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ORIGINAL RESEARCH

Cervical Health Parameters in Car Drivers: Assessing the Influence of Driving on Neck Pain, Mobility, Proprioception and Craniovertebral Angle – A Cross-Sectional Study

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Purpose: Prolonged sitting during driving is linked to neck pain, uncomfortable body positions, and repetitive motions. Recognizing these challenges, this study aimed to investigate Cervical Health Parameters in Car Drivers.

Methods: The sample consisted of 160 car drivers between 25 and 45 years. This subject was then divided into two groups based on neck pain. Participants met the required criteria, such as being between 25–45 years of age, maintaining a BMI of 18–24, and driving for at least 2 hours each day for at least 3–5 years. To evaluate the results, we employed a clinometer and compass app on a smartphone to measure the Cervical Range of Motion (CROM). We used Surgimap software to estimate the Craniovertebral Angle (CVA), and a (Cervical range of motion) CROM device was used for proprioception assessment.

Results: The result shows the participants in neck pain group displayed lower Cervical Range of Motion (CROM) values than without neck Pain Group. Similarly, the Craniovertebral Angle (CVA) was smaller in the neck Pain Group (mean difference of −6.3°), indicating a more forward head posture. Neck pain resulted in a mean difference of −4.5° in proprioception accuracy. This indicates that neck pain affects CROM, CVA, and proprioception in car drivers.

Conclusion: Car driving significantly impacts cervical parameters in individuals with neck pain, reducing cervical range of motion, altered craniovertebral angle, and diminished proprioceptive accuracy. These findings emphasize the need for ergonomic interventions and proprioceptive training tailored for drivers. Future research should broaden demographic parameters and consider potential confounders to provide a holistic understanding of the relationship between car driving and neck health.

Keywords: car driving, cervical range of motion, craniovertebral angle, proprioception, neck pain

Introduction

Neck pain is a common musculoskeletal issue affecting a significant proportion of the global population, with lifetime occurrences reaching up to 71%.[1] This condition results in considerable disability, diminished quality of life, and increased healthcare expenses.[2] Neck pain is caused by various factors, including individual, physical, and psychosocial factors.[3] Evidence shows that occupational activities, such as driving, can cause or aggravate neck pain.[4]

Professional drivers, spanning from taxi drivers to truck drivers, each have unique driving habits and challenges which may contribute to musculoskeletal discomfort. For instance, taxi drivers may experience frequent starts and stops and short bursts of driving, whereas truck drivers may engage in prolonged, continuous driving sessions. The nuances in these driving styles could influence the development and severity of neck pain and its associated biomechanical alterations.

Car driving entails prolonged sitting, uncomfortable postures, and repetitive movements, which may contribute to musculoskeletal discomfort and disorders.[5] A high incidence of neck pain has been reported among professional drivers,

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particularly those driving for extended periods.[6] While some studies have touched upon the occupational health impacts of prolonged driving, the specific effects of car driving on the cervical range of motion (CROM), craniovertebral angle (CVA), and proprioception within the context of professional drivers have not been comprehensively explored. This fault presents a critical gap in our knowledge, which this study aimed to address by providing detailed insights into these key cervical health parameters.

CROM refers to the cervical spine's ability to move in various directions, including flexion, extension, lateral flexion, and rotation.[7] CROM is an essential outcome measure for evaluating intervention strategies targeted at individuals with neck pain and has been linked to neck pain.[8] The Craniovertebral Angle (CVA) reflects the sagittal orientation of the cervical spine in the sagittal dimension. This is determined by the intersection of the C7 spinous process and a line extending from the ear tragus to this point.[9] A diminished CVA often signifies a forward-leaning head posture and possible cervical malfunctions.[10]

Proprioception, the ability to sensing the position and movement of body parts in space, is crucial for maintaining postural stability and coordinating movements.[11] Those suffering from neck pain have been reported to exhibit impaired proprioception, which may contribute to persistent and recurring symptoms.[12] Consequently, understanding car driving's influence on these factors is vital for developing effective preventive and management strategies for neck pain. The objective of this study was to determine the influence of driving on neck pain, mobility, proprioception, and the craniovertebral angle. This study aimed to describe the relationship between prolonged driving and its potential contributory role in the onset and progression of musculoskeletal discomfort and disorders in the cervical region in drivers.

Prior research has highlighted the importance of ergonomic interventions in preventing and managing neck pain among car drivers.[13] The research methodology included recruiting participants with and without neck pain, assessing their CROM, CVA, and proprioception, and evaluating the impact of car driving on these parameters. In previous studies, researchers observed notable gap in the cervical range of motion (CROM), craniovertebral angle (CVA), and proprioception among individuals with and without neck pain, tentatively associating these variances with the negative impacts of car driving. However, it is necessary to emphasize that these associations do not inherently establish causal links. Our study's design and analytical approach have set the groundwork for identifying correlations; however, they are not sufficiently equipped to definitively prove causality.

Materials and Methods

Study Design and Participants

This study, of observational design, enlisted a total of 160 individuals. The individuals for the study were selected using a convenience sampling method. The sample size was determine using formula, $n = z^2 p(1-p)/d^2$, where, p= 50.0% using Z (1.65) at 90% confidence interval, error (7%), non-response (15%). It comprises of 160 participants, falling within the age bracket of 25–45, possessing a BMI between 18–24, with 3–5 years of driving experience, and who drive at least 2 hours per day. These participants were carefully selected using a purposive sampling method. They were subsequently segmented into two groups: those grappling with neck pain for more than three months and those without any neck pain history. Exclusion criteria include any history of cervical surgery, fracture, systemic disease, or neurological disorder affecting the cervical spine.

This study was approved by the Institutional Review Board (IRB) (IEC/IIMS&R/2022/70), adhering to standard ethical procedures for human subject's research. Informed consent was obtained from all participants after a thorough explanation of the study's objectives, procedures, and potential risks. The study adhered to the ethical standards as prescribed in the 1964 Helsinki Declaration. Essential demographic information, including age, gender, and driving duration, was gathered through a self-administered questionnaire to provide context for data interpretation and analysis. Uniform verbal instructions were given to all subjects, and measurements were taken by the same examiners using identical instruments.

Measurement of Cervical Range of Motion

Cervical range of motion (CROM) was assessed using a smartphone equipped with a clinometer and compass application, following the procedure recommended by Khan AR et al (2023).[14] The smartphone applications demonstrated a high level of reliability, as indicated by their Intraclass Correlation Coefficients (ICC) of 0.80. In comparison to a universal goniometer, these applications presented good to excellent validity, as indicated by their intraclass correlation coefficients of 0.65, for all six cervical ranges of motion in both participants with and without neck pain. This method offered an inventive and dependable way to quantify cervical ROM, guaranteeing the collection of precise data. As instructed, participants were to execute a set of movements such as flexion, extension, and rotation of the neck. The angle of the neck during each motion was recorded by the smartphone application, providing an accurate assessment of cervical ROM. For every cervical movement, three evaluations were undertaken, and the average score was employed for the assessment

Measurement of Craniovertebral Angle

A lateral-view photograph was used to calculate the craniovertebral angle (CVA). For this purpose, participants were photographed standing on a plumb line. This is the angle created by a horizontal line intersecting the C7 spinous process and a line that links the ear's tragus to that same spinous process. In this assessment, the participant's neck and head posture was numerically assessed. In this study, CVA was calculated precisely with Surgimap software. When the CVA is diminished, it suggests a forward head posture, which is typically linked with cervical pain.[15]

Assessment of CJPE

To evaluate neck proprioception, the Cervical Joint Position Error (CJPE) test was used, focusing on the right and left cervical rotations. Subjects were instructed to sit upright on a stool, their feet firmly on the ground. Test administrators affixed CROM devices to the participants' heads and asked them to determine their neutral head position.[16] The CROM device was then set to zero. During the testing procedure, participants were directed to close their eyes while their heads were moved by the examiner to a target position, representing 50% of their maximum range of motion. They were asked to hold this position for five seconds and to memorize it. Afterwards, the examiner directed the participant to return their head to the position they remembered. The CJPE was assessed based on the degree of precision in head repositioning. Each cervical movement tested three times, and the mean of these movements was calculated for analysis.[17,18]

Statistical Analysis

The data was analysed comprehensively using SPSS 24. Content validity was evaluated as a validation method. A group of experts in the field assessed the significance and suitability of the questionnaire items to estimate content validity. Their knowledge was contributory in checking that the questionnaire sufficiently taken the proposed constructs and content areas. Moreover, we evaluated reliability by calculating internal consistency. Cronbach's alpha value was assessed to estimate internal consistency, ie, 0.79, which is suggestive of adequate internal consistency

The CROM, the CVA, and the proprioception of groups with and without neck pain were compared using independent *t*-tests. A multivariate analysis, including MANOVA, revealed relationships between variables, accounting for potential confounders. The results of the Hosmer-Lemeshow test contribute significantly to the overall validity of the model. A non-significant result ($p > 0.05$) indicates good model fit, suggesting that our logistic regression model accurately predicts the probability of the outcome variable. Any result with a p-value <0.05 was statistically significant.

Results

As outlined in Table 1, the characteristics of participants varied slightly between the Neck Pain Group and the Non-Neck Pain Group. The participants in the Neck Pain Group exhibited a mean age of 34.5 ±5.0 years, while their counterparts in the Non-Neck Pain Group averaged 33.8 ±4.7 years. However, this difference was not statistically significant (t=−0.456, p=0.650). Both groups maintained an almost identical mean BMI near 22 (t=0.342, p=0.734). Gender distribution indicated a higher male predominance in the Neck Pain Group at 60%, as opposed to even gender distribution in the Non-Neck Pain Group. Moreover, the Neck Pain Group reported a marginally longer average driving experience of 4.1 ±0.8 years compared to the 3.9 ±0.7 years in the Non-Neck Pain Group, but the difference remained non-significant (t=−0.841, p=0.405).

Regarding cervical range of motion (CROM) comparisons in Table 2, individuals in the Neck Pain Group consistently demonstrated reduced CROM across all directions compared to the Non-Neck Pain Group. Significant deficits were

Table 1 Characteristics of Participants

Characteristics	Neck Pain Group (n=80)	Non-Neck Pain Group (n=80)	Chi- square or t value	p-value
Mean age (years)	34.5 ±5.0	33.8 ±4.7	−0.456	0.650
Mean BMI (kg/m²)	22.1 ±1.9	22.3 ±1.8	0.342	0.734
Gender (M/F)	48/32 (60%/40%)	40/40 (50%/50%)	0.404	0.525
Driving experience (years)	4.1 ±0.8	3.9 ±0.7	−0.841	0.405

Abbreviations: BMI, Body Mass Index; M, Male; F, Female.

Table 2 Cervical Range of Motion (CROM) Comparisons Between Groups

Direction	Neck Pain Group (n=20)	Non-Neck Pain Group (n=20)	Mean Difference	95% Confidence Interval	t value	p-value
Flexion	32.2±6.5	41.4 ± 4.1	−9.2°	−12.5° to −5.9°	5.35	0.00
Extension	31.2 ± 7.1	38.8 ± 7.4	−7.6°	−12.2° to −2.9°	−3.31	0.00
Right Lateral Flexion	30.4 ± 8.1	36.8 ± 4.5	−6.4°	−10.5°to −2.2°	3.08	0.00
Right Lateral Flexion	32.2 ± 5.4	38.8 ±4.1	−6.6°	−9.6° to −3.5°	4.35	0.00
Right Rotation	46.4 ± 7.3	55.1 ± 6.4	−8.7°	−13.1° to −4.3°	4.00	0.00
Left Rotation	48.4 ± 5.4	56.5 ± 4.1	−8.1°	−11.1° to −5.0°	5.34	0.00

particularly notable in flexion (−9.2°), left rotation (−8.1°), and right rotation (−8.7°), all of which were statistically significant with p-values registering at 0.00.

Transitioning to craniovertebral angle (CVA) observations (Table 3), the Neck Pain Group showed a smaller CVA measurement (42.4 ± 3.3°) when juxtaposed against the Non-Neck Pain Group (48.7 ±2.1°). The resultant mean difference was −6.3°, which was statistically significant within a 95% confidence interval of −8.1° to −4.5° (p=0.01).

Further, proprioceptive evaluations (Table 4) revealed that the Neck Pain Group had a diminished proprioceptive accuracy, measuring at 5.9 ± 1.2, in contrast to the Non-Neck Pain Group, which acted as the reference group with an accuracy of 1.4 ± 1.1. This significant mean difference of −4.5° was confirmed with a 95% confidence limit ranging from −5.2° to −3.7° (p=0.00).

Logistic Regression Analysis (Table 5) The logistic regression model evaluated various factors influencing the incidence of neck pain among car drivers, considering CROM, CVA, and proprioception. Flexion, extension, and rotations (both left and right) were found to be significant predictors, with p-values less than 0.05. "Flexion" and "Extension" show statistically significant associations with the outcome, with odds ratios of 0.820 and 0.960, suggesting

Table 3 CVA Comparisons Between Groups

Group	CVA	Mean ± SD	Mean Difference	95% Confidence Interval	p-value
Neck Pain	Smaller	42.4 ± 3.3			
Non-Neck Pain	Larger	48.7 ±2.1	−6.3°	−8.1° to −4.5°	0.01

Abbreviation: CV, Craniovertebral Angle.

Table 4 Proprioceptive Comparisons Between Groups

Group	Proprioceptive Accuracy	Mean ± SD	Mean Difference	95% CL	p-value
Neck Pain	Decreased	5.9 ± 1.2		−5.2° to −3.7°	
Non-Neck Pain	Reference Group	1.4 ± 1.1	−4.5°		0.00

Table 5 Logistic Regression Analysis

Variable	Coefficient	Standard Error	Odd Ratio	95% Confidence Interval		p-value
				Lover	Upper	
Flexion	−0.0743	0.3495	0.820	−0.889	0.491	0.001
Extension	0.2094	0.3108	0.960	−0.640	0.558	0.012
Right Lateral Flexion	0.0827	0.1195	0.912	−0.329	0.140	0.000
Right Lateral Flexion	0.1876	0.3507	1 0.123	−0.572	0.806	0.001
Right Rotation	0.1595	0.2950	0.978	−0.598	0.554	0.023
Left Rotation	0.1334	0.4097	1 0.111	0.105	0.907	0.014
CVA	−0.7662	0.4900	0.624	−1.438	0.495	0.000
Proprioceptive Accuracy	1.0117	0.4494	1 0.323	−0.293	1.414	0.080
Constant	−24.018					

decreased odds of the outcome with increased flexion and extension, respectively. "Right Lateral Flexion" is highly statistically significant, indicating 8.8% reduced odds of the outcome with each unit increase in right lateral flexion. "Left Lateral Flexion" and "Left Rotation" have anomalous odds ratio values that require validation, but the latter is likely not statistically significant given its high p-value. "CVA" is statistically significant, indicating 37.6% decreased odds of the outcome. The Hosmer-Lemeshow test affirmed the appropriateness of our logistic regression model.

Discussion

This study investigated the Influence of Driving on Neck Pain, Mobility, Proprioception, and Cranio Vertebral Angle. A significant reduction in CROM, a smaller CVA, and a decrease in proprioceptive accuracy were observed in participants with neck pain compared with those without.

In previous studies, individuals with neck pain had reduced CROM in all directions of movement compared to those without neck pain.[19,20] CROM may be reduced due to muscle stiffness, pain, and joint restrictions associated with neck pain.[21] For car drivers, these conditions may be associated with limited range of motion and neck pain, though our observational study design does not allow for the establishment of a causal link.[22]

In previous research, forward head posture was linked to neck pain and a smaller CVA in the neck pain group.[23,24] Evidence suggests that forward head posture may increase the load on cervical spine structures, potentially leading to muscle imbalances, joint restrictions, and neck pain; however, causality cannot be inferred from our data.[25] In ergonomic interventions for car drivers with neck pain, it is important to address head posture.[26]

Moreover, the current study found a decreased proprioceptive accuracy in subject with neck-pain as compared to without neck pain. Researchers have previously found impaired proprioception in people suffering from neck pain.[27,28] As a result of neck pain, muscle spindle sensitivity, and joint mechanoreceptor function may be altered.[29] Motor control and muscle activation patterns can be affected by poor proprioception, further aggravating neck pain.[30] Incorporating proprioceptive training in the treatment of neck pain in car drivers may be beneficial, though the effectiveness of such interventions needs further investigation.[31]

Researchers found that ergonomic interventions and awareness programs can prevent and manage neck pain in car drivers. CROM, CVA, and proprioception should be studied in future research to see if such interventions improve CROM, CVA, and proprioception among car drivers with neck pain.

This study had several limitations that should be acknowledged. Given our study's observational design and the cross-sectional nature of the data, we highlight the associations observed rather than implying causation between driving and neck pain. There is a potential limitation to the generalizability of the findings in a larger population of car drivers with and without neck pain due to the relatively small sample size of 160 participants, with 80 in each group. The results need to be confirmed and enhanced with larger sample sizes in future research. Additionally, a cross-sectional study design only provides a snapshot of the participant's condition at a single point in time, making it impossible to determine if car driving causes neck pain or if neck pain progresses. It is necessary to conduct longitudinal studies in order to elucidate the causal relationship and identify potential factors that may contribute to neck pain development.

Additionally, the study relied on self-reported driving experience data, recall or social desirability bias may be present in this study. Objective measures of driving experience, such as vehicle data recorders or driving logs, could improve data accuracy. Moreover, the study included only participants aged 25–45, with a BMI of 18–24, and 3–5 years of car experience, driving at least 2 hours per day. These inclusion criteria may limit the generalizability of the findings to car drivers with different age ranges, BMIs, driving experiences, or driving durations. Future studies should consider including a more diverse population to evaluate the impact of car driving on neck pain across a broader demographic.

In addition, potential confounding factors were not taken into account, such as occupation, physical activity levels, car ergonomic adjustments, or other musculoskeletal disorders. Results may be influenced by these factors and interpreted differently. To better understand how car driving affects neck pain, future studies should control potential confounders. Lastly, this study did not investigate the effectiveness of specific interventions, such as ergonomic adjustments or proprioceptive training, in improving outcomes among car drivers with neck pain. In the future research should explore the impact of targeted interventions on CROM, CVA, and proprioception in this population.

Conclusion

The study conclusively highlights the implications of car driving on cervical parameters, including CROM, CVA, and proprioception, especially in subjects with neck pain. Our findings solidify that neck pain in car drivers can lead to marked reductions in cervical range of motion, alterations in craniovertebral angle, and decreased proprioceptive accuracy. Aspects such as forward head posture associated with a diminished CVA and the resultant biomechanical stresses on the cervical spine underline the need for improved ergonomic considerations in occupational health framework for drivers. This research underscores the importance of integrating proprioceptive training and ergonomic interventions tailored specifically for car drivers to address and ameliorate these issues, marking a crucial step in enhancing their health and wellness. Emphasizing the occupational health perspective, our study advocates for the implementation of targeted interventions based on our findings. Future studies are encouraged to delve deeper, expanding the sample size and demographic diversity while considering potential confounders to understand the nexus between car driving and neck pain comprehensively. Implementing targeted interventions to improve CROM, CVA, and proprioception in drivers with neck pain is an invaluable strategy to promote occupational health and wellness.

Institutional Review Board Statement

The study was conducted after obtaining ethical clearance from the Institutional Ethical Committee of Integral University, Lucknow, India (IEC/IIMS&R/2022/70) and performed in accordance with the principles of the Declaration of Helsinki. This work is acknowledged under Integral University manuscript communication number IU/R&D/2024-MCN0002521.

Registration

The study is registered under Clinical Trial Registry India (CTRI) with registration number CTRI/2022/11/047689.

Data Sharing Statement

The datasets analysed in the current study are available from the corresponding author on reasonable request.

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Informed Consent Statement

All participant's written informed consent was signed and obtained publication of this study.

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Disclosure

The authors declare that they have no competing interest in this work.

References

1. Kazeminasab S, Nejadghaderi SA, Amiri P, et al. Neck pain: global epidemiology, trends and risk factors. *BMC Musculoskel Disorder*. 2022;23. doi:10.1186/s12891-021-04957-4
2. Safiri S, Kolahi -A-A, Hoy D. Global, regional, and national burden of neck pain in the general population, 1990–2017: systematic analysis of the global burden of disease study 2017. *BMJ*. 2020;m791. doi:10.1136/bmj.m791
3. Khanum F, Khan AR, Khan A, et al. Predicting mechanical neck pain intensity in computer professionals using machine learning: identification and correlation of key features. *Front Public Health*. 2024;12. doi:10.3389/fpubh.2024.1307592
4. Khan A, Maurya NK, Ahmad A. Prevalence of neck pain in car and bike drivers: a comprehensive review of primary, secondary and tertiary care. *J Clin Diagn Res*. 2023;17(7):YE05–YE09.
5. Aafreen A, Khan AR, Khan A, et al. Neck Health metrics and quality of life: a comparative study in bike drivers with and without neck pain. *J Multidiscip Healthc*. 2023;16:3575–3584. doi:10.2147/JMDH.S437826
6. Ming-Lun L. Editorial: prevention of musculoskeletal pain among professional drivers. *J Occupa Health*. 2020;62(1). doi:10.1002/1348-9585.12170
7. Serrano-Fernández M-J, Boada-Grau J, Robert-Sentís L, Vigil-Colet A. Predictive Variables for Musculoskeletal Problems in Professional Drivers. *J Transport Health*. 2019;14:100576. doi:10.1016/j.jth.2019.100576
8. Joseph L, Standen M, Paungmali A, Kuisma R, Sitilertpisan P, Pirunsan U. Prevalence of musculoskeletal pain among professional drivers: a systematic review. *J Occupa Health*. 2020;62(1). doi:10.1002/1348-9585.12150
9. Mostafaee N, HasanNia F, Negahban H, Pirayeh N. Evaluating differences between participants with various forward head posture with and without postural neck pain using craniovertebral angle and forward shoulder angle. *J Manipula Physiol Therape*. 2022;45(3):179–187. doi:10.1016/j.jmpt.2022.06.007
10. Shaghayeghfard B, Ahmadi A, Maroufi N, et al. Evaluation of forward head posture in sitting and standing positions. *Eur Spine J*. 2015;25 (11):3577–3582. doi:10.1007/s00586-015-4254-x
11. Malmström E-M, Fransson P-A, Jaxmar Bruinen T, Facic S, Tjernström F. Disturbed cervical proprioception affects perception of spatial orientation while in motion. *Exp Brain Res*. 2017;235(9):2755–2766. doi:10.1007/s00221-017-4993-5
12. Peng B, Yang L, Li Y, Liu T, Liu Y. Cervical proprioception impairment in neck pain-pathophysiology, clinical evaluation, and management: a narrative review. *Pain Ther*. 2021;10(1):143–164. doi:10.1007/s40122-020-00230-z
13. Hoe Victor CW, Urquhart DM, Kelsall HL, et al. Ergonomic interventions for preventing work-related musculoskeletal disorders of the upper limb and neck among office workers. *Cochrane Database Syst Rev*. 2018;10(10):CD008570. doi:10.1002/14651858.CD008570.pub3
14. Khan AR, Aafreen Khan A, Ahmed H, Shaphe MA, Qasheesh M, Qasheesh M. Test–retest reliability and validity of cervical range of motion measurement using a smartphone clinometer and compass application among individuals with and without neck pain. *Int J Ther Rehabil*. 2023;30 (2):1–13. doi:10.12968/ijtr.2022.0004
15. Aafreen Khan A, Ahmad A, Ahmad A, et al. Clinimetric properties of a smartphone application to measure the craniovertebral angle in different age groups and positions. *Heliyon*. 2023;9(9):e19336. doi:10.1016/j.heliyon.2023.e19336
16. Kristjansson E, Hardardottir L, Asmundardottir M, Gudmundsson K. A new clinical test for cervicocephalic kinesthetic sensibility: "the fly". *Arch Phys Med Rehabil*. 2004;85(3):490–495. doi:10.1016/S0003-9993(03)00619-1
17. Roren A, Mayoux-Benhamou MA, Fayad F, Poiraudeau S, Lefevre-Colau MM, Rannou F. Comparison of visual and ultrasound based techniques to measure head repositioning in healthy and neck-pain subjects. *Manual Ther*. 2009;14(3):270–277. doi:10.1016/j.math.2008.03.002
18. Aafreen Khan AR, Khan A, Maurya NK, et al. Decoding the impact of driving postures: comparing neck pain, mobility, proprioception in car and bike drivers with and without Forward Head Posture. *J Transport Health*. 2023;33:101719. doi:10.1016/j.jth.2023.101719
19. Chiu TT, Sing KL. Evaluation of cervical range of motion and isometric neck muscle strength: reliability and validity. *Clin Rehabil*. 2002;16 (8):851–858. doi:10.1191/0269215502cr550oa
20. Dugailly PM, De Santis R, Tits M, Sobczak S, Vigne A, Feipel V. Cervical spine range of motion and proprioceptive changes in whiplash patients: a case-control study. *Eur Spine J*. 2014;23(10):2129–2137.
21. Falla D, Jull G, Russell T, Vicenzino B, Hodges P. Effect of neck exercise on sitting posture in patients with chronic neck pain. *Phys Ther*. 2007;87 (4):408–417. doi:10.2522/ptj.20060009
22. Khanum F, Khan AR, Khan A, Ahmed H. Postural correction for neck pain in computer and smartphone users- A Narrative Review. *J Clin Diagn Res*. 2023;17(5):YE01–YE05.
23. Yip CH, Chiu TT, Poon AT. The relationship between head posture and severity and disability of patients with neck pain. *Man Ther*. 2008;13 (2):148–154. doi:10.1016/j.math.2006.11.002
24. Nejati P, Lotfian S, Moezy A, Nejati M, Nejati M. The relationship of forward head posture and rounded shoulders with neck pain in Iranian office workers. *Med J Islam Repub Iran*. 2014;28:26.
25. Szeto GP, Straker L, Raine S. A field comparison of neck and shoulder postures in symptomatic and asymptomatic office workers. *Appl Ergon*. 2002;45(9):634–648.
26. Waongenngarm P, Rajaratnam BS, Janwantanakul P, Voss M. Perceived importance and self-assessed competency of ergonomics among physical therapists in Thailand. *Work*. 2014;49(2):163–174. doi:10.3233/WOR-131715
27. Revel M, Minguet M, Gregoy P, Vaillant J, Manuel JL. Changes in cervicocephalic kinesthesia after a proprioceptive rehabilitation program in patients with neck pain: a randomized controlled study. *Arch Phys Med Rehabil*. 1994;75(8):895–899. doi:10.1016/0003-9993(94)90115-5

28. Rix GD, Bagust J. Cervicocephalic kinesthetic sensibility in patients with chronic, nontraumatic cervical spine pain. *Arch Phys Med Rehabil*. 2001;82(7):911–919. doi:10.1053/apmr.2001.23300
29. Boyd-Clark LC, Briggs CA, Galea MP. Muscle spindle distribution, morphology, and density in longus colli and multifidus muscles of the cervical spine. *Spine*. 2002;27(7):694–701. doi:10.1097/00007632-200204010-00005
30. Kristjansson E, Treleaven J. Sensorimotor function and dizziness in neck pain: implications for assessment and management. *J Orthop Sports Phys Ther*. 2009;39(5):364–377. doi:10.2519/jospt.2009.2834
31. Jull GA, Falla D, Vicenzino B, Hodges PW. The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain. *Man Ther*. 2009;14(6):696–701. doi:10.1016/j.math.2009.05.004