

Original Article

Effects of cognitive loading on lumbar flexion relaxation phenomenon in healthy people

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Abstract. [Purpose] The objective of this research was to examine the impact of cognitive load on the flexion relaxation phenomenon (FRP) during trunk flexion and return from flexion task. [Subjects and Methods] Twenty-two healthy subjects (18 males, 4 females) participated in the study. Each participant was exposed to 3 experimental conditions: no cognitive task, easy cognitive task and difficult cognitive task. Surface electromyography was used to measure lumbar erector spinae muscles activity level. Flexion relaxation ratio (FRR) was compared in order to assess the differences between the three experimental conditions during flexion and extension (FLX FRR and EXT FRR). [Results] The FRR was decreased with increase in cognitive difficulty; the difficult cognitive task was associated with significant lower value of FLX FRR in both sides. However, these changes were not significant in easy cognitive task. In addition, the EXT FRR was decreased in cognitive task conditions, but these results were not statistically significant except for difficult cognitive task condition in comparison to no cognitive task condition in left side. [Conclusion] These findings suggest that cognitive loading can affect FRP in healthy subjects.

Key words: Flexion relaxation ratio, Surface electromyography, Cognitive loading

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INTRODUCTION

Trunk flexion caused by bending and lifting activities are related to increased risk of emerging spinal problems¹⁻³⁾. Abnormal biomechanics of trunk flexion predispose our lumbar spine to injury by generating large torque and heavy compressive load in the lumbar structures^{1, 4)}. Physical activities that include full trunk flexion are common during daily activities and during occupational and sports activities. Therefore, increasing the knowledge about biomechanics of trunk flexion is important^{5, 6)}. During normal end range of trunk flexion in standing, the myoelectrical activity of lumbar erector spinae muscles suddenly decreases. This reduction and eventual disappearance of the electromyographic activity of the paravertebral muscles is known as Flexion Relaxation Phenomenon (FRP)⁷⁻¹⁰⁾. This myoelectrical silence is not seen in chronic low back pain patients indicating the abnormal neuromuscular control during trunk flexion. It has been proven that FRP can be a useful tool for differentiating chronic low back pain patients from normal individuals^{8, 11)}.

Previous research studies have shown that number of factors such as magnitude of load, loading rate, fatigue, creep developed by prolonged lumbar flexion, can cause alterations in FRP in healthy subjects¹²⁻¹⁴⁾. Given that physical activity

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in most environments involves cognitive stress, it is important to know the effects of cognitive loading on the biomechanical parameters such as FRP. While various factors can be considered, knowing the role of cognitive load on the erector spinae muscles activity pattern will aid in the better understanding of the FRP. To the best of our knowledge, this study is the first attempt to identify an association between FRP measures and cognitive loading in healthy subjects. The main hypothesis of this study is that changing the cognitive demands during trunk flexion and return from flexion task would lead to an alteration in neuromuscular control and muscular activity in lumbar spine that may alter parameters of FRP.

SUBJECTS AND METHODS

Twenty-two volunteers (18 men and 4 women; with mean age, height, and weight of 25.68 ± 6.04 years, 172.31 ± 8.03 cm, and 69.18 ± 8.86 kg, respectively) were recruited by non-probability convenience sampling method. All subjects provided written informed consent before participation. Inclusion criteria included age range of 18 to 40 years and they were excluded from the study if they had a history of LBP or leg pain over the past 1 year, auditory or cognitive (memory) deficit, and any rheumatologic or neurologic disorder. The study protocol was approved by the Ethics Committee of Ahvaz Jundishapur University of Medical Sciences (Ahvaz, Iran). The code of ethics approval was IR-AJUMS-REC-1394-715.

Each participant was exposed to 3 experimental conditions: no cognitive task, easy and difficult cognitive task. In no cognitive task, subjects were asked to stand comfortably for 5 s (first standing phase) and then to bend forward as far as they were able without bending their knees (flexion phase), hold the fully flexed position for 3 s (hanging phase), return to the upright position (extension phase), and finally, maintain the return standing position for 5 s (second standing phase)¹⁵.

The cognitive task used in this study was backward digit span memory task. After two times hearing of a random digit string before testing, the participant retained them in their minds and reversed their order during the trunk flexion and return from flexion task. Immediately after the electromyographic data collection, the participant was asked to recall the reversed digits. The difficulty of cognitive task was manipulated by the length of the digit string corresponding to the maximum memory capacity of the individual. The individual's maximum digit span memory was determined using the Wechsler test. The maximum number of digits recalled plus one were considered as a difficult cognitive task and half of maximum number of digits recalled were considered as an easy cognitive task, rounded up when the number was odd¹⁶.

The electromyography signals were collected, filtered and amplified (10–500 Hz, gain 2,000) through an EMG system (ME6000, Mega Electronics Ltd., Kuopio, Finland) with a sampling frequency of 1,000 Hz. Disposable self-adhesive electrodes (Skintact F-55) were attached to the skin bilaterally at the level of L3 over the belly of the erector spinae muscles with an inter-electrode distance of 2 cm^{5, 17}. A motion capture system with seven infrared video cameras (Qualisys Inc., Sweden) was used to collect kinematic data. The flexion relaxation ratio (FRR) was calculated by dividing one second of the surface electromyography root mean square (sEMG RMS) value measured during movement, either in the flexion (FLX FRR) or extension (EXT FRR) phases, by the one second of the sEMG RMS value while in full flexion phase^{17, 18}. The mean score of the 3 trials was used in the electromyographic data analysis.

Data was analyzed using SPSS for Windows 22.0 (SPSS Inc., Chicago, IL, USA). Repeated measures analysis of variance (ANOVA) was carried out to compare FLX FRR and EXT FRR at different conditions (no cognitive task, easy and difficult cognitive task). In addition, Bonferroni correction was applied for multiple comparisons between different test conditions. P-values less than 0.05 were considered significant.

RESULTS

There are no differences between right and left side FRR in all conditions ($p=0.07$ to $p=0.67$), indicating symmetric erector spinae muscle activity during trunk flexion and return from flexion task in healthy population. EXT FRR was significantly higher than FLX FRR in all conditions, due to higher level of erector spinae EMG activity during extension (concentric) phase relative to flexion (eccentric) phase.

ANOVA results for the variables 'FLX FRR-Left', 'FLX FRR-Right', 'EXT FRR-Left', and 'EXT FRR-Right' showed that FRR values decreased with increasing cognitive difficulty levels (Table 1). The difficult cognitive task was associated

Table 1. The FRR values at different conditions (no cognitive task, easy and difficult cognitive task)

	FLX FRR		EXT FRR	
	Left	Right	Left	Right
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
No task	5.52 ± 3.21	5.25 ± 2.46	9.92 ± 4.55	8.33 ± 3.58
Easy task	5.36 ± 2.99*	4.90 ± 2.19*	9.24 ± 4.24	7.90 ± 3.82
Difficult task	4.59 ± 3.06*	4.24 ± 1.99*	8.40 ± 4.09*	7.21 ± 3.36

* $p < 0.05$. FLX FRR: flexion relaxation ratio in the flexion phase; EXT FRR: flexion relaxation ratio in the extension phase.

with significant lower values of FLX FRR in both sides ($p < 0.01$). Nevertheless, these changes were not significant in easy cognitive task ($p = 0.96$ for left to $p = 0.22$ for right), that means there was no significant difference in FRR between no cognitive task and easy cognitive task condition. In addition, the EXT FRR was decreased in cognitive task conditions, but these results were not statistically significant except for difficult cognitive task condition compared to no cognitive task condition in left side ($p = 0.02$).

DISCUSSION

The results of our study showed that increased cognitive load was associated with decrease FRR during trunk flexion/extension cycle, meaning the greater the cognitive load, the lower the FRR (less lumbar muscle relaxation). These changes were significant when difficult cognitive tasks were performed for FLX FRR compared to no-task/easy task. We already have such results for EXT FRR but not statistically significant (except for left EXT FRR in difficult cognitive task condition), probably due to small sample size. These findings suggest that erector spinae muscles activity may be affected by cognitive loading in healthy subjects. The difference between no cognitive task and easy cognitive task conditions, were not significant, because easy cognitive task used in our study may be a less challenging task to observe dual-tasking effects.

There are several possible explanations why there was lower FRR in difficult cognitive task condition compared to no cognitive/easy cognitive task conditions. First, cognitive loading may increase erector spinae muscle activity caused by increased arousal or as a result of other psychological processes¹⁹. In support of this possibility, Eijkelhof showed that cognitive loading results in an increase in cervical and upper limb muscle activity and the effect of cognitive load and physical interfering factors on the increase in muscle activity was similar¹⁹. Also, Bloemsaat found that a higher cognitive demand leads to increased muscle activity in the proximal upper extremity²⁰.

Second, these results could be explained by the neuromotor noise theory²¹. According to this theory, cognitive loading increases neuromotor noise, which leads to a greater kinematic variability throughout the period of carrying out a task. To satisfy the demands of task, this variability must be decreased. This can occur through increasing stiffness by higher levels of muscle activity²². In support of this assumption, Van Loon demonstrated that arm stiffness was increased with increasing cognitive load²³.

According to results of this research, it seems that cognitive induced increase in lumbar muscular activity is similar to effects of back pain on FRP. The results are in line with the assumption that cognitive loading could play a role in lumbar spine injury during activities of daily living and in workplace²⁴.

A potential limitation of the present study is the small sample size. Also, due to possible gender difference in dual tasking's effect on erector spinae muscles activity, inclusion of only 4 women, makes the generalization of findings of this study to female populations difficult. We thus suggest using a larger sample size with equal number of both genders in future studies.

In conclusion, the results of our study confirm the effect of cognitive loading on FRR in healthy subjects, but this effect was not significant in some conditions. Future studies should expose larger group of healthy subjects to different cognitive conditions and also examine effects of cognitive loading on FRR in CLBP patients.

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Conflict of interest

None.

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