THE DEVELOPMENT OF NEW ELECTROMYOGRAPHIC PARAMETERS TO DIAGNOSE LOW-BACK PAIN PATIENTS DURING SAGITTAL FLEXION/EXTENSION MOTION

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ABSTRACT

The Electromyographic (EMG) signals of flexor-extensor muscle pairs were investigated to identify the neural excitation pattern of low-back pain (LBP) patients during a repetitive bending motion. New parameters and EMG normalization technique were developed to quantitatively represent the difference of temporal EMG patterns between ten healthy subjects and ten LBP patients. Flexor-extensor muscle pairs such as rectus abdominis(RA)-erector spinae(ES at L5), external oblique(EO)-internal oblique(IO), rectus femoris(quadriceps:QUD)-biceps femoris(hamstrings:HAM), and tibialis anterior(TA)-gastrocnemius(GAS) pairs of muscles were selected in this study. Results indicated that the temporal EMG pattern such as the peak timing difference of QUD-HAM muscle pair and the duration of coexcitation of ES-RA muscle pair showed a statistically significant difference between healthy subjects and LBP patients. These results indicated that the new technique and parameters could be used as a diagnostic tool especially for LBP patients with soft tissue injuries that are rarely dentified by traditional imaging techniques such as X-ray, CT scan or MRI. Importantly, the new EMG technique did not require the maximal voluntary contraction (MVC) measure for normalization that helped patients minimize the pain experience during and after the session. Further study needs to be made to validate and refine this method for clinical application.

INTRODUCTION

Low-back pain (LBP) is the most costly and frequently reported musculoskeletal problem in the United States (Spengler, 1986; Mayer et al, 1987; Praemer et al, 1992). In Korea, LBP is also reported as one of the main industrial disease along with injuries caused by noise and vibration. However, when the LBP was involved with soft tissue injuries, the traditional imaging techniques such as X-ray, CT scan, or MRI could not provide anatomically accurate information (Bigos et al, 1990). Because of that, the functional measurement technique of musculoskeletal system have been widely used to quantitaitvely examine LBP. In particular, it has been known that the kinematic variables such as velocity and acceleration of the trunk motion could show the different dynamic ability between healthy subjects and LBP patients (McIntyre et al, 1991; Marras et al, 1993, 1995). Based upon he observation, it was hypothesized that the altered motion pattern among LBP patients could be due to the modified neural control strategy to guard the injured body parts or reduce the pain.

Electromyographic (EMG) signals have been used to investigate the neuromuscular pattern of the trunk system during ballistic or controlled movement (Ahern et al, 1989; Pacquet et al, 1994; Roy et al, 1995). They showed that the EMG signal could detect the different muscle excitation pattern between healthy subjects and LBP patients. In fact, the phasic abnormality of EMG signals has been used to identify the neurologic problem of patients (Knutsson and Richards, 1979; Woltering et al, 1979). Also, Oddson and Thorstensson (1987) reported a strictly reciprocal muscle excitation pattern between flexors and extensors of the back and hip among healthy subjects. Likewise, studies demostrated that the different temporal patterns of EMG signals of trunk muscles could be used as a diagnostic tool to identify LBP patients. Therefore, in this study, the temporal EMG signals was closely examined to parameterize temporal EMG pattern. In addition to that, a new EMG normalization technique was also used to process the dynamic EMG signal with a minimal inter-subject variability.

METHOD

Hypothesis

Temporal EMG pattern of flexor-extensor pairs of muscle have a significant difference between healthy subjects and LBP patients.

Subjects

Ten healthy subjects with no history of low-back disorders and ten patients with on-going LBP were recruited. All patients were diagnosed to have a musculoskeletal disorder by physician. All patients have the pain level greater than 2 and less than 9 (0 to 10 subjective scale: 10 as the worst pain) in this study. This exclusion procedure eliminated patients who might show the unwillingness to perform dynamic flexion/extension motion due to the fear of reinjury. In order to minimize the individual performance difference, only 18 to 50 years old male and 18 to 40 years old female were recruited (Marras et al, 1995). The average weight and height are 67.4 kg and 169 cm for healthy subjects, and 79.1 kg and 171 cm for patients respectively.

Apparatus

Lumbar motion monitor (LMM: Marras et al, 1992) and hip monitor (Kim, 1995) were used to record the flexion/extension motion of the trunk and hip. Noraxon 2000 EMG system with surface electrodes was used to collect the EMG signals from eight different muscles. Data were collected at 120 Hz of sampling rate via analog-digital converter. The EMG system used a band filter ranged from 16 Hz to 500 Hz and linear 15 ms window for EMG integration. The integrated EMG signals were filtered at cut-off frequency of 3Hz through Butterworth filter.

Selected muscles

Eight different flexor and extensor muscles were selected. The muscles of interest in this study were the erector spinae (ES) at L5 level, rectus abdominis (RA), external oblique (EO), internal oblique (IO), rectus femoris (quadriceps:QUD), biceps femoris (hamstrings:HAM), tibialis anterior (TA), and gastrocnemius (GAS) on the right side only.

Experimental design

'Group' including healthy subjects and LBP patients were used as an independent condition. The temporal differences of peak EMG between flexors and extensors at the back (RA-ES), hip (QUD-HAM), and the knee (TA-GAS) were used as dependent variables. Also, the duration of coexcitation between flexors and extensors such as RA-ES, QUD-HAM, TA-GAS, EO-IO was used as dependent variables. A total of seven dependent variables were selected in this study.

Procedure

After skin surfaces were prepared with alcohol, EMG surface electrodes were applied to eight muscle sites. The skin resistance was monitored and maintained at the same level to reduce the artifact of EMG signal. LMM and hip monitor were fitted with subjects and a brief instruction was given to perform a free dynamic flexion/extension motion for ten seconds. The pain level was monitored during the experiment. Subjects were verbally encouraged to perform at their best ability.

Parameterization of dependent measures

Raw EMG collected from the experiment was rectified, integrated, and filtered at 3 Hz cut-off frequency (Figure 1). The beginning and the end of flexion/extension cycle was determined based on the zero-crossing point of velocity profile showing where the trunk direction changes during trunk flexion/extension. The velocity profile was differentiated from the range of motion data collected by LMM. The filtered IEMG was normalized based on the maximum IEMG value of individual muscle that was collected during a repetitive flexion/extension motion. The average EMG profiles were determined based on the three cycles in the middle that showed the least variability in terms of variance ratio (Hershler and Milner, 1978) (Figure 2). Finally, Based on the EMG profile, the peak timing difference between flexor and extensor was expressed in terms of percentage of one cycle time for statistical analysis.

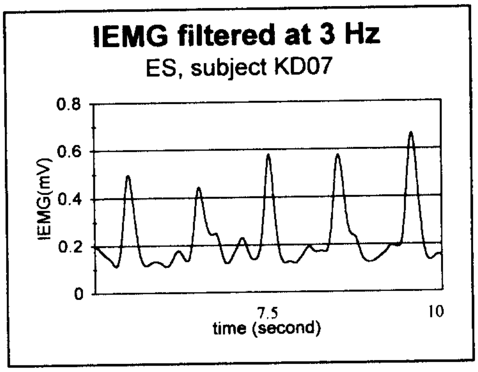

Figure 1. Example of filtered IEMG signal collected from the erector spinae muscle

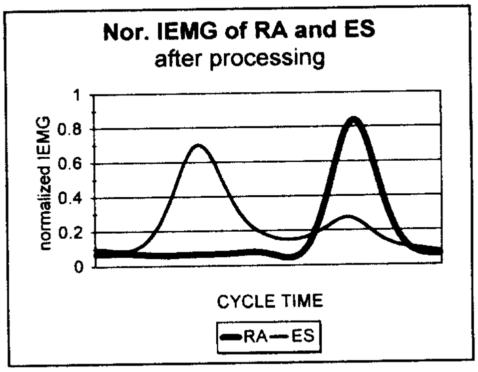

Figure 2. Average EMG profile of flexor and extensor muscles during a single cycle

In order to quantify the duration of coexcitation, IEMG profile of flexors and extensors were determined and the 30 percent and above of IEMG was used as active stage of muscles. That is, the period of time when both flexors and extensors were active was defined as the duration of coexcitation in this study. In fact, the duration of coexcitation could visually seperate the healthy subjects and LBP patients when 10 to 40 percent of threshold value based on the Figure 3.

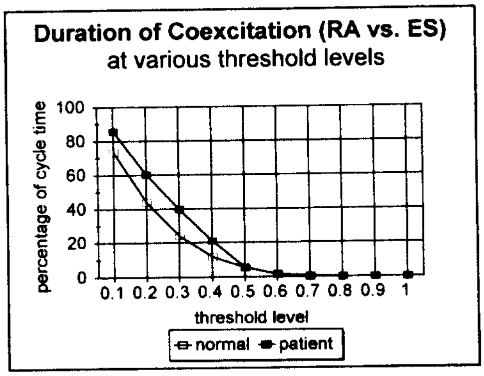

Figure 3. Difference of duration of coexcitation between healthy subjects and LBP patients at various threshold levels

RESULTS

Descriptive statistics

	healthy subjects		LBP patients	
dependent variables	average	std	average	std
peak diff. RA-ES	38.83	25.89	16.17	21.47
peak diff. QUD-HAM	**44.69**	**14.09**	**18.91**	**12.48**
peak diff. TA-GAS	27.24	13.34	28.03	19.06
coexcitation RA-ES	**24.06**	**20.78**	**47.03**	**26.71**
coexcitation QUD-HAM	16.33	19.22	25.47	30.75
coexcitation TA-GAS	23.52	22.78	18.91	14.90
coexcitation EO-IO	**18.17**	**13.50**	**36.33**	**27.02**

ANOVA

dependent variables	source	DF	F	Pr>F
peak diff. RA-ES	group	1	4.54	0.4720
peak diff. QUD-HAM	group	1	18.76	0.0004***
peak diff. TA-GAS	group	1	0.01	0.9162
coexcitation RA-ES	group	1	4.60	0.0458**
coexcitation QUD-HAM	group	1	0.64	0.4358
coexcitation TA-GAS	group	1	0.29	0.5989
coexcitation EO-IO	group	1	3.61	0.0734*

*significant at $p<0.1$, **significant at $p<0.05$, ***significant at $p<0.01$

Peak timing difference of the hip flexor-extensor pairs of muscle, the duration of coexcitation of trunk muscle pairs showed significant differences between healthy subjects and LBP patients. That is, several parameterized EMG variables selected in this study showed their effectiveness in differentiating LBP patients from healthy subjects.

DISCUSSION

Among EMG parameters, the peak timing difference between hip flexor and extensor muscle showed its effectiveness to identify the LBP patients. It is interesting to observe that the LBP significantly influenced the dynamic hip motion greater than back motion during flexion/extension task. This result requires a further study of causal relationship between and LBP and hip dynamics. Also, LBP patients showed a longer coexcitation period as we may have expected in this study. This phenomenon could explain the absence of relaxation that was observed by Pacquet et al (1994) and Ahern et al (1990) during trunk flexion motion. Usually, LBP patients try to smoothen dynamic motion to minimize the pain or they often hesitate due to the fear of pain. This type of modified motion pattern may have caused the increase of coexcitation of trunk muscles observed in this study.

On the other hand, the relatively large standard deviation in dependent variables decreased accuracy in identifying LBP patients in this study. Therefore, effort should be made to reduce the individual variability by modifying the test protocol or data processing technique in the future. At any rate, the parameterized EMG signals successfully demonstrated a diagnostic ability of LBP patients with a soft tissue injuries. This result proved that using EMG signals could be an effective diagnostic tool to identify the LBP patients regardless of injury type.

CONCLUSION

This study provided a new technique to measure the neuromuscular performance of the back and hip for LBP patients. Due to the increasing number of LBP patients with anatomically unknown cause, the quantification of LBP is becoming more important issue than the past. Accurate diagnosis and proper rehabilitation can prevent LBP patient from getting a serious and chronic musculoskeletal disease. Therefore, the current finding is meaningful to advance the diagnostic technique for an effective treatment of LBP. In the future, the validation of current results needs to be performed for larger patient population. Moreover, if a new computer software and hardware could simplify the experimental and data processing procedure, the current EMG diagnostic technique can be widely applied in clinical setting .

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