J. Phys. Ther. Sci.
23: 599–601, 2011

The Effect of Backpack Loads on FRR (Flexion-relaxation Ratio) in the Cervical Spine

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Abstract. [Purpose] This study examined the effects of various backpack loads on the cervical flexion relaxation ratio as a quantitative neurological measure. [Subjects] Fourteen subjects with no neck pain participated in the study. [Methods] Surface electromyograms of the C4 paraspinal muscles were measured bilaterally, while subjects performed cervical flexion extension, and normalized in three phases. Cervical FRR data of three different backpack loads were analyzed. The FRR was calculated as the muscle activation during the cervical extension phase divided by the muscle activation during the relaxation phase. [Result] The FRR in the unloaded condition was 2.44 on the right and 2.37 on the left; for the backpack weighing 10% BM, the FRR were 1.91 and 1.89, respectively, and for the 20% BM backpack, FRR were 1.56 and 1.53, respectively. [Conclusion] A heavier backpack increased the potential for neck pain. The FRR is a functional examination that can be used to quantitatively assess the potential for developing cervical pain and the results of intervention.

Key words: Backpack, Cervical Flexion-relaxation ratio, Electromyography

(This article was submitted Jan. 27, 2011, and was accepted Mar. 16, 2011)

INTRODUCTION

Both students and soldiers commonly use backpacks to transport objects. However, if the backpack is too heavy, it may cause back pain and other musculoskeletal damage, including neck and shoulder pain[1)]. The change in cervical alignment caused by a backpack may place a burden on the cervical joints and soft tissues[2)]. A heavy backpack also results in a forward shift of the neutral center of mass (CoM) of the body and changes the position of the head and upper and lower cervical vertebrae markedly[3)]. The comfort of a backpack is a combination of the biomechanical effects on the CoM of the body and the forward-leaning posture[4)]. Many studies have reported a correlation between the load of a backpack and pain[5)]. Neck pain is as common as lumbar pain and leads to disability and costly economic effects due to reduced ability to work[6)]. The mechanical cause of neck pain and functional disability contributes to a patient's prognosis. Few studies have obtained normative data to compare patient conditions[7)]. The physical evaluation and functional assessment of the neck are essential in the clinical management of neck pain[8)]. The flexion-relaxation phenomenon (FRP) was first described as lumbar electronic muscle silence and is related to the end-range spinal posture while moving into flexion from an upright posture, i.e., bending forward from standing[9)]. The FRP is a quantitative measure that can be used to assess differences in neuromuscular function and can discriminate between healthy individuals and those with back pain[10)]. Floyd and Silver first described flexion-relaxation in the lumbar spinal muscles using electromyography (EMG) and observed that passive factors in the posterior lumbar region and the ligaments posterior to the intervertebral disc undergo essential motion during complete flexion that silenced spinal muscle activation[11,12)]. The validity of the lumbar FRP has been proven, and the specificity and sensitivity of the test are high[13)]. A recent study proposed that patients with neck pain had a significantly low cervical flexion-relaxation ratio (FRR), which could be a useful marker of the modulation of neuromuscular activity in patients with neck pain[12)]. Studies have examined the role of the cervical FRR in functional and physiological assessments of the neck. Therefore, we examined the effect of various backpack loads on the cervical FRR.

SUBJECTS AND METHODS

Fourteen males participated in this study. Their average age, weight, and height were 23.6 ± 1.9 (mean ± SD) years, 70.71 ± 7.24 kg, and 176.14 ± 5.28 cm, respectively. Subjects were excluded if they had a history of neck pain or trauma, or spinal surgery. The study purpose and procedures were explained to all subjects, who gave their informed consent to participation. The surface electromyographic (EMG) signals of the C4 paraspinal muscles were recorded and processed using a MP150WSW (BIOPAC Systems, USA) with EL503 surface electrodes. The MP150 system changes the analogue signal into a digital signal, which is then processed using AcqKnowledge 3.9.1 software on a personal computer. Skin impedance was reduced by removing any hair and swabbing the skin with an alcohol-soaked compress. Electrodes were placed bilaterally over the paraspinal muscles 2 cm apart at the level of the C4 spinal process. A ground electrode was applied over the lateral epicondyle of the left humerus. During testing, all subjects performed cervical flexion and extension motion in three phases: the flexion phase, performing complete cervical flexion for 5 seconds; the complete cervical flexion phase, maintaining complete static cervical flexion for 5 seconds; and the extension phase, performing extension to return to the initial position for 5 seconds. The FRR was calculated as the EMG value during the extension phase divided by the value during the complete relaxation phase using the average values for each phase. Before the test, we instructed the subjects on the forward posture of the head during complete cervical flexion. All subjects were given sound signals to normalize the test times and to decrease intra- and inter-subject variability of the tester. Each subject performed two practice trials of the flexion-extension task with a rest between trials. Then, they performed five trials with each of the three backpack loads in the seated position. Sufficient rest was allowed between trials to prevent fatigue. The maximum and minimum values for the five trials were excluded, and the remaining three results were averaged. The three backpack loads tested were as follows: 1) a load equal to 0% of the subject's body mass (BM), i.e., the no-backpack condition; 2) a load equal to 10% of BM; and 3) a load equal to 20% of BM. All tests were performed in a random order by each subject. The subjects were seated on a stool without a backrest, and maintained upright lumbar and head positions and 90 degrees of hip and knee flexion.

The cervical FRR was compared using one-way repeated-measures analysis of variance (ANOVA). Windows SPSS ver. 12.0 was used to process the data. Post hoc analysis was performed using the Bonferroni correction, and $p<0.05$ was considered statistically significant.

RESULTS

The average cervical FRR significantly decreased in order of unloaded backpack condition >10% BM load >20% BM load ($p<0.05$). The FRR in the unloaded backpack condition was 2.44 ± 1.00 on the right and 2.37 ± 1.00 on the left; with a 10% BM load, the respective values were $1.91 \pm .69$ and $1.89 \pm .62$; and with a 20% load, they were $1.56 \pm .37$ and $1.53 \pm .31$.

DISCUSSION

This study investigated the effect of backpack load on the FRR. With a heavier load, the FRR decreased significantly in the 14 subjects. Pialasse JP (2009) determined the presence or absence of an FRP response in the cervical region by reducing the FR ratio by 2.58). Our study showed the mean value of 20% load backpack condition was 1.5. Recently, Murphy et al. (2010) reported that patients with neck injuries have a low FRR[10)]. We evaluated the relationship between backpack load and neck pain using the FRR and backpack load was related to pain. A backpack load places considerable backward strain on the shoulders. Several studies have demonstrated that carrying a backpack results in a significant difference in the alignment of the head and spine and in sagittal shoulder posture. The stress while carrying a backpack straightens the neck, significantly decreasing the cervical curve[14)]. The biomechanical effects of a backpack load alter the body CoM and result in forward lean[3)]. This effect is similar to a forward head posture, which is the poor head posture commonly seen in neck pain patients[14,15)]. In a forward head posture, the head is in front of the vertical line through the center of gravity of the body[16)]. This posture differs significantly between patients with neck pain and asymptomatic individuals[17)]. Similar to the biomechanical effects related to neck pain, the cervical FRR is also decreased.

Several studies have demonstrated a relationship between backpack load and pain[18)]. In this FRR study, the increased muscle activation in the complete flexion phase might have been caused by a neuroreflex that occurs to protect the spine from damage[19)]. A complex reflex regulating mechanism is involved in the control of spine segment motion. Therefore, a low FRR of the cervical spine indicates an imbalance between neural discharges to the muscles, and this dysfunction in the reflex arc would be expressed in continuous cervical paraspinal activity to protect the spine[10)]. Increased muscle pain can result from disturbed motor control, proprioceptive sensation, regulation of stiffness by altered sensitivity to stretching, and discharge of fusimotor neurons. Increased afferent receptor activity causes stiff muscles and increased electronic muscle activity to maintain spinal stability[19,20)]. Therefore, muscle activation may be increased during the complete flexion phase. Murphy et al.[10)] described cervical FRR as a sensitive outcome measure that distinguishes symptomatic patients with neck pain from asymptomatic individuals. Another recent study of cervical FRR not only distinguished patients with neck pain and healthy individuals, but also identified various factors that affected the pain. In our study, the decrease in FRR with a heavier backpack may be related to the potential for developing neck pain with continuous use of heavy backpacks.

A limitation of our study was that it examined only healthy males in their 20s; therefore, we do not know the effects of gender. In addition, we examined a small number of subjects. In summary, our results suggest that cervical FRR is a quantitative way of evaluating the potential for developing neck pain with heavy backpack loads. Furthermore, this study provides basic information for studies examining the combined effects of various factors on the neck, including backpacks.

ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (No. 2011-0005580).

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