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**Original Article**

# Changes in Pressure Pain in the Upper Trapezius Muscle, Cervical Range of Motion, and the Cervical Flexion–relaxation Ratio after Overhead Work

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**Abstract: This study examined the changes in pressure pain in the upper trapezius muscle, cervical range of motion, and cervical flexion–relaxation ratio after overhead work. 14 workers were recruited. Pressure pain in the upper trapezius muscle, active cervical range of motion, and cervical flexion–relaxation ratio were measured in all subjects once before and once after overhead work. The pressure-pain threshold of the left upper trapezius muscle was 8.6 ± 2.5 lb before overhead work and 7.3 ± 2.4 lb after overhead work; that of the right upper trapezius muscle was 8.8 ± 2.9 and 7.3 ± 2.8 lb, respectively, revealing a significant decrease in pressure-pain threshold with overhead work. All cervical range of motion measures decreased significantly with overhead work. The cervical flexion–relaxation ratio on the left side was 1.3 ± 0.2 before overhead work and 1.1 ± 0.2 after overhead work; the respective values for the right side were 1.4 ± 0.5 and 1.2 ± 0.3 before and after overhead work, revealing a significant decrease with overhead work. We postulate that overhead work can reduce the pressure-pain threshold in the upper trapezius muscle and cause changes in the cervical range of motion and cervical flexion–relaxation ratio.**

**Key words:** Cervical FRR, CROM, Overhead work, Pressure pain, Shoulder pain

## Introduction

A common concern in the modern workplace is upper extremity disorders arising from overhead work[1)], which is associated with neck and shoulder disorders and pain[1–3)]. Long-term overhead working postures result in strain and fatigue in the shoulder muscles[4)] because arm elevation is associated with shoulder muscular fatigue[5)]. The relationship between upward rotation of the scapula and arm flexion is a kinesiological chain, so previous studies have examined the associated neck and shoulder muscle activity and pain in overhead work[3)].

Shoulder and neck pain are widespread problems[6–11)]. Although it is difficult to identify a clear reason for neck pain and impairment, it can contribute to poor patient prognosis. There are many methods for evaluating the cervical region, including evaluating posture, cervical range of motion (CROM), and neck muscle power. Pain questionnaires used to assess subjective neck pain include the Neck Disability Index (NDI)[12, 13)] and Neck Pain and Disability Scale (NPDS)[14)]. Pressure algometers are used widely in research and clinical medicine to measure the pressure-pain threshold (PPT) objectively[15–17)]. The

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PPT is defined as the minimum amount of pressure that causes pain[18]. Pressure algometers have also been used to assess the effect of remedies for myofascial pain and to study changes in the PPT of root pain, headache, reflex sympathetic dystrophy, and pregnant or post-pregnant woman[19–24]. The PPT is a reliable measure that can be measured for individual muscles[25].

Goniometer-based systems for evaluating the CROM can reliably measure uniplanar cervical spine movement[26]. The Spin T is a three-dimensional goniometer with demonstrated accuracy and reliability for measuring cervical spine mobility[27]. The active cervical range of motion, which has frequently been used to discriminate between individuals with pain and those who are asymptomatic, and assessments of ROM are reported to be two of the best estimators of cervical disability[28].

Cervical flexion–relaxation phenomenon is a quantitative neck-pain assessment tool. It has been suggested that silence, *i.e.*, the absence of cervical or thoracolumbar paraspinal muscle activity, differs between healthy individuals and those with neck pain[29, 30]. The cervical flexion–relaxation ratio (FRR) is significantly lower in patients with neck pain than in controls and may be a useful marker of altered neuromuscular control in patients with neck pain[31]. Murphy *et al.* suggested that the cervical FRR be measured as a functional assessment of patients with neck pain as a means to evaluate neck disease and the effects of treatment by quantifying the damage and disability[31]. By dividing the neck movement in the sagittal plane into three specific phases, (1) flexion, (2) relaxation, and (3) re-extension, the cervical flexion–relaxation ratio can be calculated by dividing the maximum muscle activation during the re-extension phase by the activation during the relaxation phase[31].

Few studies have objectively quantified the changes in neck and shoulder pain during overhead work. Therefore, this study examined the changes in pressure pain in the upper trapezius muscle, CROM, and the cervical FRR after 10 min of overhead work.

## Methods

*Subjects*

Fourteen young workers (eight males, six females), aged 21–32 yr, with a mean height of 168.7 ± 6.9 cm and weight of 61.5 ± 9.7 kg, participated in this study (Table 1). All of the subjects were healthy and had been free of any neck and back pain for a minimum of 1 yr before the study; they had no upper limb or cervical spine pathologies and no rheumatological or neurological conditions. All subjects were right-hand dominant. None complained of subjective discomfort or pain. The subjects were not accustomed to overhead work. This study was approved by the Inje University Faculty of Health Sciences Human Ethics Committee. The subjects provided informed consent before participating.

**Table1. Subjects demographic information**

| Variable | Description |
|---|---|
| Gender | 8 males, 6 females |
| Age | 26.3 (± 3.2) yr |
| Height | 168.7 (± 6.9) cm |
| Mass | 61.5 (± 9.7) kg |

*Instrumentation*

Baseline® Dolorimeter

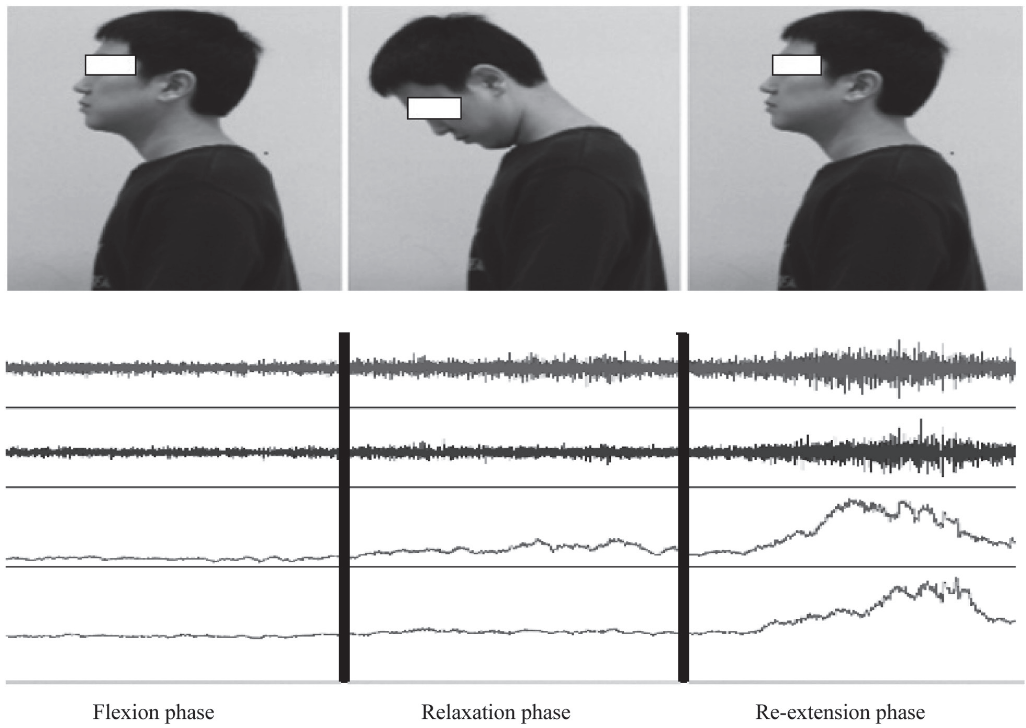
A dolorimeter (Fabrication Enterprises, White Plains, NY, USA) pressure algometer was used to measure pressure pain. The dolorimeter consists of a metal probe that can measure pressures up to 20 lb in 0.25-lb increments. A 1-$cm^2$ rubber plate delivers pressure from the probe to the body, and the pressure is read from a needle gauge.

Cervical range of motion instrument

Each participant was assessed using a cervical range of motion instrument (Performance Attainment Associates, St. Paul, MN, USA) that attaches to the subject's head and contains two gravity goniometers and one compass goniometer. The sagittal- and frontal-plane gravity goniometers measure flexion–extension and lateral flexion, respectively, and the compass goniometer measures rotation. The CROM was measured before and after overhead work. Each participant was seated in a standard folding chair and fitted with the CROM device. Before the measurements, the participants were asked to self-correct their posture by demonstrating the most erect posture they could achieve. Then, the subjects were asked to place the CROM device on the head like a pair of glasses, and measurements of cervical flexion, cervical extension, right and left lateral flexion, and right and left rotation were recorded in randomized order.

EMG

After abrading the skin carefully and cleaning it with an isopropyl alcohol swab, pairs of Ag/AgCl electrodes (3 M red Dot) were applied to the right and left cervical extensor muscles, aligned parallel to the direction of the muscle




1st row : raw EMG signal of left cervical ES, 2nd row : raw EMG signal of right cervical ES.

3rd row: rms EMG signal of left cervical ES, 4th row: EMG signal of right cervical ES.

**Fig. 1. Three phases of movement were measured: flexion, relaxation, and re-extension.**

fibers, with a center-to-center distance of 2 cm. The electrode pairs were placed over the muscle belly at the $C_4$ level approximately 2 cm from the spinous process[31]. The subjects were required to sit erect in a straight-backed chair with lumbar and mid-thoracic support, but with no support for the upper thoracic and cervical regions. The electromyography (EMG) signals were pre-amplified by a preamplifier placed close to the electrodes, and the signals were sent to the data-acquisition unit of an MP150 system (BIOPAC Systems, Santa Barbara, CA, USA), which amplified and sampled the EMG inputs at 1,000 Hz. The EMG signals were band-stop filtered at 60 Hz, and the root mean square (rms) values were calculated. The EMG data were analyzed using a program created with AcqKnowledge (ver. 3.9.1) and are expressed as the mean percentage reference voluntary contraction (RVC).

*Procedures*

The pressure-pain threshold of the upper trapezius muscle, active CROM, and cervical FRR were measured in all subjects once before and once after overhead work. Before making the measurement with the pressure algometer, we instructed subjects to say 'ah!' when they started to feel pain. Then, we applied pressure with the dolorimeter at a right angle to the body to measure the PPT in the upper trapezius muscle. This is the portion of the upper trapezius, which is a common site of pain in overhead workers.

We made the measurement over the belly of the muscle between the midline and acromion moving from right to left. The subject was in a natural sitting posture during the procedure, and we marked the measurement sites with a pen. This is for testing reliability. To avoid bias, the subject was not told the measured values during the procedure. The CROM was measured in a natural sitting posture before and after overhead work. The subjects were asked to lower their heads slowly with the goal of approximating the chin to the upper chest (manubrium) and then to maintain this position until asked to return to the neutral position. During the measurement, the trunk was fixed in an initial posture ensured by the therapist, and each subject was asked to move the head until muscle tightness or pain occurred. Three phases of movement were measured: flexion, relaxation, and re-extension. The duration of each movement phase was 5 s (Fig. 1). The EMG signal was collected for 3 s, excluding the first and last seconds. An audio signal was used to indicate each movement phase.

**Table 2. The mean values of the pressure pain of upper trapezius muscles**

| Pressure pain | mean ± SD (Lb) | | t-value | *p* |
|---|---|---|---|---|
| | before overhead work | after overhead work | | |
| Left upper trapezius | 8.6 ± 2.5 | 7.3 ± 2.4 | 4.99 | 0.000 |
| Right upper trapezius | 8.8 ± 2.9 | 7.3 ± 2.8 | 4.96 | 0.000 |

**Table 3. The mean values of the cervical range of motion**

| Cervical range of motion | mean ± SD (°) | | t-value | *p* |
|---|---|---|---|---|
| | before overhead work | after overhead work | | |
| Flexion | 58.7 ± 7.5 | 51.9 ± 10.9 | 3.51 | 0.004 |
| Extension | 76.1 ± 15.4 | 71.3 ± 16.1 | 3.88 | 0.002 |
| Right lateral flexion | 42.6 ± 8.3 | 37.7 ± 7.3 | 5.84 | 0.000 |
| Left lateral flexion | 46.3 ± 8.9 | 41.9 ± 7.3 | 3.72 | 0.003 |
| Right rotation | 67.1 ± 7.5 | 59.9 ± 8.2 | 3.92 | 0.002 |
| Left rotation | 65.3 ± 11.5 | 59.4 ± 11.2 | 3.79 | 0.002 |

**Table 4. The mean values of the cervical flexion-relaxation ratio**

| Cervical FRR (%RVC) | mean ± SD (%) | | t-value | *p* |
|---|---|---|---|---|
| | before overhead work | after overhead work | | |
| Left Cervical FRR | 1.3 ± 0.2 | 1.1 ± 0.2 | 3.42 | 0.005 |
| Right Cervical FRR | 1.4 ± 0.5 | 1.2 ± 0.3 | 2.22 | 0.045 |

Sufficient practice was allowed before data collection to familiarize each subject with the movement phases and speeds. One trial was performed at each testing session. The cervical flexion–relaxation ratio was calculated by dividing the maximal muscle activation during the 3-s re-extension phase by the average activation during the 3-s relaxation phase. All subjects performed overhead work for 10 min using the same workstation, and we required that their arms be overhead for the entire 10 min. The overhead work was performed at a height of 25 cm above the head of each subject. The overhead work was a bolt and nut assembly work. They required to keep their arms up overhead the entire 10 min. During data collection, the participants were barefoot, with their feet positioned 20 cm apart.

*Data analysis*

The SPSS statistical package (ver. 18.0, SPSS, Chicago, IL, USA) was used to analyze the differences in the PPT of the upper trapezius muscle, active CROM, and cervical FRR between before and after overhead work using the paired *t*-test; significance was defined as $p<0.05$.

## Result

The PPT of the left and right trapezius muscles decreased significantly with overhead work ($p<0.05$) (Table 2). The CROM for all measures decreased significantly with overhead work ($p<0.05$) (Table 3). The cervical FRR on the left and right sides decreased significantly with overhead work ($p<0.05$) (Table 4).

## Discussion

This study examined changes in pressure pain in the upper trapezius muscle, CROM, and the cervical FRR with overhead work. The PPT of the left upper trapezius muscle was 8.6 ± 2.5 lb before overhead work and 7.3 ± 2.4 lb after overhead work; that of the right upper trapezius muscle was 8.8 ± 2.9 and 7.3 ± 2.8 lb, respectively, revealing a significant decrease in PPT with overhead work. Horikawa reported that the hardness of the upper trapezius was increased during 15 min of computer work from 91.4 ± 10.1 kPa/cm before the work, to 102.1 ± 13.5 (kPa/cm) after the work. When increased muscle hardness is sustained, it can cause muscle stiffness, dullness, and occasionally muscle pain[32]. Industrial workers with risk factors for neck and shoulder pain have a low PPT[33]. The pain and fatigue are caused by reduced metabolism such as a reduction in sodium–potassium pump activity and adenosine diphosphate (ADP) levels in muscle tissue[34]. This shows that, short-term overhead work, subjects increase pressure pain in the upper trapezius muscle. Perhaps workers elevate their arms increasing upper trapezius muscle activity. We found that a short period of overhead work (10 min) was sufficient to lower the pain threshold.

We found that all CROM measures decreased significantly with overhead work ($p$<0.05). Yoo and An reported that the active CROM decreased after video display terminal work[35]. Shortening of scalenus muscles can cause limited range of motion in neck extension and shortening of levator scapular muscle can cause limited range of motion of neck flexion[35]. Ariens *et al*. reported that neck pain was correlated with the CROM[36]. We found that the CROM decreased rapidly with even a short period of overhead work. Perhaps overhead work increase tension and tightness around neck and shoulders muscles. The CROM is a useful measure of the severity of neck symptoms[37]. It can be measured clinically and reliably with a cervical goniometer[38]. The CROM is considered the most sensitive measure of the risk of neck pain.

The cervical FRR on the left side was 1.3 ± 0.2 before and 1.1 ± 0.2 after overhead work; the respective values for the right side were 1.4 ± 0.5 and 1.2 ± 0.3, revealing a significant decrease with overhead work. According to Murphy *et al*., the cervical FRR distinguishes patients with and without pain. The mean value of the right-side FRR of patients with neck pain was 2.20, and that for the left side was 1.65. Four weeks later, the FRR was reduced to 1.85 and 1.61 for the right and left sides, respectively. The cervical FRR had relatively lower values in the symptomatic population than in the controls[31]. The cervical FRR, which is expressed as a numerical value, is a sensitive marker for measuring neuromuscular changes associated with even mild discomfort. Lee *et al*. suggested that there is correlation between the CROM and cervical FRR. They also reported that there was significant reduction in the CROM and cervical FRR as the weight of a bag was increased. The CROM and cervical FRR identified individuals with muscle dysfunction[39]. With overhead work, workers elevate their arms, increasing cervical tension and muscle fatigue and placing abnormal load on muscles and ligaments. Ultimately, the reduction in the range of motion and neuro-myological changes in the neck reduce the cervical FRR. We showed that overhead work was a high risk work leading to the musculoskeletal disorder. Therefore, rest period must be in addition to regularly scheduled during overhead work. Also, overhead workers must be provided the modified job conditions or ergonomic devices.

One limitation of this study was the small number of subjects. Additionally, we were unable to assess a pain, discomfort rating and muscle fatigue other than pressure pain. Moreover, the subjects were not used to overhead work, and the cervical FRR values in the subjects were lower than those typically found in asymptomatic people. Further study must include subjects who are used to overhead work, and a pain, discomfort rating and muscle fatigue other than pressure pain must also be studied.

This study is important because it measured the change in neck pain caused by overhead work and expressed this quantitatively in terms of the CROM and cervical FRR. We suggest that the pressure-pain threshold, CROM, and cervical FRR be used to evaluate the potential risk for neck discomfort.

## Conclusion

We postulate that 10 min of overhead work can lead to pressure pain in the upper trapezius muscle and changes in the active cervical range of motion and cervical flexion–relaxation ratio. These changes could be used to evaluate the potential risk for neck discomfort in overhead workers.

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## References

1) Bernard B (1997) Musculoskeletal disorders and workplace factors. DHHS(NIOSH) Publication 97–141, US Department of Health and Human Services, NIOSH, Cincinnati.
2) Punnett L, Fine LJ, Keyserling WM, Herrin GD, Chaffin DB (2000) Shoulder disorders and postural stress in automobile assembly work. Scand J Work Environ Health **26**, 283–91.
3) Grieve JR, Dickerson CR (2008) Overhead work: Identification of evidence-based exposure guideline. Occup Ergon **8**, 53–66.
4) Herberts P, Kadefors R (1976) A study of painful shoulder in welders. Acta Orthop Scand **47**, 381–7.
5) Herberts P, Kadefors R, Broman H (1980) Arm positioning in manual tasks: an electromyographic study of localized

muscle fatigue. Ergonomics **23**, 655–65.
6) Holmström EB, Lindell J, Moritz U (1992) Low back and neck/shoulder pain in construction workers: occupational workload and psychosocial risk factors. Part 2: Relationship to neck and shoulder pain. Spine (Phila Pa 1976) **17**, 672–7.
7) Hunting KL, Welch LS, Cuccherini BA, Seiger LA (1994) Musculoskeletal symptoms among electricians. Am J Ind Med **25**, 149–63.
8) Olson P (1987) Musculoskeletal disorders of the neck-shoulder region related to working positions in the construction industry. Bygghalsan Bulletin 05–01. 1987English Abstract.
9) Welch LS, Hunting KL, Kellogg J (1995) Work-related musculoskeletal symptoms among sheet metal workers. Am J Ind Med **27**, 783–91.
10) Borghouts JA, Koes BW, Vondeling H, Bouter LM (1999) Cost-of-illness of neck pain in The Netherlands in 1996. Pain **80**, 629–36.
11) Côté P, Cassidy JD, Carroll LJ, Kristman V (2004) The annual incidence and course of neck pain in the general population: a population-based cohort study. Pain **112**, 267–73.
12) Vernon H, Mior S (1991) The neck disability index: a study of reliability and validity. J Manipulative Physiol Ther **14**, 409–15.
13) Hains F, Waalen J, Mior S (1998) Psychometric properties of the neck disability index. J Manipulative Physiol Ther **21**, 75–80.
14) Wheeler AH, Goolkasian P, Baird AC, Darden BV 2nd (1999) Development of the Neck Pain and Disability Scale. Item analysis, face, and criterion-related validity. Spine (Phila Pa 1976) **24**, 1290–4.
15) Itoh K, Okada K, Kawakita K (2004) A proposed experimental model of myofascial trigger points in human muscle after slow eccentric exercise. Acupunct Med **22**, 2–12, discussion 12–3.
16) Maquet D, Croisier JL, Demoulin C, Crielaard JM (2004) Pressure pain thresholds of tender point sites in patients with fibromyalgia and in healthy controls. Eur J Pain **8**, 111–7.
17) Rolke R, Magerl W, Campbell KA, Schalber C, Caspari S, Birklein F, Treede RD (2006) Quantitative sensory testing: a comprehensive protocol for clinical trials. Eur J Pain **10**, 77–88.
18) Ylinen J (2007) Pressure algometry. Aust J Physiother **53**, 207.
19) Bovim G (1992) Cervicogenic headache, migraine, and tension-type headache. Pressure-pain threshold measurements. Pain **51**, 169–73.
20) Bryan AS, Klenerman L, Bowsher D (1991) The diagnosis of reflex sympathetic dystrophy using an algometer. J Bone Joint Surg Br **73**, 644–6.
21) Granges G, Littlejohn G (1993) Pressure pain threshold in pain-free subjects, in patients with chronic regional pain syndromes, and in patients with fibromyalgia syndrome. Arthritis Rheum **36**, 642–6.
22) Incel NA, Erdem HR, Ozgocmen S, Catal SA, Yorgancioglu ZR (2002) Pain pressure threshold values in ankylosing spondylitis. Rheumatol Int **22**, 148–50.
23) Shapira SC, Magora F, Chrubasik S, Feigin E, Vatine JJ, Weinstein D (1995) Assessment of pain threshold and pain tolerance in women in labour and in the early post-partum period by pressure algometry. Eur J Anaesthesiol **12**, 495–9.
24) Smania N, Corato E, Fiaschi A, Pietropoli P, Aglioti SM, Tinazzi M (2003) Therapeutic effects of peripheral magnetic stimulation on myofascial pain syndrome. Clin Neurophysiol **114**, 350–8.
25) Fischer AA (1987) Pressure algometry over normal muscles: Standard values, validity, and reproducibility of pressure threshold. Pain **30**, 115–26.
26) Tousignant M, de Bellefeuille L, O'Donoughue S, Grahovac S (2000) Criterion validity of the cervical range of motion (CROM) goniometer for cervical flexion and extension. Spine (Phila Pa 1976) **25**, 324–30.
27) Haynes MJ, Edmondston S (2002) Accuracy and reliability of a new, protractor-based neck goniometer. J Manipulative Physiol Ther **25**, 579–86.
28) Johnston V, Jull G, Souvlis T, Jimmieson NL (2008) Neck Movement and Muscle Activity Characteristics in Female Office Workers with Neck Pain. Spine **33**, 555–63.
29) Pauly JE (1966) An electromyographic analysis of certain movements and exercises. I. Some deep muscles of the back. Anat Rec **155**, 223–34.
30) Meyer JJ, Berk RJ, Anderson AV (1993) Recruitment patterns in the cervical paraspinal muscles during cervical forward flexion: evidence of cervical flexion-relaxation. Electromyogr Clin Neurophysiol **33**, 217–23.
31) Murphy BA, Marshall PW, Taylor HH (2010) The Cervical Flexion-Relaxation Ratio: reproducibility and comparison between chronic neck pain patients and controls. Spine **35**, 2103–8.
32) Horikawa M (2001) Effect of visual display terminal height on the trapezius muscle hardness: quantitative evaluation by a newly developed muscle hardness meter. Appl Ergon **32**, 473–8.
33) Andersen JH, Kaergaard A, Frost P, Thomsen JF, Bonde JP, Fallentin N, Borg V, Mikkelsen S (2002) Physical, psychosocial, and individual risk factors for neck/shoulder pain with pressure tenderness in the muscles among workers performing monotonous, repetitive work. Spine (Phila Pa 1976) **27**, 660–7.
34) Clausen T (2003) The sodium pump keeps us going. Ann N Y Acad Sci **986**, 595–602.
35) Yoo WG, An DH (2009) The relationship between the active cervical range of motion and changes in head and neck posture after continuous VDT work. Ind Health **47**, 183–8.
36) Ariëns GA, Bongers PM, Douwes M, Miedema MC, Hoogendoorn WE, van der Wal G, Bouter LM, van Mechelen W (2001) Are neck flexion, neck rotation, and

sitting at work risk factors for neck pain? Results of a prospective cohort study. Occup Environ Med **58**, 200–7.
37) Gargan MF, Bannister GC (1990) Long-term prognosis of soft tissue injuries of the neck. J Bone Joint Surg Br **72**, 901–3.
38) Youdas JW, Carey JR, Garrett TR (1991) Reliability of measurements of cervical spine range of motion-comparison of three methods. Phys Ther **71**, 98–104, discussion 105–6.
39) Lee M, Yoo W, An D, Kim M, Oh J (2011) The effect of backpack loads on FRR(Flexion-relaxation Ratio) in the cervical spine. J Phys Ther Sci **23**, 599–601.