A comparative investigation of flexion relaxation phenomenon in healthy and chronic neck pain subjects

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Abstract

Purpose The cervical flexion relaxation phenomenon (FRP) is a neck extensor myoelectric “silence” that occurs during complete cervical and lumbar flexion. In contrast to low back pain, the changes that occur during FRP in chronic neck pain (CNP) patients are still not clear. The aim of this study was to assess the characteristics of this phenomenon in the cervical region in CNP patients and controls.

Methods Twenty-two women (23 ± 2.62 years) with chronic non-specific neck pain and 21 healthy women (23.4 ± 1.68 years) participated in this study. They accomplished a cervical flexion and extension from neutral position. Neck angle and surface electromyographic activity of cervical erector spinae (CES) and upper trapezius muscles were recorded. Appearance, onset and offset angle of the FRP were analysed and compared between the two groups.

Results There were significant differences in the appearance of FRP between the two groups ($P \leq 0.001$). The FRP in the CES muscles was observed in 85.7 % of healthy subjects and in 36.3 % of CNP patients, and no FRP was observed in the upper trapezius. Results of this study show that the onset and offset of FRP parameters were significantly different between the two groups ($P \leq 0.001$).

Conclusions The results of the present study indicate that FRP in CNP patients was seen less than the healthy subjects, and moreover the FRP period was reduced in CNP patients. Our results also suggest that the changes in FRP of

CNP patients may be due to the increased CES activity in these patients.

Keywords Flexion relaxation phenomenon · Surface electromyography · Chronic neck pain · Cervical erector spinae

Background

Neck pain is a common musculoskeletal problem, chiefly among women [1, 2]. In the general population up to 30–50 % of adults will experience neck pain in any given year [3]. Weak neck muscles of women could be a cause of the higher prevalence of neck pain in this group of people [2]. Although history and diagnostic examination can suggest a potential cause, in most cases the pathologic basis for neck pain is unclear and therefore it is labelled as non-specific [4]. Neck pain patients demonstrated an altered pattern of muscle activation, such as deep cervical extensor and flexor muscles [5]. Surface electromyography (SEMG) provides a non-invasive and a objective tool to investigate the muscle activity in addition to the kinesiological analysis of movement disorders [6, 7]. Previous studies have shown that the electrical activity in the lumbar erector spinae muscles is reduced after a certain amount of trunk flexion, which is known as flexion relaxation phenomenon (FRP) [8]. The FRP was first defined by Floyd and Silver [9] and refers to a reduced or sudden onset of myoelectric silence in erector spinae muscles during full trunk flexion. Three mechanisms have been proposed for this phenomenon: (a) transfer of the moment force of weight to passive structures of the spine [7, 9, 10], (b) transfer of the extension moment force from the superficial muscles to deeper muscles [11, 12] and finally,

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(c) reflexive mechanisms involving tension mechanoreceptors which are in ligaments and other viscoelastic structures which may trigger the FRP [13], although the last suggested mechanism is questionable for it could only explain the FRP [14].

In many low back pain (LBP) studies there is strong evidence that those subjects with LBP exhibit an altered recruitment pattern of trunk muscles when compared with healthy subjects [15–18]. Some studies reported absence or delay of FRP during complete trunk flexion, which could be used to differentiate subjects with LBP from healthy or asymptomatic subjects [7, 15, 17–19]. In contrast to LBP, there is still a lack of evidence about the changes that occur during FRP in chronic neck pain (CNP) patients. One pilot study reported the existence of the FRP in a single healthy subject, while in a CNP patient the FRP was blurred [6]. A recent study measured flexion relaxation ratio (FRR) in both CNP patients and controls, and the authors also suggested that FRR is a useful, reliable marker to show altered neuromuscular function [20]. Also, another new study suggested that FRR could be used to calculate the potential risk of neck discomfort in computer workers. In addition they concluded that dysfunction of cervical erector spinae (CES) muscles could occur in this group of people prior to occurrence of pain [21]. To our knowledge there is no study describing the changes in FRP parameters in the non-specific CNP patients. The objectives of this study were to: (a) characterise the appearance of the cervical FRP, (b) define the onset and the offset angles of the FRP, and (c) estimate the FRR value in two groups of non-specific CNP patients and controls.

Method

Participants

A convenient sample of 21 healthy women and 22 women with CNP was recruited. Healthy subjects were matched with patients (in weight, height, body mass index and age) and excluded if they had experienced neck pain 1 year prior to the study. Patients were examined by a physiotherapist with 6-year clinical experience and diagnosed with non-specific CNP. They were included if their pain persisted for more than 3 months with no significant pathology (e.g. any evidence of fracture, mechanical instability, radiculopathy or myelopathy) and excluded if their pain was greater than 30 mm based on the visual analog scale (VAS) during the assessment session. Moreover, the exclusion criteria for both the groups included spinal or shoulder trauma, surgery or any systemic disease and participated in strengthening exercise programmes for

Table 1 Subjects' anthropometric and clinical characteristics ($n = 43$)

	Healthy ($n = 21$) (mean $\pm$ SD)	CNP ($n = 22$) (mean $\pm$ SD)	<i>P</i> value
Age (years)	23.48 $\pm$ 1.8	23.45 $\pm$ 2.6	0.97
Weight (kg)	56.24 $\pm$ 6.2	55.36 $\pm$ 4.3	0.59
Height (cm)	162.86 $\pm$ 1	162.41 $\pm$ 2.4	0.73
BMI (kg/m ²)	21.2 $\pm$ 2.2	21 $\pm$ 1.7	0.75
Cervical range of motion (deg)	51.17 $\pm$ 5	50.6 $\pm$ 3.7	0.66
Pain; VAS (mm)	–	20.9 $\pm$ 7.5	–
Duration of pain (years)	–	2.09 $\pm$ 0.6	–

The results of independent sample *t* test showed no significant differences among the two groups

BMI body mass index, *VAS* visual analog scale

the neck muscles [22]. Anthropometric and clinical characteristics of the subjects are listed in Table 1.

All the participants were given a clear explanation of tests approved by Tehran University of Medical Sciences Research Ethics Committee and signed the informed consent before taking part in this research. Anthropometric characteristics of all subjects are presented in Table 1.

Experimental protocol

All participants were tested in a 60-min experimental session in a laboratory. They were seated on an adjustable stool with hips and knees at 90°, feet positioned, shoulder-width apart, with their arms relaxed by their side and viewing a point at eye level during the test. The thorax was tightly fixed by a strap at the level of spine of scapula (Fig. 1).

From this position they were asked to maintain the starting position for 4 s (phase 1), complete cervical flexion for 4 s (phase 2), sustain cervical full flexion for 4 s (phase 3) and cervical extension with return to the starting position for 4 s (phase 4) [22]. Each subject performed three trials of this protocol. Throughout the test to prevent the effect of speed on FRP, the pace was controlled by a digital metronome [10, 23]. Before the test, all subjects were instructed to perform full correct cervical flexion, without protrusion of the head at the preset pace. The SEMG activity of CES and upper trapezius (UTr) muscles was recorded simultaneously with electrogoniometer during all phases of movement. For the purpose of SEMG data normalisation, the subjects performed maximum voluntary isometric contractions (MVICs) of CES and UTr muscles after the trials and electromyographic activities were recorded. The MVIC for CES muscles were obtained in sitting position, and for this reason a cuff was wrapped

Fig. 1 Placement of an electrogoniometer sensor in order to determine the angle among head and trunk

around the head which was connected to a stable attachment at the same height and subjects maximally pulled back on the wire [24]. In order to obtain MVIC for UTr in seated position, the subjects were asked to perform an isometric shoulder shrug [22]. For obtaining MVIC the subjects performed three repetitions for 5 s, and 2 min interval was considered between contractions to prevent muscle fatigue. In order to investigate the intra-session reliability of study variables, the result of three tests was recorded.

Instrumentation

During each trial, myoelectrical activity of CES and UTr muscles was recorded with a SEMG device (Biometrics Ltd, UK). Bipolar disposal surface Ag–AgCl electrodes were applied bilaterally, 2 cm lateral to C4 spinous process for recording myoelectrical activity of CES muscles [25, 26] and also were placed lateral to the half-way point of an imaginary line formed by the posterior aspect of the acromion and the spinous process of C7 for the UTr [22]. The electrodes were positioned in the direction of the muscle fibres. Skin impedance was reduced by shaving, abrasion and washing the skin with cotton soaked in alcohol before application of the SEMG electrodes. Inter-electrode distance was 20 mm and electrode leads were taped to the skin. A ground electrode was placed on the right wrist. A sampling rate of 1,000 Hz, band pass filtered between 10 and 500 Hz (amplified with common mode rejection ratio >110 dB, overall gain 1,000, noise <1 μ V RMS) were used.

The angle between the head and trunk was recorded simultaneously with an electrogoniometer sensor with a sampling rate of 50 Hz (Biometrics Ltd) and introduced as a cervical range of motion (ROM). Placement of electrogoniometer sensor is depicted in Fig. 1.

Data analysis

The EMG data were filtered and RMS values (window length of 250 ms and window slide of 50 %) were obtained to determine the onset and offset of FRP using a digital software (Matlab, version 6.1).

Threshold was determined to be 10 % of maximum activity in the concentric phase (phase 4) of movement [27]. During flexion movement, the FRP onset was determined whenever the activity level was less than the threshold, and also during extension movement the activity level greater than this threshold was determined as FRP offset and the mean of three trials was used for each variable. The angle at which the EMG onset and offset occurred was determined by a synchronised electrogoniometer. Maximal cervical flexion ROM was obtained for each subject from neutral head position to maximum cervical flexion without protrusion and was used for normalisation of the onset and offset angles.

The FRR was calculated by dividing the peak of EMG activity during the extension phase by the peak of EMG activity during the relaxation phase. The intensity of electromyographic activity of each phase was obtained by normalising its RMS values with MVIC values.

Another criterion named relaxation time ratio (RTR) was also calculated among the two groups. It refers to the percent of the full flexion phase in which the CES muscles were in EMG silence. Furthermore to evaluate CES muscle activity, maximum EMG activity of CES muscles was calculated during four phases and normalised to MIVC of the CES. These ratios investigate differences in muscle activation in each phase between two groups. The data were coded before analysing and therefore analysing process was blinded.

Statistical analysis

A Kolmogorov–Smirnov (K–S) test was performed to determine the normal distribution of each variable. The intraclass correlation coefficients ($ICC_{(3,1)}$) and standard error of measurement (SEM) were calculated to determine reliability and response stability of each measure, respectively. Independent sample *t* test was used to test if there was any difference between two groups for age, height, weight and BMI.

A Chi-square test was used to identify differences between groups in the appearance of FRP. An independent sample *t* test was performed to identify the difference of onset and offset angle, ROM and normalised SEMG activity between two groups. Confidence level was set at $\alpha < 0.05$ for statistical significance.

All statistical analyses were performed using SPSS statistical software version 17.0 (SPSS, Chicago, IL, USA).

Table 2 Intra-session reliability of the studied parameters

	ICC _(3,1)	SEM
Cervical range of motion (deg)	0.98	1.31
FRP onset (%)	0.96	3.5
FRP offset (%)	0.95	1.14

ICC_(3,1) interclass correlation coefficient model (3, 1), SEM standard error of the measurement

Fig. 2 Onset and offset angels of the FRP in healthy and CNP patients. Independent sample *t* test indicated significant differences among two groups ($P < 0.05$)

Results

The K–S test was not significant in any variables. There was no significant difference in variables, such as weight, height, age and BMI between two groups (Table 1). The average ICC and SEM are depicted in Table 2.

There was a significant difference in the appearance of FRP between the two groups ($P \leq 0.001$). The FRP of the CES muscles was observed in 85.7 % (18 from 21) of healthy subjects and in 36.3 % (9 from 22) of CNP patients but no FRP was observed in the UTr muscles of any groups.

Results of this study indicated that FRP onset and offset angles were significantly different among the two groups ($P \leq 0.05$) (Fig. 2). The mean FRR for the CNP group was 2.22 ± 0.7 and for the control group was 4.88 ± 1.4 ($P < 0.001$). There was a significant difference in RTR between the two groups ($P < 0.001$), and this ratio was 100 % in healthy subjects and 46 % in CNP patients.

Although cervical flexion ROM was reduced in CNP patients, there was no significant differences between the two groups ($P = 0.287$). Intensity of surface electromyographic activity of CES muscles in background activity, activity during flexion movement and activity during maintaining full flexion in CNP patients were significantly higher than in the control group ($P < 0.05$) (Fig. 3).

Fig. 3 Normalised SENG activity of CES muscles in different phases of movement. *Phase 1* Maintain the starting position. *Phase 2* Complete cervical flexion. *Phase 3* Sustain cervical full flexion. *Phase 4* Extension with return to the starting position

Discussion

Appearance of FRP

Since repetitive and prolonged neck flexion is considered as a predisposing factor of neck pain [28], behaviour of cervical muscles during flexion is critical, and on the other hand FRP can be an objective way of measuring the neuromuscular alterations [20]. The difference in the occurrence of the cervical FRP between the healthy subjects and CNP patients was the main result of this study. Furthermore, this study indicated high reliability in the measurement of parameters, such as FRP onset and offset, and ROM of flexion movement.

In the current study, FRP was observed in most of the healthy subjects and was similar to the findings of Pialasse et al. [29] that observed this phenomenon in 95 % of healthy subjects. However, in some studies the FRP appearance in the cervical spine was reported in all of the healthy subjects [6, 30]. Burnett et al. [22] reported that between 0 and 65 % of healthy subjects displayed the FRP, depending upon which method was used.

The current study showed that FRP was seen only in 36.3 % of CNP patients, which confirmed the result of Airaksinen et al. [6], which stated that the patients with neck pain have difficulties in relaxing their neck muscles. Movements in the spine are supported by a complex neuromuscular system involving active (muscle), passive (vertebrae, intervertebral discs, ligaments, tendons and fascia) and neural components [31]. During full flexion, this supporting role transfers from the superficial extensor musculature to other stabilisation systems [7, 9–12]. The relationship between pain and altered muscle activation

patterns is also complex, and researchers use experimental pain models to explain how pain can change the motor control and load transfer between tissues [7, 32]. Altered motor control strategies may be seen as compensatory mechanisms, such as reorganisation of activity among agonist, synergists and antagonist muscles to allow the movement in painful and painless conditions. Nevertheless, this alteration in motor control strategy can provide the basis for chronicity and perpetuation of symptoms [33]. Additionally, neuromuscular changes that are seen in patients with CNP may be associated with inhibition in the activity of deep neck muscles and excitation of superficial muscles [5, 33, 34].

Although this study did not measure deep cervical muscle myoelectric activity, reduced activity of deep neck muscles and the inadequacy of these elements to create the extensor torque required to counteract with gravity during flexion may cause disturbances in the load transfer from surface neck muscles and loss of relaxation of these surface muscles.

Some similar lumbar spine studies introduced the FRP as a tool to distinguish LBP patients from healthy subjects [7, 16–18, 20]. Pialasse et al. [29] indicated that the cervical FRP can be used to differentiate between the healthy and CNP subjects and mentioned that the lack of FRP in the healthy subjects may be related to sub-clinical conditions affecting the cervical spine. However, the results of this study suggest that further surveys are required to clarify the clinical applications of cervical FRP.

In our study, similar to previous researches, FRP was not obtained in the UTr muscles for any of the participants [22, 29].

FRP onset and offset angles

From the results of SEMG and electrogoniometer data it can be suggested that FRP in CES muscles of CNP patients was started later and ended sooner, which indicated that this phenomenon was shorter in this group and additionally in all patients who showed the FRP, it was ended in full flexion phase. Pialasse et al. [29] assessed the onset and offset angle of FRP in CES muscles of 19 healthy subjects and reported that this phenomenon appeared between 72.6 and 76.3 % of maximal cervical flexion and disappeared during the return to neutral position between 91.9 and 93.1 % of maximal cervical flexion, which was in agreement with our findings in the present study. To our knowledge, there is no study on characteristics of FRP onset and offset in CNP patients so far, although some studies which have been conducted on people with chronic LBP indicated that the behaviour of erector spinae muscles in LBP patients was different with healthy subjects [16–18].

A pain adaptation model may explain reorganisation of neck muscle activation patterns in the patients with CNP as

a useful adaptation to prevent further pain and injury [35]. Indahl et al. [36] reported that some complex regulatory mechanisms of reflexes exist for control of movement of lumbar region, and also suggested that loss of the lumbar FRP in LBP patient may be due to the imbalance between the neural outputs from the damaged structure to the muscles. This imbalance in the reflex arc can lead to additional muscle activity to protect spinal structures. So possibly the neuromuscular system in cases of muscle damage and pain in the spine may behave in two ways, by eliminating or shortening the FRP.

Normalised SEMG activity

In the current study, normalised SEMG activity of CES in some phases of movement in CNP patients was higher than that in the control group. This increased the activity of CES muscles in static starting position in CNP patients may be necessary to protect the cervical spine in this group. Some studies analysed the SEMG activity levels of back erector spinae muscles during flexion and extension movements, and concluded that the activity of these muscles in the LBP patients during lumbar flexion movement [18] and lumbar full flexion [37] seems to be higher than that in healthy subjects. Changes in FRP could be due to modified neurological reflexes that enhance the CES muscle activity in full flexion phase to protect the spine from further injury [20]. Another study has been shown on the changing pattern in the activity of neck muscles during upper repetitive limb movements in CNP patients, and these results indicate that patients with CNP demonstrate greater SEMG amplitude of the superficial cervical muscle activity compared to the healthy control group. Greater activation of these muscles may represent an altered pattern of motor control to compensate for reduced activity of deep muscles [38].

FRR

There are some studies in the cervical literature that calculated and reported the FRR [20, 21, 29, 39]. A recent study examined the effects of various backpack loads on the cervical FRR and concluded that with a heavier backpack, FRR decreases significantly in the healthy subject, and so described that continuous use of heavy backpacks may provide potential for neck pain [40]. Murphy et al. [20] compared this ratio between 14 healthy and neck pain patients and surveyed the reproducibility of FRR 4 weeks apart in two groups. Their results showed that FRR in neck pain patients was lower than control group and highly reliable. Another study by Murphy et al. [39] investigated the effect of a 4-week period of chiropractic care on improvement of FRR and showed minimal improvement in this ratio. According to the present study, FRR in CNP was

significantly lower than in control, healthy subjects, which was consistent with the results of Murphy et al. [20]. Substantially, a decrease in FRR in CNP patients may be the result of increased muscle activity during the full flexion phase or the decreased activity of these muscles during the extension phase. According to the results of this study, the myoelectrical activity of CES during the full flexion phase was significantly higher than in healthy subjects, and therefore in the CNP patients, increased activity of CES muscles in full flexion leads to the decrease in the FRR. In this study, FRR in the control group was less than that reported by Watson et al. [41] in the lumbar region (FRR = 12–15), and this could be due to the smaller cross-sectional area of cervical muscles compared with large lumbar muscles [20].

RTR

The RTR was calculated and introduced for the first time in this study. This ratio refers to the percentage of full flexion phase at which the CES muscles were electromyographically silenced. The results of this study showed that RTR was reduced in CNP patients, which may be due to prolonged CES muscle activity during flexion movement or early recruitment of these muscles during extension movement. A decrease in RTR may indicate insufficiency in other spinal stabilisation systems to maintain the stability of the spine.

Few studies have investigated FRP in CNP patients, and there is a need for more studies in this area. To date, cervical FRP parameters in CNP patients have not been defined, and this study has provided useful data in CES muscle behaviour in this group. Further studies are required to understand the effect of rehabilitation and treatment on cervical FRP in CNP patients.

Conclusion

The results of this study demonstrated that, similar to the lumbar region, FRP may be altered in CNP patients. However, the use of cervical FRP as a tool to distinguish between healthy and CNP patients is still not clear. Additionally, the results of this study showed that CNP patients have altered muscle activation in dynamic tasks.

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Conflict of interest The authors declare no conflict of interest.

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