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Original Article

Time-varying surface electromyography topography as a prognostic tool for chronic low back pain rehabilitation

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Abstract

BACKGROUND CONTEXT: Nonsurgical rehabilitation therapy is a commonly used strategy to treat chronic low back pain (LBP). The selection of the most appropriate therapeutic options is still a big challenge in clinical practices. Surface electromyography (sEMG) topography has been proposed to be an objective assessment of LBP rehabilitation. The quantitative analysis of dynamic sEMG would provide an objective tool of prognosis for LBP rehabilitation.

PURPOSE: To evaluate the prognostic value of quantitative sEMG topographic analysis and to verify the accuracy of the performance of proposed time-varying topographic parameters for identifying the patients who have better response toward the rehabilitation program.

STUDY DESIGN: A retrospective study of consecutive patients.

PATIENT SAMPLE: Thirty-eight patients with chronic nonspecific LBP and 43 healthy subjects.

OUTCOME MEASURES: The accuracy of the time-varying quantitative sEMG topographic analysis for monitoring LBP rehabilitation progress was determined by calculating the corresponding receiver-operating characteristic (ROC) curves. Physiologic measure was the sEMG during lumbar flexion and extension.

METHODS: Patients who suffered from chronic nonspecific LBP without the history of back surgery and any medical conditions causing acute exacerbation of LBP during the clinical test were enlisted to perform the clinical test during the 12-week physiotherapy (PT) treatment. Low back pain patients were classified into two groups: "responding" and "nonresponding" based on the clinical assessment. The responding group referred to the LBP patients who began to recover after the PT treatment, whereas the nonresponding group referred to some LBP patients who did not recover or got worse after the treatment. The results of the time-varying analysis in the responding group were compared with those in the nonresponding group. In addition, the accuracy of the analysis was analyzed through ROC curves.

RESULTS: The time-varying analysis showed discrepancies in the root-mean-square difference (RMSD) parameters between the responding and nonresponding groups. The relative area (RA) and relative width (RW) of RMSD at flexion and extension in the responding group were significantly lower than those in the nonresponding group ($p<.05$). The areas under the ROC curve of RA and RW of RMSD at flexion and extension were greater than 0.7 and were statistically significant.

CONCLUSIONS: The quantitative time-varying analysis of sEMG topography showed significant difference between the healthy and LBP groups. The discrepancies in quantitative dynamic sEMG topography of LBP group from normal group, in terms of RA and RW of RMSD at flexion and extension, were able to identify those LBP subjects who would respond to a conservative

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rehabilitation program focused on functional restoration of lumbar muscle.

Keywords: Chronic low back pain (LBP); Rehabilitation therapy; Prognosis; Surface electromyography; Time-varying topography; Root-mean-square difference

Introduction

In the majority of persons with low back pain (LBP), a specific diagnosis cannot be made [1,2]. Without knowledge of the underlying cause, finding an efficacious match between any individual LBP patient and an almost infinite selection of therapeutic options is highly problematic [2,3]. Consequently, the resulting trial and error approach to match patients and treatment perpetuates the expense and prevalence of LBP [4–7].

Although the various etiologies of LBP await discovery, investigators have attempted to improve treatment efficacy by developing diagnosis-independent techniques to match LBP patients and treatments that are likely to succeed [2,8–10]. To date, several baseline variables have been identified that predict which patients are likely to respond preferentially to a specific therapeutic intervention. For example, Childs et al. [8] formulated a clinical prediction rule based on a constellation of five variables (symptom duration, symptom location, fear-avoidance beliefs, hip rotation range of motion, and lumbar mobility). In persons who were positive for four or more of the five prediction variables, the estimated probability of treatment success using spinal manipulation was at 92% of those subjects [8].

Musculoskeletal dysfunction is one of the causes of LBP, and surface electromyography (sEMG) is widely used in clinical experiments for biomechanical and musculoskeletal analyses. Surface EMG has been renowned for being noninvasive and dynamic application, a gold standard for measuring muscle function [4,11–13]. With the use of surface electrodes (sEMG), this painless and easily applied technique has been used extensively to document muscle impairments [4,12,13]. The objective sEMG measurement of global muscle groups is potential to offer a reliable reference for physiotherapy (PT) treatment of LBP and so to play a role as diagnostic and monitoring tools. In the past few decades, many researchers have been working in quantitizing sEMG signal for LBP assessment, such as raw sEMG, median frequency, reflex latency and positions of standing, trunk flexion/extension and sitting, etc. [14–18]. Increasing number of literature report that there are significant differences in sEMG between the LBP patients and the normal people that offer potential clinical application of sEMG for diagnosis of LBP [13,19–21].

Although sEMG is used commonly in the spine, interpretation of its results can be problematic given the spine's multiple layers of overlapping muscles. As a result, several investigators have developed spatial arrays of sEMG electrodes to describe regional muscle activity rather than activity on a per muscle basis. From data derived in this way, the localized sEMG root mean square [22] value of an array point can be estimated by a two-dimensional (2D) topographic representation of muscle electrical activity using a linear cubic spline interpolation [13]. The result is a visual representation of muscle activity over a 2D region [13]. Our hypothesis was that topography sEMG testing may prove more valuable to assess the lumbar muscle function during dynamic flexion-extension and its potential use to predict the prognosis of functional restoration rehabilitation in a population of chronic LBP subjects. It would be helpful to classify those patients who have good response to conservative care.

Methods

Subjects

A total of 43 healthy subjects (mean age=32±6.5 years, 23 men and 20 women) and 38 patients with chronic nonspecific LBP (mean age=42±9.7 years, 28 men and 10 women) were recruited based on the inclusion and exclusion criteria (Table). Approval for the study was received in advance of testing by the institutional review board for clinical research ethics review. A written consent was collected from each participant.

sEMG test

All subjects received lumbar muscle sEMG test after enrollment. The sEMG data were collected from the lumbar region using a 3×7 array of electrodes applied evenly in the lumbar region from the spinal level L2–L5 (Fig. 1). Each sEMG electrode was 1.5 cm in diameter and applied to alcohol-cleaned skin having impedance of less than 10 kΩ as measured by a multimeter (UT611; Uni-T LTD, Shenzhen, China). sEMG signals were amplified by 2,000 times and filtered between 15 and 950 Hz. The data were acquired at a sampling rate of 2,000 Hz by a data acquisition card (DAQ6063; National Instruments, Inc., Austin, TX, USA). Then, subjects were asked to perform a trunk-bending motion that has been suggested as one of the useful dynamic tasks for evaluating lumbar muscle function [13]. The trunk-bending motion consisted of three phases: flexion, relaxation, and extension. Subjects were asked to bend their trunk forward for 1 second with the range of the flexion angle between 20° and 30° as estimated by using a protractor. Subsequently, they held their flexed posture for 2 seconds and then returned to the original straight standing posture for 2 seconds. The whole sEMG measurement