 2. The overall order of the postures alongside with the duration of the simulation.

The anthropometries for the virtual human model used in the simulation are based on the 95<sup>th</sup> percentile from the ANSUR database from the male population. Jack software has various options for the anthropometric database with different population measures to choose from. Figure 3 below shows the Anthropometric measure chosen for this simulation.

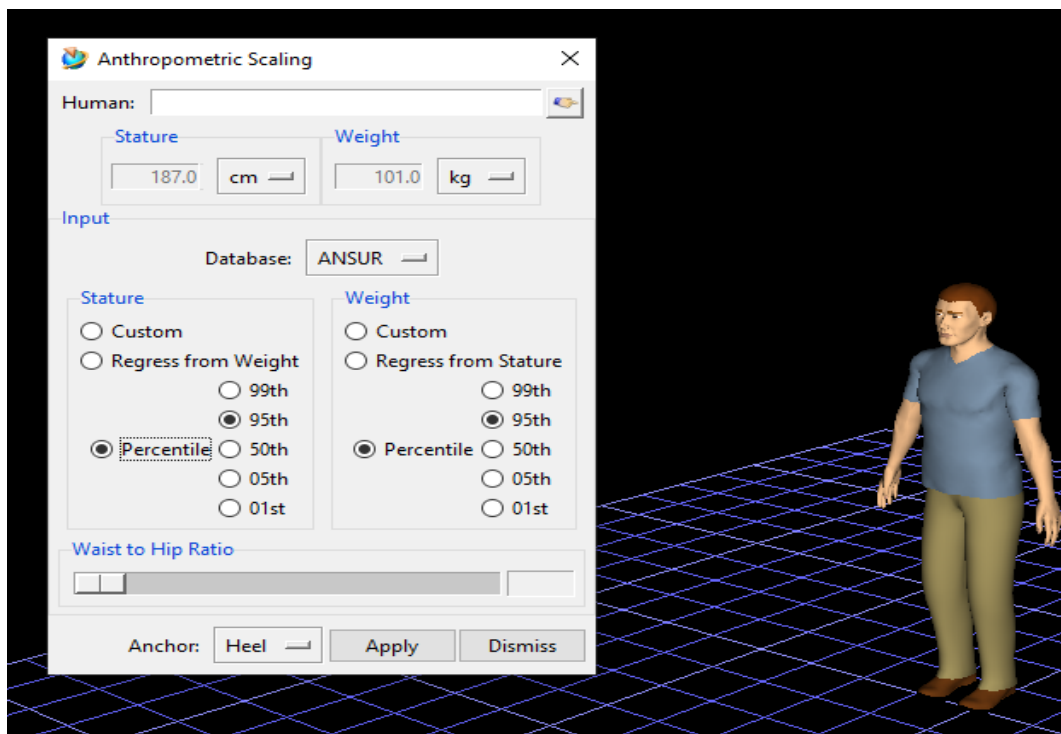


Figure 3. The Anthropometric measure chosen for this simulation.

## 6. Results and Discussion

For the sake of demonstration, the anthropometric scale was fixed on the 95<sup>th</sup> percentile and both hands were in the grasping posture pointed on the wheels.

### 6.1 Numerical Results

After conducting the simulation using JACK software, three different trunk postures, natural, flexion and extension, concluded with different results of the effect on the shoulder joint. As shown in figure 4, the only parameter changed during the experiment was the flexion degree of the trunk in the driver's body, while the driver was in the driving posture. The numerical data was taken from the software in excel sheet format, which was then sorted and simplified to reflect the required parameters. Then, the resulting data was converted into an x-y graph. The data shown in the graphs was demonstrated by the average value of four different locations of the shoulder joints, which are the Shoulder Abdominal Right, Shoulder Abdominal Left, Shoulder for Back Right and Shoulder for Back Left for each posture with respect to time agent. Note that the shoulder abdominal had significantly higher torques than the back of the shoulder, due to the tension caused by the 9 and 3" hands technique.

First, in a neutral posture where the Trunk flexion degree was fixed at 61.20°, Figure 5 shows a constant joint torque during each pose, which is the driving pose, looking left pose, looking up pose and looking right pose. The driving pose had the lowest joint torque, which is 4.26325 Nm. Followed by a rise in the shoulder joint torque as the driver moved his head to look at the blind spots on the left and right-hand sides of the vehicle, with a 4.263 Nm, which is a result of the tension generated by the axial rotation movement of the neck in both directions. This rotation induces torque increment due to the neck-shoulder elongated force required for the movement. And finally, the highest joint torque, 4.26275 Nm, was calculated at the third pose, looking up, where the neck had the highest flexion degree compared to the other poses and impacted the shoulder joints accordingly.

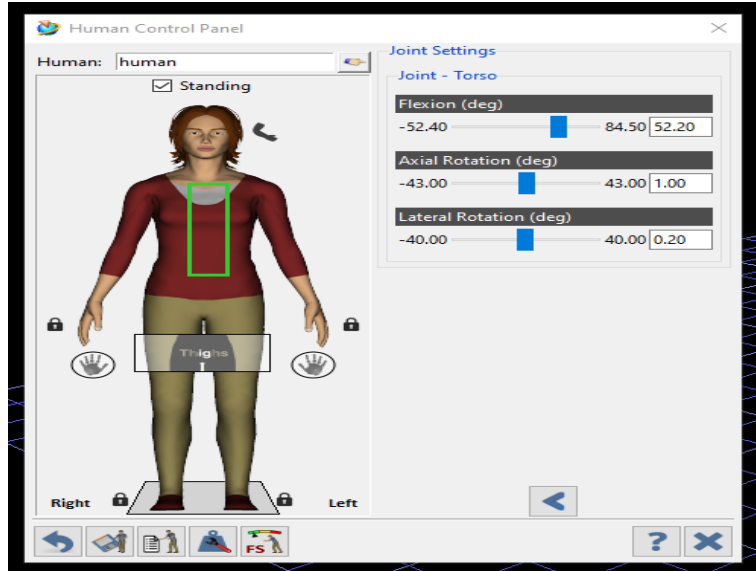


Figure 4. The Parameters used for this study with the flexion degree of the trunk in the driver's

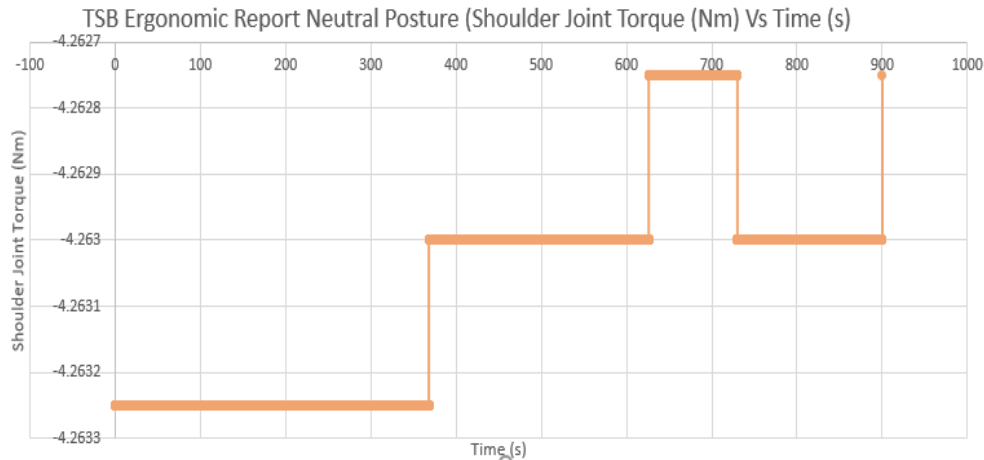


Figure 5. The graphic analysis for the Neutral posture for shoulder Joint torque with time.

Second, in the Extension Trunk Posture with a flexion angle of  $51.20^\circ$ , a  $7.6605 \text{ Nm}$  torque was applied on shoulder joints during the driving pose and decreased rapidly, reaching a steady state situation for the other three poses with a  $6.60425 \text{ Nm}$  on the shoulder joint. Third, the Flexion Trunk Posture with a flexion angle of  $71.20^\circ$ , where the shoulder joint torque was also at the maximum,  $7.6605 \text{ Nm}$ , during the first driving pose and decreasing until it reaches a steady state phase with a  $7.43525 \text{ Nm}$  for the three following poses, as shown in the figures 6 and 7, respectively.

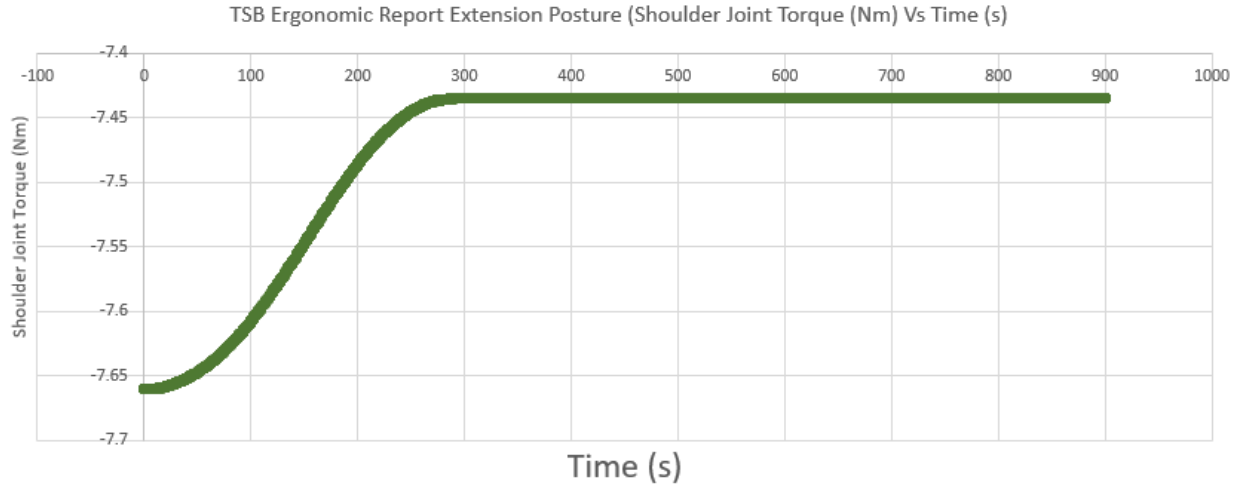


Figure 6. The graphic analysis for the Extension posture for shoulder Joint torque with time.

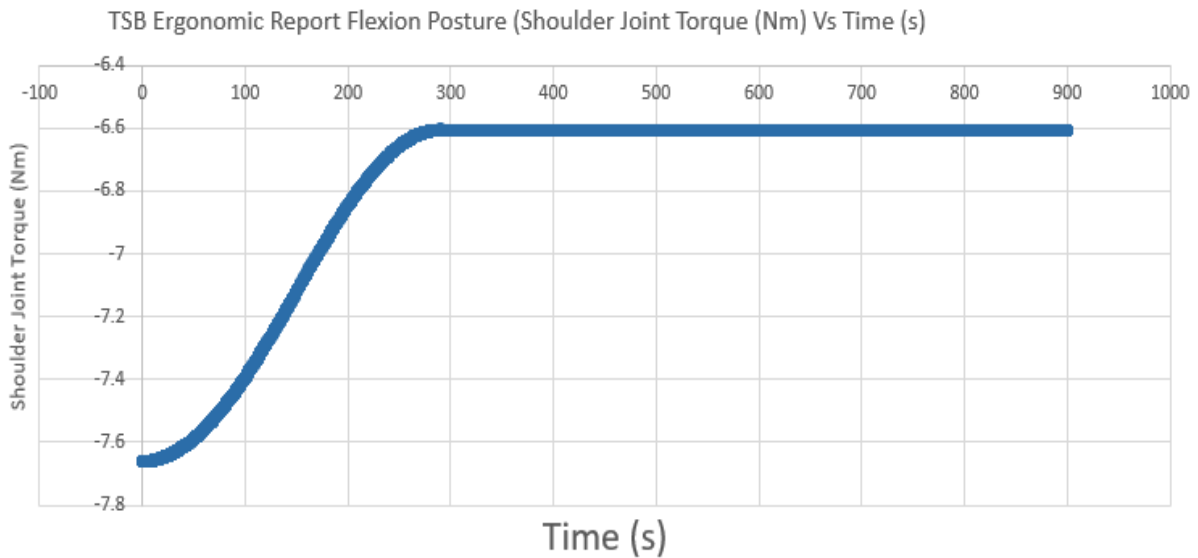


Figure 7. The graphic analysis for the Flexion posture for shoulder Joint torque with time.

Comparing the three different postures together shows that the shoulder joint torque was at the highest during the extension posture. This is a result of the stress exerted on the neck and shoulder joints while driving, as the spinal discs will have an abnormal bend direction (forward bend) that will increase the forces applied on the joints and hence the torque will increase as well, as shown in figure 8.

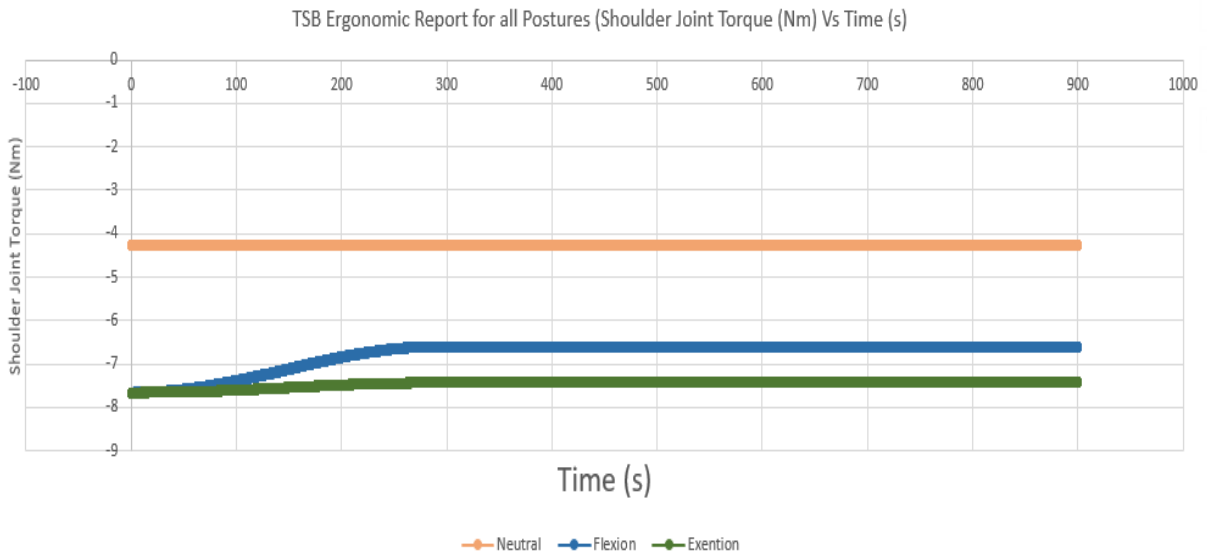


Figure 8. The graphic analysis for the three different postures for shoulder Joint torque with time.

## 6.2 Graphical Results

The comfort assessment tool in JACK software purposes to evaluate the comfort level at specific joints based on the driving posture. Human posture comfort is assessed during the four postures using the Krist scale. Krist data source measures the comfort of the neck, shoulder, back, both legs, and both arms as well as the comfort and fatigue indices. The fatigue measures how fast fatigue will be felt and the comfort indices measure the general comfort of the body at that posture. The scale ranges from 0 to 80, the closer the number to 80 the highest the discomfort level is. For the purpose of this study, the neck and shoulder comfort level was recorded at four postures during driving with respect to the changes in the trunk angle. The tool provided 6 different databases for comfort analysis. Figure 9 below shows the comfort analysis obtained during the first posture where the trunk angle is neutral.

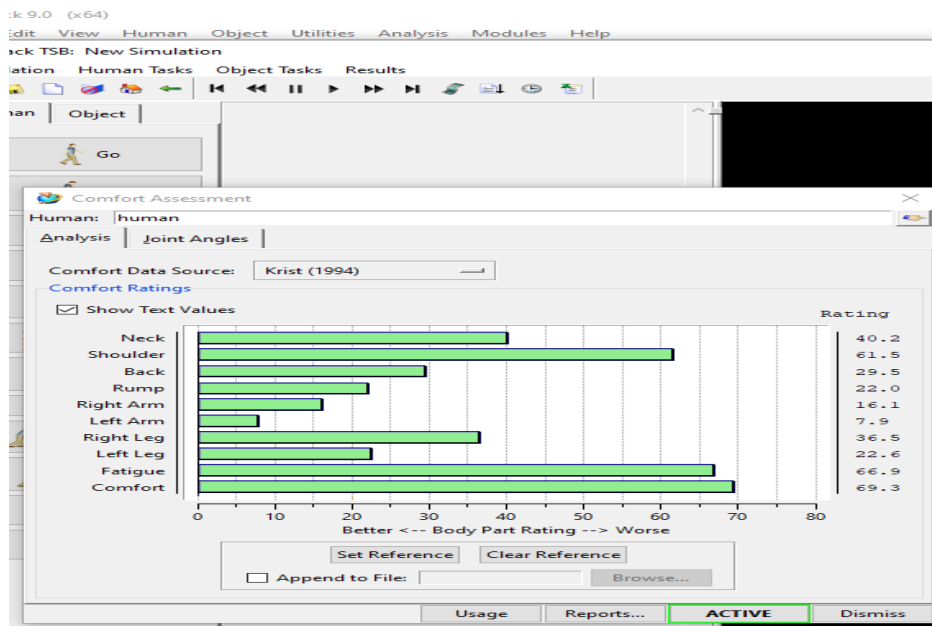


Figure 9. Comfort analysis was obtained during the first posture where the trunk angle is at neutral.



The comfort analysis for the four positions during different trunk angles was carried out. Figure 10 below shows the comfort analysis for the neck and shoulder joints at different trunk angle conditions. It can be concluded from the comfort analysis that the shoulder joint has scored high discomfort levels in all of the postures and at different trunk angle conditions compared to the neck joint. The highest discomfort score for the shoulder joint have been recorded at the first driving posture when the trunk angle was at the neutral condition and during flexion. Both of these measures are recorded during posture one where the subject is driving with hand placement on the steering wheel. This finding is supported by this paper which suggests that higher angles of the trunk flexion cause higher shoulder joints hence higher discomfort level (kim et al. 2015) Contrary to the shoulder the neck joint had the highest discomfort level during trunk extension condition where the neck is a position to left lateral at a 45-degree angle and the lowest discomfort level during trunk extension was at the third posture where the neck extension at 15-degree angles to view the rearview mirror. This lower level of discomfort during the neck extension at 15 degrees can be explained by the findings of this paper which proved that the greater the neck extension angle is the less muscle activation in the middle trapezius hence less discomfort level (Cheon & Park 2017).

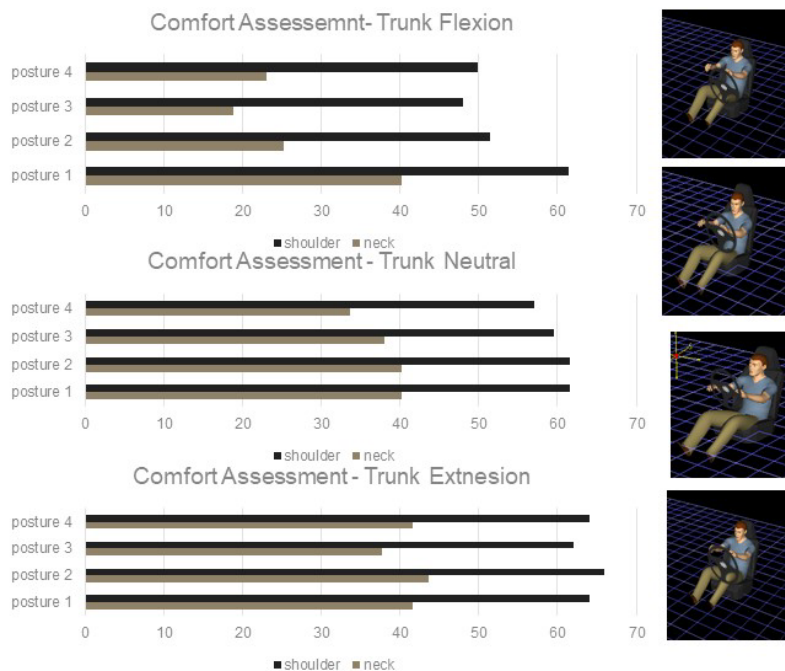


Figure 10. The comfort analysis for the neck and shoulder joints at different trunk angle conditions.

The initial hypothesis of this study is that during both the trunk flexion and extension, it was expected to have higher discomfort recorded compared to the neutral condition. However, this hypothesis has been rejected as the results of the simulation in figure 11 below where at the trunk flexion condition the lowest discomfort level has been recorded. This finding was unexpected and it can be explained as reported in several papers that flexion of the trunk angle typically increases the muscle strain and viscoelastic deformation of the tissue which in turn decreases the angle of stability and hence cause upper extremities discomfort however some researchers suggest that it could be the decrease in the passive stiffness that successfully compensate the reflect gain and hence less discomfort (Hendershot et al. 2011).

## Comfort Assessment

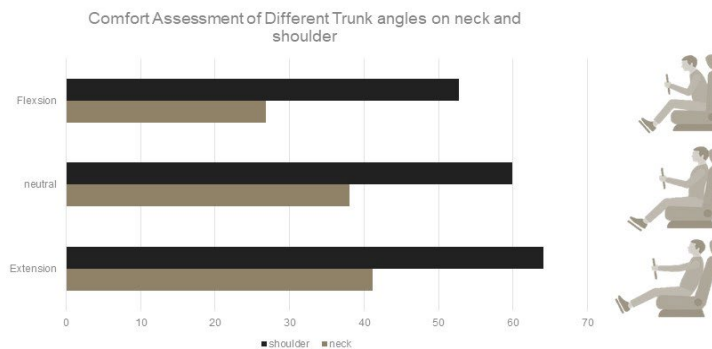


Figure 11. The comfort assessment of different Trunk angles on the neck and shoulder joints.

### 6.3 Proposed Improvements

Based on the results obtained in this study, the lowest discomfort level of the neck was recorded during the trunk flexion condition and specifically during the third posture which is the extension of the neck at 15 degrees. This finding can suggest that having a headrest that can support the neck angle at this degree can help to reduce the strain on the joint and hence a more comfortable position. Most of the industries with fixed headrests, it's suggested to include an adjustable headrest. According to the Federal Motor Vehicle Safety Standard 202, Head restraints are required to be positioned in all cars manufacture. The National Highway Traffic Safety Administration, has extended this standard to include trucks as well (US Department of transportation 2001).

### 7. Conclusion

The study results showed that the lowest discomfort levels of the neck and shoulders are at the trunk flexion position, which is contrary to the expectation of having the lowest discomfort at the neutral position since this is the most common driving position. Among the results of the study, it is useful to note that the addition of a proper headrest that would support the neck at 15 degrees extension would help to reduce the strain on the joint. Future work recommended to validate the findings of this study is to measure the pressure during the different postures to assess to which extent it matches the comfort assessments and hence propose a better and improved seat design for industrial vehicles.

### References

- Ben Ayed, H. et al. (2019) Prevalence, risk factors and outcomes of neck, shoulders and low-back pain in secondary-school children, *Journal of research in health sciences*. U.S. National Library of Medicine. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6941626/>
- Cardoso, M. et al. (2018) Prime pubmed: Biomechanical investigation of prolonged driving in an ergonomically designed truck seat prototype, PRIME PubMed | Biomechanical investigation of prolonged driving in an ergonomically designed truck seat prototype. Available at: [https://www.unboundmedicine.com/medline/citation/28697645/Biomechanical\\_investigation\\_of\\_prolonged\\_driving\\_in\\_an\\_ergonomically\\_designed\\_truck\\_seat\\_prototype\\_](https://www.unboundmedicine.com/medline/citation/28697645/Biomechanical_investigation_of_prolonged_driving_in_an_ergonomically_designed_truck_seat_prototype_)
- Cardoso M;Fulton F;Callaghan JP;Johnson M;Albert WJ; (2019) A pre/post evaluation of fatigue, stress and vigilance amongst commercially licensed truck drivers performing a prolonged driving task, *International journal of occupational safety and ergonomics* : JOSE. U.S. National Library of Medicine. Available at: <https://pubmed.ncbi.nlm.nih.gov/29952733/>
- Cardoso M;McKinnon C;Viggiani D;Johnson MJ;Callaghan JP;Albert WJ; (2018) Biomechanical investigation of prolonged driving in an ergonomically designed truck seat prototype, *Ergonomics*. U.S. National Library of Medicine. Available at: <https://pubmed.ncbi.nlm.nih.gov/28697645/>
- Cheon, S.H. and Park, S.H. (2017) "Changes in neck and upper trunk muscle activities according to the angle of movement of the neck in subjects with forward head posture," *Journal of Physical Therapy Science*, 29(2), pp. 191–193. Available at: <https://doi.org/10.1589/jpts.29.191>.
- Effectiveness of head restraints in light trucks - transportation (no date). Available at: <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809247>

- Godwin, A.A. et al., “Classic Jack modelling of driver posture and line-of-sight for operators of lift-trucks,” *International Journal of Human Factors Modelling and Simulation*, 1(3), p. 259,2010. Available at: <https://doi.org/10.1504/ijhfms.2010.036790>.
- Goggins, K.A. et al., Examining the impact of rotated neck and trunk postures on vertical seat-to-head vibration transmissibility and self-reported discomfort, MDPI. Multidisciplinary Digital Publishing Institute, 2022. Available at: [https://www.mdpi.com/2571-631X/5/2/18?type=check\\_update&version=1](https://www.mdpi.com/2571-631X/5/2/18?type=check_update&version=1)
- Hendershot, B. et al. , “Disturbance and recovery of trunk stiffness and reflexive muscle responses following prolonged trunk flexion: Influences of flexion angle and duration,” *Clinical Biomechanics*, 26(3), pp. 250–256, 2011. Available at: <https://doi.org/10.1016/j.clinbiomech.2010.09.019>.
- Kasemsan, A. et al. (2021) Prevalence of musculoskeletal pain and associated disability among professional bus drivers: A cross-sectional study - international archives of occupational and environmental health, SpringerLink. Springer Berlin Heidelberg. Available at: <https://link.springer.com/article/10.1007/s00420-021-01683-1>.
- Kim, S.S., Her, J.G. and Ko, T.S., “Effect of different hand positions on trunk and shoulder kinematics and reaction forces in sitting pivot transfer,” *Journal of Physical Therapy Science*, 27(7), pp. 2307–2311,2015. Available at: <https://doi.org/10.1589/jpts.27.2307>.
- Kumagai, G. et al. (2021) The effect of low back pain and neck-shoulder stiffness on health-related quality of life: A cross-sectional population-based study - BMC musculoskeletal disorders, BioMed Central. BioMed Central. Available at: <https://bmc-musculoskeletal-disord.biomedcentral.com/articles/10.1186/s12891-020-03871-5>
- Musculoskeletal health (2022) World Health Organization. World Health Organization. Available at: <https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions#:~:text=Low%20back%20pain%20is%20the,7.4%25%20of%20global%20YLDs>
- Nazerian, R.; Korhan, O.; Shakeri, E. Work-related musculoskeletal discomfort among heavy truck drivers. *Int. J. Occup. Saf. Ergon.* **2020**, 26, 233–244.
- Risto, M. and Martens, M.H., “Driver headway choice: A comparison between driving simulator and real-road driving,” *Transportation Research Part F: Traffic Psychology and Behaviour*, 25, pp. 1–9,2014. Available at: <https://doi.org/10.1016/j.trf.2014.05.001>.
- Sudarma, M. et al. (no date) Digital Human modeling Tecnomatix Jack to analyze the visibility of traffic light, *Journal of Ergonomics Studies and Research*. Scholarena Journals. Available at: <http://fulltext.scholarena.co/Digital-Human-Modeling-Tecnomatix.php>
- Yosef, T., Belachew, A. and Tefera, Y.. Magnitude and contributing factors of low back pain among long distance truck drivers at Modjo Dry Port, Ethiopia: A cross-sectional study, *Journal of environmental and public health*. U.S. National Library of Medicine, 2019. Available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6778925/>

## **Biographies**

**Aisha Dhaiban** is a Master’s student of Engineering at the Department of Industrial Engineering at Khalifa University, United Arab Emirates.

**Areej Bin Amro** is a Master’s student of Engineering at the Department of Industrial Engineering at Khalifa University, United Arab Emirates.

**Dr.Saed Talib Amer** is a faculty member at Khalifa University. His research focuses on computer-integrated manufacturing and robot-controlled nondestructive testing. Dr. Amer also worked on sustainability metrics research and systematic measures to enforce engineering sustainability education. His previous work included seat comfort analyses for Boeing aircraft and robotics solutions for Unexploded Ordnance (UXO) remediation. Finally, Dr. Amer worked on simulation solutions for hybrid renewable energy research.