Lu et al. BMC Musculoskeletal Disorders (2025) 26:484
https://doi.org/10.1186/s12891-025-08594-z

BMC Musculoskeletal Disorders

RESEARCH

Open Access

Correlation analysis between neck muscles and lifestyle habits in patients with cervical instability

Guangqi Lu[1†], Jing Li[1†], Hanze Mao[1], Minghui Zhuang[1], Tiantian Li[2], Xinyue Sun[1], Mingming Ma[1], Yakun Liu[1], Ying Cui[3], Liguo Zhu[1], Jie Yu[1*] and Long Liang[1*]

Abstract

Background The neck muscles play a crucial role in maintaining cervical spine stability. A thorough understanding of the changes in neck muscles during cervical instability (CI), along with an analysis of their correlation with lifestyle habits, can provide valuable data for the prevention and treatment of CI.

Methods A total of 98 patients with CI and 88 healthy subjects were included in the study. Their cervical MRI images and lifestyle habits information were collected. The relative cross-sectional area (RCSA) and fat signal fraction (FSF) of the neck muscles were obtained from the MRI images. Correlation analysis was conducted between the muscle parameters, CI, and lifestyle habits information.

Results CI subjects spent more time working (P=.026) and using computers daily than the healthy subjects (P=.023). The cervical curvature of the CI subjects was significantly smaller compared to healthy subjects (P=.004). CI subjects had significantly smaller RCSA (P=.003) and greater FSF (P=.011) in the deep muscles at the back of the neck compared to healthy subjects. FSF in the deep muscles at the back of the neck (OR = 2.343, 95%CI = 1.261–4.352) and cervical curvature (OR = 0.904, 95%CI = 0.848–0.965) were risk factors for CI. Keeping head down time per day (r = - 0.286) and using the computer time per day (r = - 0.230) were negatively correlated with the RCSA in the deep muscles at the back of the neck.

Conclusions Changes in the deep muscles at the back of the neck are key factors in the development of CI. Prolonged maintenance of a single downward head posture is closely related to changes in the deep muscles at the back of the neck.

Trial registration The study protocol is registered with Chinese Clinical Trial Registry (registration number: ChiCTR2100053525, registration date: November 24, 2021).

Keywords Cervical instability, Neck muscles, Lifestyle habits

†Guangqi Lu and Jing Li contributed equally to this work.

*Correspondence:
Jie Yu
18800122947@163.com
Long Liang
leungloongtcm@163.com
Full list of author information is available at the end of the article

Introduction

Cervical instability (CI) is a critical pathological stage and a major early indicator of cervical spondylosis [1, 2]. With the widespread use of electronic devices, the incidence of CI is steadily increasing in the word, particularly among middle-aged and young adults. The recurrent and persistent symptoms severely affect their physical and mental health as well as their quality of life. A proper understanding of CI can aid in early prevention and precise intervention, which is crucial for reducing the incidence of cervical spondylosis in the word.

The neck muscles play a crucial role in maintaining cervical spine stability and coordinating cervical movement [3–5]. The primary cause of CI in middle-aged and young adults is fatigue-induced neck muscle injury, often resulting from poor lifestyle habits, particularly prolonged periods in a single forward-bending posture [6, 7]. In this study, we analyzed the neck muscle characteristics of participants with CI using cervical MRI images and collected their daily lifestyle habit information to explore the correlation between the two. The findings aim to provide valuable insights for the prevention and management of CI.

Materials and methods

Subject selection

This prospective single-center study was reviewed and approved by the institutional review board of Wangjing Hospital, China Academy of Chinese Medical Sciences (identifier: WJEC-KT- 2021–044-P002). Our study subjects included middle-aged and young adults with C4/5 CI and healthy controls. From January 2022 to October 2023, 251 young and middle-aged subjects were recruited through advertisements. After screening according to the inclusion and exclusion criteria, 186 subjects met the requirements and were included in the study: 98 CI and 88 healthy subjects. The subject flowchart is displayed in Fig. 1. All subjects were aged between 18 and 45 and signed the informed consent form. CI was diagnosed using lateral or flexion–extension lateral X-ray radiographs: 2 adjacent vertebras appeared larger than 3.5 mm horizontal displacement or more than 11° rotational difference [8]. Participants with CI were required to exhibit instability only at the C4/5, with no instability in other segments. The exclusion criteria were as follows: (1) CI resulting from congenital abnormalities, trauma, tumors, tuberculosis, rheumatoid arthritis, or other diseases. (2) Cervical iatrogenic instability. (3) Severe cervical degeneration, including prominent osteophytes in the cervical vertebrae, significant narrowing of the vertebral space, or ligament ossification. (4) Spinal infections, traumatic fractures, tuberculosis, severe osteoporosis, or ankylosing spondylitis. (5) Subjects who were unable to undergo MRI. (6) Special populations, including pregnant or lactating women, as well as individuals who are blind, deaf, mute, or have intellectual or mental disorders.

Basic information collection

Basic information includes age, gender, body mass index (BMI, calculated as weight (kg)/height (m)^2), neck circumference and length. (Neck circumference and neck length were measured using a flexible, non-elastic measuring tape with a precision of 0.1 cm. For neck circumference, the measurement was taken at the level of the cricoid cartilage, with the subject seated in an upright position, looking straight ahead, and shoulders relaxed. For neck length, the measurement was taken from the external occipital protuberance to the spinous process of C7, with the subject in the same seated position.).

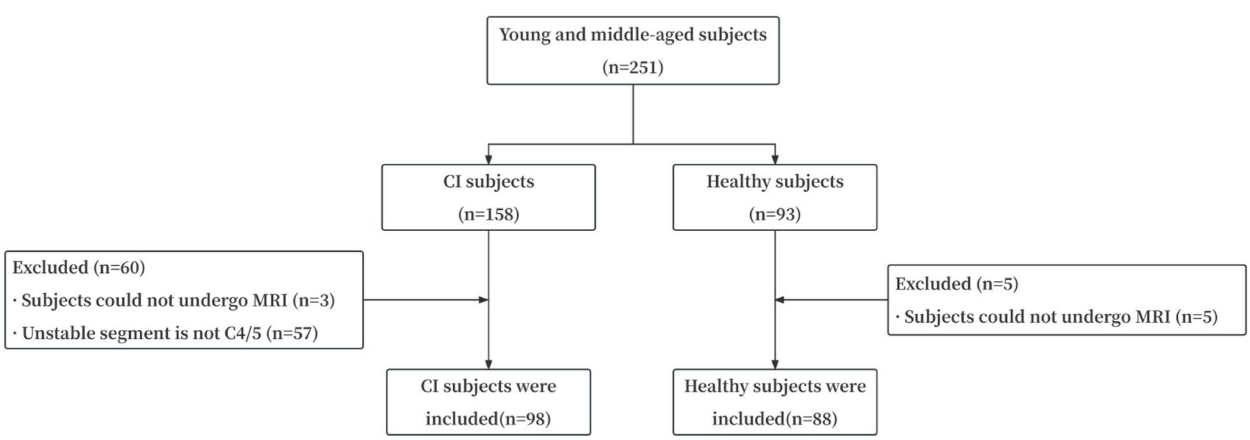

Fig. 1 Subject flowchart. CI = cervical instability

Lifestyle habit information collection

Lifestyle habit information over the past year was collected on-site using questionnaires covering various aspects: daily work duration, time spent with the head in a downward position, exercise frequency and duration per week, daily sleep duration, and daily use of computers and smartphone. The questionnaire was developed through multiple rounds of expert discussions and consensus, ensuring its scientific rigor and applicability to our research objectives. To ensure its validity and reliability, the questionnaire was pilot-tested and refined based on feedback from both experts and participants. The final version demonstrated good internal consistency and test–retest reliability. Before administering the questionnaires, researchers provided detailed explanations of each item to the participants and assisted them in completing the forms. After submission, another researcher reviewed the questionnaires to ensure completeness and accuracy, following up with participants to address any missing information.

X-ray data collection

All participants underwent lateral and functional X-ray of the cervical spine. Images were taken in a standing position with both shoulders fully relaxed to ensure a clear view of the cervicothoracic junction. For lateral X-rays, participants were instructed to slightly lift their mandible and look straight ahead, with their gaze forming an approximately 15°angle with the horizontal plane. For functional X-rays, participants were required to achieve maximum flexion and extension without external force. A radiologist supervised the quality control of all X-ray images.

The measured data of X-ray included cervical curvature, horizontal displacement, and angular displacement between adjacent vertebrae. Cervical curvature was measured based on the method described by Borden et al. [9], while displacement between vertebrae followed the method described by White et al. [8]. Image J software (National Institutes of Health, USA) was used for image processing and measurements. The measurements were independently performed by a spine specialist and a radiologist, both with extensive experience. Measurement data were subjected to inter-rater reliability analysis using the intraclass correlation coefficient (ICC). Data with ICC ≥ 0.75 were averaged and included in the analysis, while data with ICC < 0.75 were re-measured by both doctors before final calculations. We conducted periodic calibration sessions throughout the study to minimize drift in measurement techniques over time. These sessions involved re-evaluating a subset of previously analyzed images to confirm consistency across different time points. The measuring method of X-ray is displayed in Supplementary Figure S1.

MRI data collection

MRI acquisition was performed with a 3.0-T MRI scanner (SIEMENS, Germany) with a specialized spinal coil. The scanning mode was consistent throughout, employing the T2-SPACE-TRA sequence. Scanning parameters were as follows: TR 1500-ms, TE 106-ms, turnover Angle 60°, matrix 512×512, layer thickness 2.5-mm, layer spacing 0.2-mm, excitation times 1.4 times. A total of 40 layers were obtained, centered on the midpoint of the posterior margin of the C4 vertebra.

The measured data of MRI included the cross-sectional area (CSA) and fat signal fraction (FSF) of the neck muscles, as well as the intervertebral disc signal intensity. On the MRI axial image at the C4/5 disc level, we conducted region of interest (ROI) segmentation and data extraction. ROI segmentation was performed using AccuContour3.0 software [10] (Manteia Technologies Co., Ltd.). We selected 3 specific ROIs for manual segmentation: (1) Prevertebral muscles, primarily the longus colli muscle; (2) Deep muscles at the back of the neck, primarily the semispinalis cervicis muscle; (3) Superficial muscles at the back of the neck, including the complexus, splenius capitis, splenius cervicis, levator scapulae, scalenus medius, and scalenus posterior muscles. The method of ROI segmentation and processing is displayed in Fig. 2A. The segmentation was performed independently by a spinal surgeon and a radiologist, both of whom have extensive experience. To ensure the segmentation focused on the most solid parts of each neck structure and excluded the surrounding tissues'uncertainties, they strictly followed the anatomical structure of the neck and used the minimum contour method. FSF was represented as the fraction of pixels representing fat/(number of pixels representing fat + number of pixels representing muscles). To establish the FSF, an intensity histogram was defined for each ROI. To determine the threshold between lower intensities representing muscles and higher intensities representing fat, we applied Otsu's mathematical method [11], which is a widely used thresholding technique in image processing. Otsu's method automatically determines the optimal threshold value to separate foreground and background pixels by minimizing intra-class variance and maximizing inter-class variance. This approach is particularly effective for distinguishing ROI in medical images, such as differentiating between muscle and fat in our study. Figure 2B shows the distinction between fat and muscle pixel intensity.

To compensate for the bias caused by the relative body size of the individual on muscle CSA, we calculated the relative CSA (RCSA) by dividing the muscle CSA by the

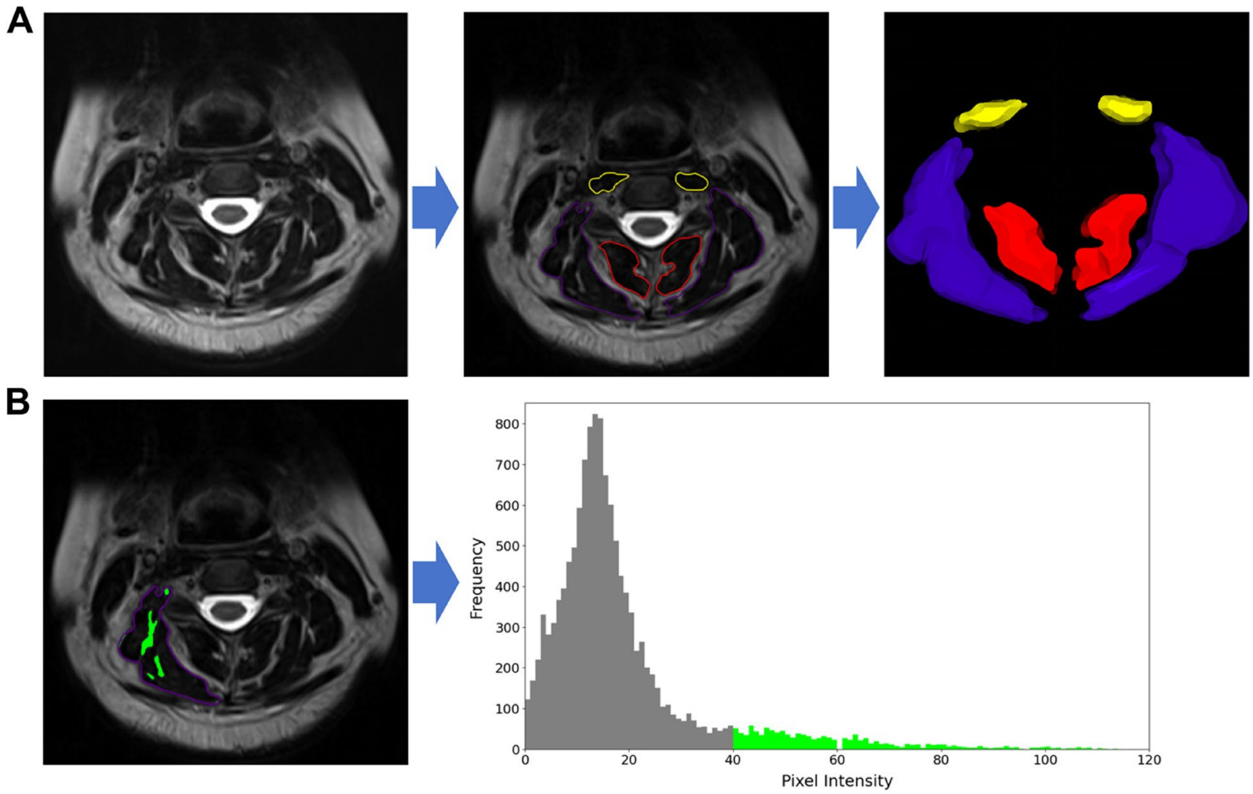

Fig. 2 MRI data collection. (A) ROI segmentation and processing. Yellow areas: the prevertebral muscles. Red areas: the deep muscles at the back of the neck. Purple areas: the superficial muscles at the back of the neck. (B) Distinction between fat and muscle pixel intensity. Green areas: the fat

CSA of the vertebral body of C4; such compensation has been recently described by Hyun et al. [12]. The average gray values of the intervertebral disc and cerebrospinal fluid were measured to determine the signal intensity of the disc: The disc signal intensity was calculated as the average gray value of the disc divided by that of the cerebrospinal fluid. This method is based on the study by Urbanschitz et al. [13]. MRI measurement data were obtained from the ROIs segmented by the two doctors. The data were subjected to ICC analysis, and values with ICC $\geq$0.75 were averaged and included in the analysis. For ICC <0.75, the ROIs were re-delineated by the two doctors before recalculation. We conducted periodic calibration sessions throughout the study to minimize drift in measurement techniques over time. These sessions involved re-evaluating a subset of previously analyzed images to confirm consistency across different time points.

Statistical analysis

Statistical analysis was performed using SPSS 26.0 software. Univariate analysis was conducted to compare characteristics between the 2 groups of subjects. The measurement data was tested using the Shapiro–Wilk test. Data following a normal distribution was expressed as mean ±standard deviation ($\bar{x}$±s), and comparisons between groups were made using the independent samples t-test. Data that did not follow a normal distribution was expressed as the median (interquartile range) [M (P25-P75)], and non-parametric tests were used for comparisons between groups. Qualitative data were described using frequency counts, and the chi-square test was employed for comparisons between groups. Binary logistic regression was used for multifactorial analysis, with CI as the dependent variable and variables identified as statistically significant in the univariate analysis included as independent variables. Spearman correlation analysis was used to assess strength and direction of relationship between characteristics. $P< 0.05$ was considered to indicate a statistically significant difference.

Results

Univariate analysis between CI and healthy subjects

The age of the CI subjects was significantly greater compared to healthy subjects ($P< 0.001$), see Table 1. Those with CI spent considerably more time working ($P=$ 0.026) and using computers daily than the healthy subjects ($P=$ 0.023), see Table 2. The cervical curvature of

Table 1 Univariate analysis of basic information between CI and healthy subjects

Basic Information	CI Subjects (n = 98)	Healthy Subjects (n = 88)	*P* Value
Sex			.132
Male	35 (36)	41 (47)	
Female	63 (64)	47 (53)	
Age (years)[a]	28.00 (21.00–43.00) [25.00–32.00]	25.00 (21.00–45.00) [24.00–28.75]	<.001
BMI (kg/m^2)[a]	21.58 (15.63–32.85) [19.90–24.23]	23.12 (15.43–33.14) [20.20–25.46]	.109
Neck circumference (cm)[a]	33.45 (28.00–45.10) [31.28–37.10]	35.20 (29.20–43.20) [31.50–38.88]	.093
Neck length (cm)[*]	11.50 (7.50–15.60) [10.30 – 13.10]	11.50 (8.50–16.60) [10.50–12.60]	.950

Unless otherwise specified, data are numbers of subjects, with percentages in parentheses

[a] Data are medians, with ranges in parentheses and interquartile ranges in brackets

The measurement data did not follow a normal distribution was expressed as the median (interquartile range) [M (P25-P75)], and non-parametric tests were used for comparisons between groups. Qualitative data were described using frequency counts, and the chi-square test was employed for comparisons between groups. *BMI* body mass index, *CI* cervical instability

the CI subjects was significantly smaller compared to healthy subjects (P= 0.004). CI subjects had significantly smaller RCSA (P= 0.003) and greater FSF (P= 0.011) in the deep muscles at the back of the neck compared to healthy subjects. See Table 3. Figures 3 and 4 show the comparison of cervical X-ray and MRI images between a CI and healthy subject, respectively.

Multifactorial logistic regression analysis of CI

To further clarify the risk factors for CI, we took whether CI as the dependent variable to perform multivariate analysis by binary logistic regression analysis. Independent variables include Age, FSF in the deep muscles at the back of the neck, RCSA in the deep muscles at the back of the neck, cervical curvature, working time per day and using the computer time per day. The results showed that FSF in the deep muscles at the back of the neck (OR =2.343, 95%CI =1.261–4.352) and cervical curvature (OR =0.904, 95%CI =0.848–0.965) were risk factors for CI. See Fig. 5.

Spearman correlation analysis between lifestyle habits and imaging data in CI subjects

A Spearman correlation analysis was conducted between the lifestyle habits of CI subjects and their RCSA in the deep muscles at the back of the neck, FSF in the deep muscles at the back of the neck, and cervical curvature, all of which showed significant intergroup differences in the univariate analysis of characteristics between CI and healthy subjects. The results showed that keeping the head down time per day (r =− 0.286) and using the computer time per day (r =− 0.230) were negatively correlated with the RCSA in the deep muscles at the back of the neck. See Table 4 and Fig. 6.

Discussion

Neck muscles are a vital component of the external stabilizing system of the cervical spine. They enable real-time adjustments to achieve dynamic balance, thereby maintaining normal physiological movement and stability [14, 15]. Among them, the superficial muscles primarily provide the power for cervical spine movement, while the deep muscles play a more significant role in maintaining cervical spine stability [16]. With the increasing use of electronic devices, prolonged forward head posture has become common among middle-aged and young adults in daily life and work [17, 18]. This posture shifts the center of gravity of the head to the anterior portion of the vertebrae, as the cervical spine remains in a hyperflexed position for extended periods [19]. Consequently, the posterior neck muscles and ligaments are passively stretched, while the anterior muscles and ligaments are in a state of passive contraction. Over time, these factors disrupt the balance of the overall neck muscle system, leading to changes in cervical curvature and stability [18, 20]. The posterior neck muscles may experience more severe fatigue-related injuries as it works to counteract cervical flexion [21]. The movements of the neck rely on the coordinated control of both deep and superficial muscles. Poor posture tends to activate more superficial muscles, leading to disuse and atrophy of deep muscles [16]. The results of this study indicate that the RCSA in the deep muscles at the back of the neck of CI patients is significantly smaller than that of healthy individuals, while the FSF is notably higher. Further analysis revealed

Table 2 Univariate analysis of lifestyle habit between CI and healthy subjects

Lifestyle Habit		CI Subjects ($n = 98$)	Healthy Subjects ($n = 88$)	*P* Value
Working time per day (hours)				.026
	< 6	3 (3)	4 (5)	
	6-	27 (28)	39 (44)	
	8-	43 (44)	28 (32)	
	≥ 10	25 (25)	17 (19)	
Keeping head down time per day (hours)				.100
	< 2	5 (5)	6 (7)	
	2-	18 (18)	24 (27)	
	4-	36 (37)	31 (35)	
	≥ 6	39 (40)	27 (31)	
Keeping head down time once (hours)				.752
	< 0.5	19 (19)	15 (17)	
	0.5-	47 (48)	47 (53)	
	1-	17 (17)	18 (21)	
	≥ 1.5	15 (15)	8 (9)	
Exercising frequency per week				.096
	No exercise	20 (20)	17 (19)	
	1-	55 (56)	37 (42)	
	3-	20 (20)	29 (33)	
	≥ 5	3 (3)	5 (6)	
Exercising time once (hours)				.200
	No exercise	14 (14)	10 (11)	
	< 1	65 (66)	54 (62)	
	1-	18 (18)	22 (25)	
	≥ 1.5	1 (1)	2 (2)	
Sleeping time per day (hours)				.751
	< 6	11 (11)	8 (9)	
	6-	78 (80)	72 (82)	
	8-	9 (9)	8 (9)	
	≥ 10	0 (0)	0 (0)	
Using the computer time per day (hours)				.023
	< 2	9 (9)	17 (19)	
	2-	30 (31)	26 (30)	
	4-	22 (22)	26 (30)	
	≥ 6	37 (38)	19 (21)	
Using the smartphone time per day (hours)				.147
	< 3	13 (13)	15 (17)	
	3-	35 (36)	36 (41)	
	5-	22 (22)	20 (23)	
	≥ 7	28 (29)	17 (19)	

Data are numbers of subjects, with percentages in parentheses

Qualitative data were described using frequency counts, and the chi-square test was employed for comparisons between groups. *CI* cervical instability

that the FSF in the deep muscles at the back of the neck is one of the risk factors associated CI. Similar findings have been reported in other studies as well. Peter et al. [22] found that there was close relationship between fatty infiltration of cervical spine extensor musculature and cervical sagittal balance. Tamai et al. [5] and Yoon et al. [23]. reported that cervical muscular functions were worse in patients with cervical sagittal imbalance.

There are numerous risk factors for CI and cervical spondylosis, with poor living and working habits being among the primary contributors. Lv et al. [24] found that work intensity and maintaining the same posture for 1 to

Table 3 Univariate analysis of imaging data between CI and healthy subjects

Imaging Data	CI Subjects ($n = 98$)	Healthy Subjects ($n = 88$)	*P* Value
Cervical curvature (mm)	2.15 (− 14.01–19.76) [− 2.46–5.93]	3.94 (− 5.07–15.22) [1.82–6.69]	.004
RCSA in the prevertebral muscles	0.77 (0.35–1.26) [0.64–0.92]	0.71 (0.36–1.19) [0.58–0.87]	.125
FSF in the prevertebral muscles (%)	22.30 (7.32–55.26) [17.09–29.49]	20.88 (10.99–43.48) [16.57–26.13]	.180
RCSA in the deep muscles at the back of the neck	1.71 (1.23–2.62) [1.46–1.98]	1.91 (1.25–2.73) [1.68–2.13]	.003
FSF in the deep muscles at the back of the neck (%)	19.89 (10.35–33.93) [15.58–24.47]	16.78 (7.63–32.54) [14.61–21.64]	.011
RCSA in the superficial muscles at the back of the neck	6.71 (4.69–11.36) [5.61–7.83]	6.66 (4.60–11.01) [5.95–7.32]	.952
FSF in the superficial muscles at the back of the neck (%)	12.57 (6.31–33.17) [10.86–15.33]	12.30 (6.50–29.19) [10.51–15.86]	.991
Cervical disc signal strength	0.10 (0.05–0.14) [0.08–0.11]	0.09 (0.06–0.16) [0.08–0.11]	.959

Data are medians, with ranges in parentheses and interquartile ranges in brackets

The measurement data did not follow a normal distribution was expressed as the median (interquartile range) [M (P25-P75)], and non-parametric tests were used for comparisons between groups. *CI* cervical instability, *FSF* fat signal fraction, *RCSA* relative cross-sectional area

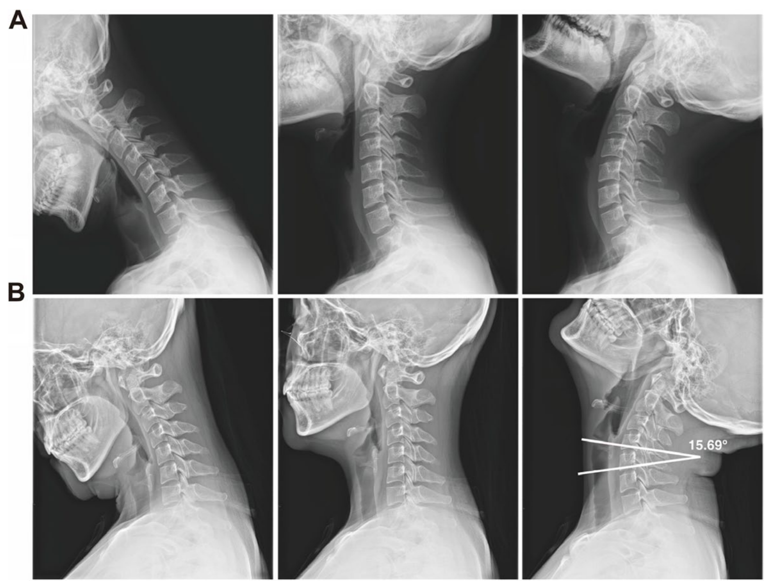

Fig. 3 Comparison of CI and healthy subject X-ray images. **A** A healthy subject, male, 29 years old, with normal cervical curvature. **B** A CI subject, male, 29 years old, showing a 15.69°rotational difference between the vertebrae of C4 and C5, accompanied by significant cervical curvature hyperextension

3 h per day were associated with cervical spondylosis in individuals under 30 years of age. Repetitive and precision tasks, sedentary work positions, and prolonged cervical spine flexion further increased the risk of neck pain [25]. Kazeminasab et al. also reached similar conclusions [26]. Long-term neck flexion significantly increases the effective weight of the head on the cervical spine, resulting in a greater biomechanical burden on kinematics, gravitational moments, and neck muscle loading. This elevated strain may raise the risk of musculoskeletal discomfort and injuries in the neck [19]. In our study, participants with CI spent significantly more time working and using computers daily compared to healthy subjects, consistent with the findings of previous studies. Obesity is a risk factor for intervertebral disc degeneration and spinal disorders, as it increases skeletal load and accelerates the

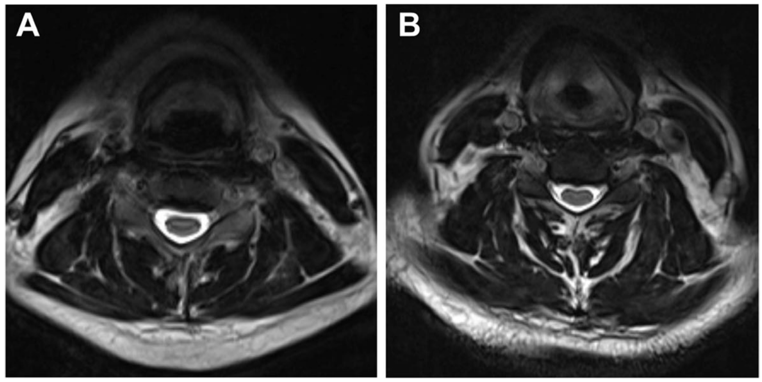

Fig. 4 Comparison of CI and healthy subject MRI images. **A** A healthy subject, male, 29 years old, with a RCSA and FSF of the deep muscles at the back of the neck of 1.85 and 15.48%, respectively. **B** A CI subject, male, 29 years old, with a RCSA and FSF of the deep muscles at the back of the neck of 1.52 and 21.63%, respectively

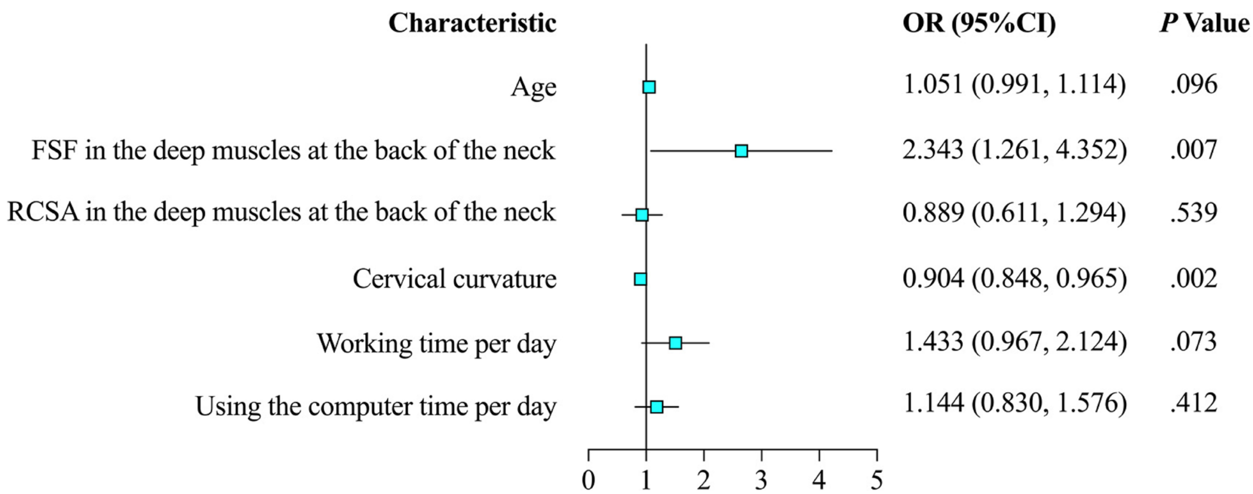

Fig. 5 Multifactorial logistic regression analysis of CI. FSF = fat signal fraction, RCSA = relative cross-sectional area

Table 4 Spearman correlation analysis between the lifestyle habits of CI subjects and their RCSA in the deep muscles at the back of the neck, FSF in the deep muscles at the back of the neck, and cervical curvature

Lifestyle habit	RCSA in the deep muscles at the back of the neck		FSF in the deep muscles at the back of the neck		Cervical curvature	
	r	*P* Value	r	*P* Value	r	*P* Value
Working time per day	− 0.010	0.919	− 0.118	0.249	− 0.072	0.484
Keeping head down time per day	− 0.286	0.004	0.005	0.961	− 0.068	0.507
Keeping head down time once	0.145	0.155	− 0.002	0.985	0.033	0.749
Exercising frequency per week	0.019	0.853	0.086	0.399	0.170	0.094
Exercising time once	0.067	0.510	0.031	0.761	0.047	0.643
Sleeping time per day	0.043	0.673	− 0.091	0.374	− 0.024	0.815
Using the computer time per day	− 0.230	0.023	0.002	0.984	− 0.033	0.747
Using the smartphone time per day	− 0.044	0.664	− 0.140	0.168	− 0.022	0.830

FSF fat signal fraction, *RCSA* relative cross-sectional area

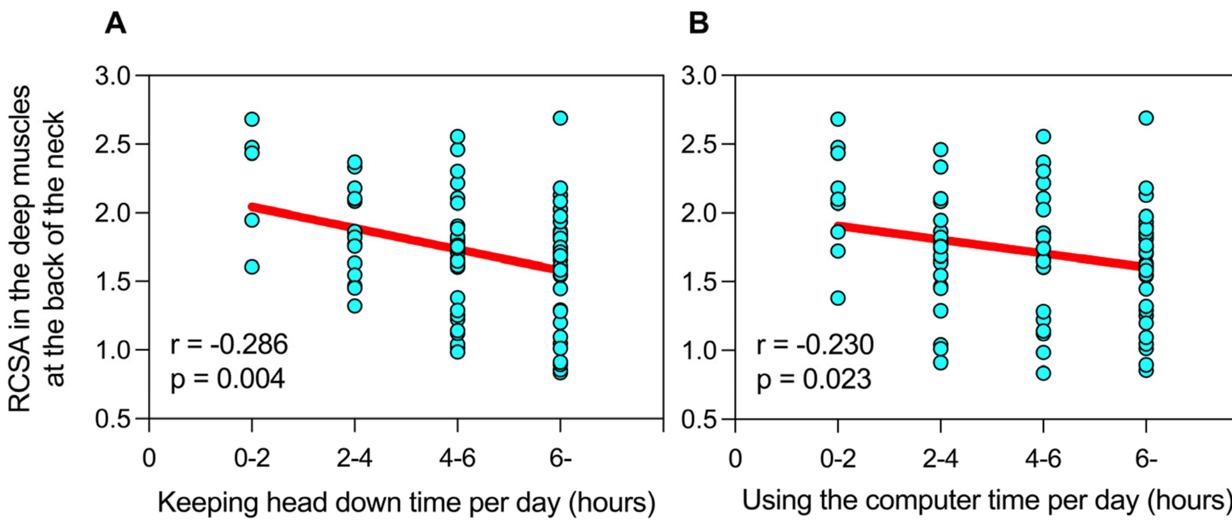

Fig. 6 Scatter plot of spearman correlation analysis between the RCSA in the deep muscle group in the back of the neck with (**A**) keeping head down time per day; (**B**) using the computer time per day. RCSA = relative cross-sectional area

degenerative process of the discs [27, 28]. However, in our study, no significant difference in BMI was observed between the two groups of participants. This may be attributed to the relatively high anatomical position of the cervical spine, making it less affected by body weight. Some studies have also found that sleep duration can influence the occurrence of cervical spondylosis. Shorter sleep periods increase the load-bearing time of spine, thereby accelerating its degeneration [24]. Our study did not find any difference in the length of sleep between the two groups. Correlation analysis revealed that keeping the head down time per day and using the computer time per day were negatively correlated with the RCSA in the deep muscles at the back of the neck. This supports our hypothesis that improving lifestyle habits, particularly by reducing the time spent in a forward head posture each day, can aid in the recovery of deep neck muscles injuries, which is crucial for enhancing cervical spine stability.

Once the human body reaches maturity, spinal degeneration naturally occurs and progressively worsens, leading to a gradual decline in the cervical spine's ability to maintain stability. With increasing age or prolonged exposure to abnormal stress, intervertebral discs begin to degenerate, primarily characterized by a decrease in water content in the annulus fibrosus and nucleus pulposus, resulting in reduced elasticity and height. These changes lower the pressure at the center of the endplate while increasing the surrounding pressure, disrupting normal biomechanical balance and affecting intervertebral stability [29]. In this study, no significant difference in intervertebral disc signal intensity was observed between the two groups of participants. This finding suggests that CI in middle-aged and young adults may result from early mechanical imbalances caused by neck muscle strain, without significant intervertebral disc degeneration. With appropriate intervention, stability remodeling may still be possible. Based on the data from this study and previous research, the prevention and treatment of CI should focus on the deep muscles at the back of the neck. Muscle strain can be alleviated and restored through targeted functional exercises and therapeutic interventions [30–32]. Ergonomic adjustments, postural training, and therapeutic exercises, for example, can help alleviate cervical muscle fatigue and reduce the risk of musculoskeletal disorders [33]. Therefore, CI in middle-aged and young adults can be improved or even reversed to some extent.

This study has several limitations. Firstly, due to limitations in the resolution of the original MRI images, accurately segmenting certain muscle boundaries, such as the complexus and splenius capitis muscles, was difficult during ROI segmentation. To maintain consistency in ROI segmentation and align with the study's objectives, we decided, after discussion within the expert group, to segment the entire superficial muscle group region at the back of the neck. This decision was made despite the possibility that the overly large, segmented region could dilute the intergroup differences in that area and potentially affect the results. Additionally, since MRI cannot determine the absolute concentration of fat, a method analyzing differences in signal intensity was chosen as an indicator of fat content in muscle. While this method has proven reliable, it has not been validated through muscle biopsy [34]. Other factors, such as blood flow, may also affect signal intensity differences. To ensure the accuracy of this technique, further investigation into the mechanisms underlying MRI signal intensity changes is recommended, along with validation through muscle biopsy. In order to minimize the interference of confounding factors, this study exclusively focused on C4/5 segment instability when selecting patients with cervical instability. The C4/5 segment was chosen because it represents the convex point of the cervical curve. According to biomechanical principles, the stability at the intersection of two opposing curvatures is inherently weaker, making the C4/5 segment the most susceptible to cervical instability. While this approach allowed for a focused and in-depth analysis, it may have limited our ability to fully capture the influence of adjacent segments and reduced the generalizability of our findings. To address this limitation, we are planning a follow-up study that will include a broader analysis of multiple cervical levels, with particular attention to compensatory mechanisms at adjacent levels and their impact on overall cervical stability. Finally, the limited sample size may have affected the reliability of the results. The conclusions of this study require further validation through large-scale, multicenter studies.

Conclusion

In summary, we conducted a study on the neck muscles of young and middle-aged patients with CI based on cervical MRI images and analyzed their correlation with lifestyle habits. Changes in the deep muscles at the back of the neck are key factors in the development of CI. Prolonged maintenance of a single downward head posture is closely related to changes in the deep muscles at the back of the neck. We hope this can provide valuable insights for the early prevention and treatment of CI in young and middle-aged individuals.

Abbreviations

BMI	Body mass index
CI	Cervical instability
CSA	Cross-sectional area
FSF	Fat signal fraction
RCSA	Relative cross-sectional area
ROI	Region of interest

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12891-025-08594-z.

Supplementary Material 1.

Acknowledgements

Funding sources were not involved in the study design, data collection, analysis and interpretation, writing of the report, or decision to submit the article for publication.

Authors' contributions

Guarantors of integrity of entire study, J.Y., L.L.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; agrees to ensure any questions related to the work are appropriately resolved, all authors; literature research, G.L., J.L., H.M., M.Z., T.L., X.S., M.M., Y.L., L.Z.; clinical studies, G.L., J.L., X.S., M.M., Y.L.; experimental studies, G.L., J.L., Y.C.; statistical analysis, G.L., Y.C.; and manuscript editing, G.L., J.L., M.Z., T.L., X.S., M.M., Y.L., L.Z., J.Y., L.L.

Funding

Supported by National Natural Science Foundation of China (No.82274560); High-level Traditional Chinese Medicine Hospital Construction Project (WJYY-XZKT- 2023–01); Scientific and Technological Innovation Project of China Academy of Chinese Medical Sciences (CI2021B010).

Data availability

Data generated or analyzed during the study are available from the corresponding author by request.

Declarations

Ethics approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This study was reviewed and approved by the institutional review board of Wangjing Hospital, China Academy of Chinese Medical Sciences (identifier: WJEC-KT- 2021–044-P002). Written informed consent was obtained from each participant before the data was collected.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Spine, Wangjing Hospital, China Academy of Chinese Medical Sciences, No.6 Wangjing Zhonghuan South Road, Chaoyang District, Beijing 100102, China. [2]Department of Research Management, Wangjing Hospital, China Academy of Chinese Medical Sciences, No.6 Wangjing Zhonghuan South Road, Chaoyang District, Beijing 100102, China. [3]Department of Radiology, Wangjing Hospital, China Academy of Chinese Medical Sciences, No.6 Wangjing Zhonghuan South Road, Chaoyang District, Beijing 100102, China.

Received: 6 February 2025 Accepted: 28 March 2025
Published online: 15 May 2025

References

1. Dai L. Disc degeneration and cervical instability. Correlation of magnetic resonance imaging with radiography. Spine (Phila Pa 1976). 1998;23(16):1734–8.
2. Alizada M, Li RR, Hayatullah G. Cervical instability in cervical spondylosis patients: Significance of the radiographic index method for evaluation. Orthopade. 2018;47(12):977–85.
3. Passias PG, Segreto FA, Horn SR, et al. Fatty infiltration of the cervical extensor musculature, cervical sagittal balance, and clinical outcomes: An analysis of operative adult cervical deformity patients. J Clin Neurosci. 2020;72:134–41.
4. Kim CY, Lee SM, Lim SA, et al. Impact of Fat Infiltration in Cervical Extensor Muscles on Cervical Lordosis and Neck Pain: A Cross-Sectional Study. Clin Orthop Surg. 2018;10(2):197–203.
5. Tamai K, Grisdela P Jr, Romanu J, et al. The Impact of Cervical Spinal Muscle Degeneration on Cervical Sagittal Balance and Spinal Degenerative Disorders. Clin Spine Surg. 2019;32(4):E206–13.

6. Jun D, Zoe M, Johnston V, et al. Physical risk factors for developing non-specific neck pain in office workers: a systematic review and meta-analysis. Int Arch Occup Environ Health. 2017;90(5):373–410.
7. Sarraf F, Varmazyar S. Comparing the effect of the posture of using smartphones on head and neck angles among college students. Ergonomics. 2022;65(12):1631–8.
8. White AA 3rd, Johnson RM, Panjabi MM, et al. Biomechanical analysis of clinical stability in the cervical spine. Clin Orthop Relat Res. 1975;109:85–96.
9. Borden AG, Rechtman AM, Gershon-cohen J. The normal cervical lordosis. Radiology. 1960;74:806–9.
10. U.S. Food and Drug Administration; Picture Archiving and Communications System. AccuContour K191928 Approval Letter. 2020. Available online: https://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpmn/pmn.cfm?ID=K191928 (accessed on 1 October 2021).
11. Otsu N. A Threshold Selection Method from Gray-Level Histograms. IEEE Trans Syst, Man, Cybernet: Syst. 1979;9:62–6.
12. Hyun SJ, Bae CW, Lee SH, et al. Fatty Degeneration of the Paraspinal Muscle in Patients with Degenerative Lumbar Kyphosis: A New Evaluation Method of Quantitative Digital Analysis Using MRI and CT scan. Clin Spine Surg. 2016;29(10):441–7.
13. Urbanschitz L, Bensler S, Merat S, et al. How Should We Grade Cervical Disk Degeneration? A Comparison of Two Popular Classification Systems. Spine Surg Relat Res. 2021;5(6):347–51.
14. Anderson JS, Hsu AW, Vasavada AN. Morphology, architecture, and biomechanics of human cervical multifidus. Spine (Phila Pa 1976). 2005;30(4):E86-91.
15. Wharton SB, Chan KK, Pickard JD, et al. Paravertebral muscles in disease of the cervical spine. J Neurol Neurosurg Psychiatry. 1996;61(5):461–5.
16. Blouin JS, Siegmund GP, Carpenter MG, et al. Neural control of superficial and deep neck muscles in humans. J Neurophysiol. 2007;98(2):920–8.
17. Zhuang L, Wang L, Xu D, et al. Association between excessive smartphone use and cervical disc degeneration in young patients suffering from chronic neck pain. J Orthop Sci. 2021;26(1):110–5.
18. Gheysvandi E, Dianat I, Heidarimoghadam R, et al. Neck and shoulder pain among elementary school students: prevalence and its risk factors. BMC Public Health. 2019;19(1):1299.
19. Tapanya W, Puntumetakul R, Swangnetr Neubert M, et al. Influence of neck flexion angle on gravitational moment and neck muscle activity when using a smartphone while standing. Ergonomics. 2021;64(7):900–11.
20. Goel A, Dandpat S, Shah A, et al. Muscle Weakness-Related Spinal Instability Is the Cause of Cervical Spinal Degeneration and Spinal Stabilization Is the Treatment: An Experience with 215 Cases Surgically Treated over 7 Years. World Neurosurg. 2020;140:614–21.
21. Cheng CH, Chien A, Hsu WL, et al. Investigation of the Differential Contributions of Superficial and Deep Muscles on Cervical Spinal Loads with Changing Head Postures. PLoS ONE. 2016;11(3): e0150608.
22. Passias PG, Segreto FA, Bortz CA, et al. Fatty Infiltration of Cervical Spine Extensor Musculature: Is there a Relationship with Cervical Sagittal Balance? Clin Spine Surg. 2018;31(10):428–34.
23. Yoon SY, Moon HI, Lee SC, et al. Association between cervical lordotic curvature and cervical muscle cross-sectional area in patients with loss of cervical lordosis. Clin Anat. 2018;31(5):710–5.
24. Lv Y, Tian W, Chen D, et al. The prevalence and associated factors of symptomatic cervical Spondylosis in Chinese adults: a community-based cross-sectional study. BMC Musculoskelet Disord. 2018;19(1):325.
25. Haldeman S, Carroll L, Cassidy JD. Findings from the bone and joint decade 2000 to 2010 task force on neck pain and its associated disorders. J Occup Environ Med. 2010;52(4):424–7.
26. Kazeminasab S, Nejadghaderi SA, Amiri P, et al. Neck pain: global epidemiology, trends and risk factors. BMC Musculoskelet Disord. 2022;23(1):26.
27. Teraguchi M, Yoshimura N, Hashizume H, et al. Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: the Wakayama Spine Study. Osteoarthritis Cartilage. 2014;22(1):104–10.
28. Fanuele JC, Abdu WA, Hanscom B, et al. Association between obesity and functional status in patients with spine disease. Spine (Phila Pa 1976). 2002;27(3):306–12.
29. Miyazaki M, Hong SW, Yoon SH, et al. Kinematic analysis of the relationship between the grade of disc degeneration and motion unit of the cervical spine. Spine (Phila Pa 1976). 2008;33(2):187–93.
30. Dirito AM, Abichandani D, Jadhakhan F, et al. The effects of exercise on neuromuscular function in people with chronic neck pain: A systematic review and meta-analysis. PLoS ONE. 2024;19(12): e0315817.
31. Liu Z, Hu H, Wen X, et al. Baduanjin improves neck pain and functional movement in middle-aged and elderly people: A systematic review and meta-analysis of randomized controlled trials. Front Med (Lausanne). 2023;9: 920102.
32. Nazwar TA, Bal'afif F, Wardhana DW, et al. Impact of physical exercise (strength and stretching) on repairing craniovertebral and reducing neck pain: A systematic review and meta-analysis. J Craniovertebr Junction Spine. 2024;15(3):266–79.
33. Kuligowski T, Skrzek A, Cieślik B. Manual Therapy in Cervical and Lumbar Radiculopathy: A Systematic Review of the Literature. Int J Environ Res Public Health. 2021;18(11):6176.
34. Cagnie B, Barbe T, Vandemaele P, et al. MRI analysis of muscle/fat index of the superficial and deep neck muscles in an asymptomatic cohort. Eur Spine J. 2009;18(5):704–9.

Publisher's Note