The Influence of Cervical Spine Angulation on Symptoms Associated With Wearing a Rigid Neck Collar

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Abstract

Introduction: Rigid cervical spine collars can be used to maintain the position of the cervical spine following injury or surgery. However, they have been associated with difficulty swallowing, pressure sores and pain, particularly in older patients. We aimed to investigate the relationship between cervical spine angulation, a rigid neck collar and neck pain in healthy young and older adults.

Methods: Twenty healthy young adults aged 25 ± 3 years and 17 healthy older adults aged 80 ± 8 years were tested. Magnetic resonance imaging scans of their cervical spines were taken before and after the rigid neck collar was worn for 1 hour. Measurement of vertebral angulation involved digitization of the scans and joint angle calculations using image processing software. Pain was quantified before and after the collar was worn, using a visual analogue scale.

Results: Pain scores increased in the young group after the collar was worn (p = 0.001). The older group showed no difference in pain score after the collar was worn. Statistical tests showed no significant correlations between the change in cervical angles and the change in pain scores after the collar was worn.

Discussion: The aging process may contribute to the changing distribution of subcutaneous tissue and increase risk of symptoms associated with wearing a collar. Oesophageal compression is not a result of collar use.

Conclusion: There is no correlation between cervical spine vertebrae angulation and symptoms associated with wearing a neck collar. Generally, older individuals have greater cervical lordosis angles, and more straight and lordotic neck shapes. Older individuals may be more prone to skin-interface pressures from the neck collar than younger individuals.

Keywords
c-spine, rigid collar, vertebral angulation, visual analogue scale, cervical lordosis

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application of a collar may lead to spinal cord damage. There are documented cases of worsened neurological injury due to the application of rigid orthoses causing hyperextension and fracture displacement, particularly in older patients with underlying degenerative spinal disease.

The angulation of the c-spine is a key feature in patients with neck pain complaints. Vertebral angulation of the c-spine is the measurement of orientation and wedging of C1 to C7 vertebral bodies along the sagittal plane of the head and trunk. The lordotic curve is the crescent shape formed by vertebrae found in the c-spine (Figure 1). The degree of lordotic curve in the c-spine is measured by the orientation of the foramen magnum and the wedging of the vertebral bodies and intervertebral discs. A study showed that 95% of men and 70% of women aged 60-65 years had at least 1 degenerative change to their c-spine and cervical lordosis increased with age in both gender groups. Patients who lack the lordotic curve in the c-spine and are treated with a rigid cervical orthosis have been shown to present with neck pain and stiffness in retrospective studies. However, prior studies that have measured vertebral angulation of the c-spine with a rigid cervical orthosis were performed on injured patients and did not quantify the degree of neck pain in individuals. In this case, the use of a psychometric measuring tool such as a visual analogue scale (VAS) would be beneficial. What is more, data collected from injured patients brings distinction between pain from the injury and pain from the collar alone. The application of a neck collar alone can lead to increased temperature, humidity and cytokine concentration at skin-orthosis interface, which makes the skin increasingly susceptible to pressure ulcers.

In addition to this, collars can prolong the duration of various stages of swallowing and may cause difficulties in swallowing that can contribute to problems with aspiration and further discomfort or pain. Cervical orthoses have also been found to exert pressure on the jugular venous system raising intracranial pressure. The purpose of this study was to evaluate the effect of a rigid cervical orthosis on neck pain, vertebral angulation, neck soft tissue and surrounding structures involved in swallowing.

Methods

All participants provided written informed consent to take part in the study, which was approved by the local Research Ethics Committee. Exclusion criteria included those with current neck pain, known previous c-spine injury or any known medical condition affecting the spine. A post-hoc power analysis revealed that on the basis of the between-groups comparison effect size and within-groups comparison effect size, the statistical power for the young and elderly population groups were 0.8 and 0.8 respectively. Therefore, a total n of 20 in the young group and 20 in the older group would be needed to obtain statistical power at the recommended 80% level. However, due to the lack of participation, we were only able to obtain data from 17 participants in the older group.

Twenty healthy young adults (10 males and 10 females, 25 ± 3 years) and 17 healthy older individuals (10 males and 7 females, 80 ± 8 years) volunteered to participate. All participants completed a baseline VAS questionnaire to quantify their neck pain and underwent a c-spine MRI scan (Maximize 1.5 T, MAGNETOM Area, Siemens). The images obtained were T2 sagittal CISS 3-D images with a slice thickness of 0.8 mm and each MRI examination was reviewed and reported by an experienced radiologist. Following this, participants were fitted with a rigid cervical orthosis (Miami J Collar, Össur, Reykjavik, Iceland); they were correctly sized and fitted by 2 trained and experienced clinicians. After 1 hour of wearing the collar, the participants completed a second VAS to quantify neck pain and a second MRI of the c-spine was performed while the participants were still wearing the collar. To complete the VAS participants were asked to mark their level of neck pain on a line between 2 endpoints 10 cm apart. The distance between 0 cm and the mark placed by the participant was rounded to the nearest whole number and was defined as the participant’s pain score.

The MRI scans were digitized (Mimics v. 17.0, Materialise, Leuven, Belgium); all measurements were performed on the midsagittal plane, unless stated otherwise. Total lordosis (TL), upper cervical lordosis (UCL), lower cervical lordosis (LCL), T1 slope (T1 S), neck tilt (NT) and thoracic inlet angle (TIA) were measured on each scan (Figure 2) and the individual vertebral angles were calculated for all vertebrae from C1 to T2. An example of the individual vertebral angle, C6 is illustrated in Figure 3b. Each of the participants were classified into a specific neck subtype group (Figure 4) to approximate a general sagittal alignment of the c-spine. The 5 neck subtypes were selected according to the modified Takeshima-Herbst subtype guidelines. The thickness of the subcutaneous tissue layer surrounding the c-spine in the mid-sagittal plane was measured for each of the scans (Figure 3c). The 2D area of the oesophagus was segmented and measured in the axial plane, from the level of C1 to the upper region of the sternum (Figure 3a).

Statistical analysis: All statistical analyses were performed on SPSS (IBM SPSS Statistics v. 24, IBM, Armonk, USA). A Shapiro-Wilk test was performed to confirm a normal distribution of data.
distribution of the data. Descriptive statistics (mean ± standard deviation) were used for analysis of the vertebral angles, pain scores, oesophagus area and subcutaneous tissue measurements. The relationships between the measures were analyzed using factorial mixed ANOVA, paired samples t-test, Pearson’s correlation and independent t-test. For all outcomes, the statistical significance level was set to p < 0.05.

Results

The Shapiro-Wilk test confirmed that the data was normally distributed. The paired samples t-test showed a significant increase in pain scores in the young group after the collar was worn (t = -3.541, df = 19, p = 0.001). The older group showed no significant difference between pre-and post-collar pain scores (t = -0.972, df = 16, p = 0.345).
The mean TL, UCL, LCL, NT and TIA angles were greater in the older group than in the young group, apart from T1 S, which was lower in the older group (Figure 5). Additionally, TL and LCL were the only angles that showed significantly greater values in the older group than the young group (p < 0.003). The remaining angles showed no differences when comparing the young and older groups and before and after the collar was worn. Pears on's correlation test showed that the change in NT angle and TIA had a negative and non-significant correlation to the change in pain scores from before collar to after collar (r = -0.132, df = 35, p = 0.218), (r = -0.009, df = 35, p = 0.478), respectively. The remaining angles all showed positive non-significant correlations to the change in pain scores.

The baseline individual angles of the older group were greater than that of the young group (Table 1). The independent t-test showed a significant difference between young and older groups in the individual vertebral angles, C3 and C5 to T2 (p < 0.001). The remaining angles showed no significant differences between age groups and between before and after the collar was worn.

Forty percent of individuals in the young group were classified as the straight spine subtype, 20% were global kyphotic subtype, 20% were reverse sigmoidal subtype, 15% were sigmoidal subtype and 5% were lordotic subtype. Thirty-five percent of individuals in the older group were classified as the straight subtype, 20% were lordotic subtype, 15% were reverse sigmoidal subtype, 10% were global kyphotic subtype and 5% were sigmoidal subtype.
The subcutaneous tissue thickness was compressed more in the older participants (1.0 ± 2.7 mm) than in the young participants (0.1 ± 1.6 mm) at all observed vertebral levels (C1 to T2) while the collar was worn. In the young participant group, a decrease in subcutaneous tissue thickness was found posteriorly at the levels of C2 (p = 0.008) and C3 (p = 0.018) after the collar was worn. In the older participant group, a significant decrease in subcutaneous tissue thickness was found posteriorly at C1 (p = 0.049), C2 (p = 0.011), T2 (p = 0.032) and anteriorly at C6 (p = 0.023) after the collar was worn. The total pre-collar subcutaneous tissue thickness was greater at all vertebral levels in the older participants than the young. An independent t-test showed no significant difference between the measurements of oesophagus areas in the 2 participant groups. Additionally, the oesophagus areas before and after the collar was worn showed no significant difference in either the young or older groups.

**Table 1.** Mean (± 1 Standard Deviation) of the Baseline Individual Vertebral Angles in the Young and Older Groups.

|                       | Young group (°) | Older group (°) | Independent t-test p-value |
|-----------------------|-----------------|-----------------|----------------------------|
| C1                    | 0.5 ± 11.3      | 0.2 ± 6.2       | >0.050                     |
| C2                    | 1.5 ± 7.0       | -1.0 ± 4.6      | >0.050                     |
| C3                    | -1.3 ± 6.1      | -0.6 ± 3.5      | 0.030*                     |
| C4                    | -2.4 ± 7.1      | -1.4 ± 3.8      | 0.928                      |
| C5                    | -2.2 ± 8.8      | -1.3 ± 4.0      | <0.001*                    |
| C6                    | -0.9 ± 9.7      | -4.5 ± 2.9      | <0.001*                    |
| C7                    | -1.3 ± 10.9     | -5.0 ± 6.2      | <0.001*                    |
| T1                    | -0.3 ± 9.5      | -5.6 ± 6.5      | <0.001*                    |
| T2                    | -0.9 ± 11.1     | -3.8 ± 7.0      | <0.001*                    |

The interpretation of these results is subject to certain limitations. For instance, the time that the participants were wearing the collar. One hour is not clinically representative, as those who are injured would typically wear the collar consistently for a period of up to 8 weeks. However, to the authors knowledge
this is one of few studies that investigate both pain and vertebral angulation with a rigid collar in healthy individuals. Future work should consider a longer time period for participants to wear the collar. It should be noted that there may be differences between different rigid collar models \(^{26-28}\) and as only 1 rigid collar model was investigated in this study, the results should be interpreted with caution. Though prior research has utilized static MRI measurements to assess dynamic function, the use of a dynamic modality such as dynamic MRI or videofluoroscopy may be more useful to observe the changes in vertebral angulation and the structures involved in the stages of swallowing. The use of the VAS as the only measurement for pain intensity is considered a limitation in this study, as though it is commonly used in clinical applications and has been validated in literature, \(^ {17,29-32}\) its outputs may be influenced by factors unrelated to the desired target and thus are not universally accepted. This study was also limited by the small sample size of the older group. As previously stated, a sample size of 20 in the older group was required to obtain statistical power of 80%. However, due to low participation, only 17 participants were recruited in the older group.

**Conclusion**

This study explored the relationships between neck pain, a rigid collar and vertebral joint angles in young and older adults. The results show that the rigid collar has no effect on the joint angles in the c-spine and there is no correlation between cervical lordosis angles and pain score. However, through the analysis of subcutaneous tissue thickness, a greater understanding has been gained of the particular areas in the neck that may be more prone to skin reactions due to a rigid collar. This brings opportunities for future work toward improved collar design to counter the reduced soft tissue observed in the older neck and hence aim to reduce risk of pressure sores arising secondary to rigid collar immobilization.

The study shows there is no effect on oesophageal constriction in both young and older adults from rigid collar use. Moreover, as oesophageal compression is not a result of collar use and that the pain experienced is not due to the collar, this suggests that there are other causes for dysphagia during rigid cervical orthosis use. Future studies should target the effect of the collar on structures involved in swallowing and should include the use of dynamic MRI.

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**References**

1. Bowker P, ed. Biomechanical Basis of Orthotic Management. Butterworth-Heinemann; 1993.
2. Benger J, Blackham J. Why do we put cervical collars on conscious trauma patients? Scand J Trauma Resusc Emerg Med. 2009;17:44-44. doi:10.1186/1757-7241-17-44
3. Hauswald M, Ong G, Tandberg D, Omar Z. Out-of-hospital spinal immobilization: its effect on neurologic injury. Acad Emerg Med. 1998;5(3):214-219. doi:10.1111/j.1553-2712.1998.tb02615.x
4. Kreinest M, Gliwitzky B, Schüler S, Grüntzer PA, Münzberg M. Development of a new Emergency Medicine Spinal Immobilization Protocol for trauma patients and a test of applicability by German emergency care providers. Scand J Trauma Resusc Emerg Med. 2016;24(1):71. doi:10.1186/s13049-016-0267-7
5. Liao S, Schneider NRE, Hüttlin P, et al. Motion and dural sac compression in the upper cervical spine during the application of a cervical collar in case of unstable cranio-cervical junction—a study in two new cadaveric trauma models. Maiman D, ed. PLoS One. 2018;13(4):e0195215. doi:10.1371/journal.pone.0195215
6. Liao S, Schneider NRE, Weißbacher F, et al. Spinal movement and dural sac compression during airway management in a cadaveric model with atlanto-occipital instability. Eur Spine J. 2018;27(6):1295-1302. doi:10.1007/s00586-017-5416-9
7. Papadopoulos MC, Chakraborty A, Waldron G, Bell BA. Lesson of the week: exacerbating cervical spine injury by applying a hard collar. BMJ. 1999;319(7203):171-172. doi:10.1136/bmj.319.7203.171
8. Peck GE, Shipway DJH, Tsang K, Fertleman M. Cervical spine immobilisation in the elderly: a literature review. Br J Neurosurg. 2018;32(3):286-290. doi:10.1007/s00580-018-1445-82
9. Vrtovec T, Pernuš F, Likar B. A review of methods for quantitative evaluation of spinal curvature. Eur Spine J. 2009;18(5):1-15. doi:10.1007/s00586-009-0913-0
10. Gore DR, Sepic SB, Gardner GM. Roentgenographic findings of the cervical spine in asymptomatic people. Spine (Phila Pa 1976). 1986;11(6):521-524. doi:10.1097/00007632-198607000-00003
11. Muzin S, Isaac Z, Walker J, Abd OE, Baima J. When should a cervical collar be used to treat neck pain? Curr Rev Musculoskelet Med. 2008;1(2):114-119. doi:10.1007/s12178-007-9017-9
12. McAviney J, Schulz D, Bock R, Harrison DE, Holland B. Determining the relationship between cervical lordosis and neck complaints. J Manipulative Physiol Ther. 2005;28(3):187-193. doi:10.1016/j.jmpt.2005.02.015
13. Worsley PR, Stanger ND, Horrell AK, Bader DL. Investigating the effects of cervical collar design and fit on the biomechanical and biomarker reaction at the skin. Med Devices (Auckl). 2018;11:87-94. doi:10.2147/MEDER.S149419
14. Mekata K, Takigawa T, Matsubayashi J, Toda K, Hasegawa Y, Ito Y. The effect of the cervical orthosis on swallowing physiology and cervical spine motion during swallowing. Dysphagia. 2016;31(1):74-83. doi:10.1007/s00455-015-9660-z

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15. Janusz P, Tryrakowski M, Yu H, Siemionow K. Reliability of cervical lordosis measurement techniques on long-cassette radiographs. Eur Spine J. 2016;25(11):3596-3601. doi:10.1007/s00586-015-4345-8

16. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). Arthritis Care Res (Hoboken). 2011;63(Suppl 11):S240-S252. doi:10.1002/acr.20543

17. MacDowall A, Skeppholm M, Robinson Y, Olerud C. Validation of the visual analog scale in the cervical spine. J Neurosurg Spine. 2018;28(3):227-235. doi:10.3171/2017.5.SPINE1732

18. Daffin L, Stuelcken M, L Sayers M. The efficacy of sagittal cervical spine subtyping: investigating radiological classification methods within 150 asymptomatic participants. J Craniovert Jun Spine. 2017;8(3):231. doi:10.4103/jcvjs.JCVJS_84_17

19. Shilton M, Branney J, de Vries BP, Breen AC. Does cervical lordosis change after spinal manipulation for non-specific neck pain? A prospective cohort study. Chiropr Man Therap. 2015;23(1):33. doi:10.1186/s12998-015-0078-3

20. Steilen D, Hauser R, Woldin B, Sawyer S. Chronic neck pain: making the connection between capsular ligament laxity and cervical instability. Open Orthop J. 2014;8:326-345. doi:10.2174/1874325001408010326

21. Aşkin A, Bayram KB, DemirDal US, et al. The evaluation of cervical spinal angle in patients with acute and chronic neck pain. Turk J Med Sci. 2017;47(3):806-811.

22. Gong H, Sun L, Yang R, et al. Changes of upright body posture in the sagittal plane of men and women occurring with aging—a cross sectional study. BMC Geriatr. 2019;19(1):71. doi:10.1186/s12877-019-1096-0

23. Joshi S, Balthillaya G, Neelapala YVR. Thoracic posture and mobility in mechanical neck pain population: a review of the literature. Asian Spine J. 2019;13(5):849-860. doi:10.31616/asj.2018.0302

24. Schwartz RS, Shuman WP, Bradbury VL, et al. Body fat distribution in healthy young and older men. J Gerontol. 1990;45(6):M181-M185. doi:10.1093/geronj/45.6.m181

25. Guide to Wearing Your Cervical Hard Collar. Hull University Teaching Hospitals NHS Trust. Published May 18, 2016. Accessed March 4, 2021. https://www.hey.nhs.uk/patient-leaflet/guide-wearing-cervical-hard-collar/

26. Karason S, Reynisson K, Sigvaldason K, Sigurdsson GH. Evaluation of clinical efficacy and safety of cervical trauma collars: differences in immobilization, effect on jugular venous pressure and patient comfort. Scand J Trauma Resusc Emerg Med. 2014;22(1):37. doi:10.1186/1757-7241-22-37

27. Evans NR, Hooper G, Edwards R, et al. A 3D motion analysis study comparing the effectiveness of cervical spine orthoses at restricting spinal motion through physiological ranges. Eur Spine J. 2013;22(1):10-15. doi:10.1007/s00586-012-2641-0

28. Gavin TM, Carandang G, Havey R, Flanagan P, Ghanayem A, Patwardhan AG. Biomechanical analysis of cervical orthoses in flexion and extension: a comparison of cervical collars and cervical thoracic orthoses. J Rehabil Res Dev. 2003;40(6):527-537. doi:10.1682/jrrd.2003.11.0527

29. Price DD, McGrath PA, Rafi A, Buckingham B. The validation of visual analogue scales as ratio scale measures for chronic and experimental pain. Pain. 1983;17(1):45-56. doi:10.1016/0304-3959(83)90126-4

30. Ferreira-Valente MA, Pais-Ribeiro JL, Jensen MP. Validity of four pain intensity rating scales. PAIN®. 2011;152(10):2399-2404. doi:10.1016/j.pain.2011.07.005

31. Thong ISK, Jensen MP, Miró J, Tan G. The validity of pain intensity measures: what do the NRS, VAS, VRS, and FPS-R measure? Scand J Pain. 2018;18(1):99-107. doi:10.1515/ sjpain-2018-0012

32. Gallagher EJ, Bijur PE, Latimer C, Silver W. Reliability and validity of a visual analog scale for acute abdominal pain in the ED. Am J Emerg Med. 2002;20(4):287-290. doi:10.1053/ajem.2002.33778