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The relationship between shoulder joint response with cervical multifidus muscle dimensions

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ABSTRACT

Deep cervical muscles play an important role in creating neck stability. Several changes in muscles function have been observed in people with neck pain. With regard to the problems of recording activity of cervical multifidus muscle with EMG, ultrasound has been used to evaluate the activity of this muscle. Purpose of this paper is investigation the effect of shoulder joint activities on the cervical multifidus muscle thickness changes in people with and without neck pain and providing predictive models by response surface methodology for the relationship between this factors. So, after data clustering in two groups of over 50% and less than 50% of maximum voluntary contraction (MVC), predictive models for each subjects, two groups, both left and right sides and six activities calculated. R^2 (regression correlation coefficient) values of the resulting models in healthy subjects and people with neck pain are between 0.24–0.96 and 0.09–0.87, respectively. By assessing the resulting models, it seems that assessment the thickness of this muscle in the dominant hand side during shoulder abduction activity in the strength of 0–50% MVC for healthy subjects and 50–100% MVC for people with neck pain can be an appropriate factor for evaluation the behavior of this muscle.

1. Introduction

Neck pain is a growing problem in society. Chronic neck pain can be defined as having frequent pain and disability, with symptoms that last more than three months [1]. Deep neck muscles are responsible in creating balance and stability of neck [2]. Mechanical stability of cervical vertebrae in static and dynamic situations can be occur by its adjacent muscles and it can restrain the damages of neck structure [2]. In this way cervical multifidus muscle known as one of the neck extensor muscles that helps to create this stability [2].

Several physiological and biomechanical changes have been observed in people who suffering from neck pain [3–7]. In these individiuls, the normal pattern of muscle is changes. These people have a low muscle endurance, early muscle fatigue and altered activation patterns in the neck muscles compared to healthy controls [8]. Morphological and electromyographical studies indicates that people with neck pain have a deformation and onset delay in the deep spinal muscles [9]. Also some differences in the dimensions of multifidus muscle between healthy subjects and patients with neck pain have been reported [10,11]. Arimi showed that in people with neck pain, this muscle dimensions are smaller than healthy controls [12].

The knowledge of muscle function during various activities may be effective on prescribing therapeutic exercises and physical treatments in various musculoskeletal disorders [11,13].

Electromyography (EMG) and dynamometry are used to inform about the muscle function during various activities. EMG recording is done in two ways of needle, and surface EMG and has many applications such as diagnosis of muscle and nerve disorders, assessment of muscle function and biomechanical modelings. Mayoux-Benhamou et al. showed that using of needle EMG to record the activity of deep cervical muscles has shortcoming of separating the activity of multifidus and semispinalis capitis muscles from each other [14]. Furthermore the needle EMG has an invasive nature.

Given the dependence of muscle properties (such as the biological and bioelectrical properties) on its structure, muscle imaging is used to evaluation of skeletal muscles activities [15]. Studies show that the thickness change of muscle occurs during its activity

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[13,16–19]. Therefore, the electrical activity level of muscle can be found by evaluating its dimensions changes.

Among the available methods for assessing the muscle size, magnetic resonance imaging, computerized tomography and ultrasonography can be noted [20,21]. Ultrasonography is more appropriate to evaluate muscle structure because it is cheaper and more accessible. Also the dimension changes of muscle during various activities can be observed using ultrasound in a real-time and non-invasive manner. High reliability has been reported for assessing the dimensions of skeletal muscles using ultrasound in numerous articles [8,17,22–26]. Also due to the expanding of the useing of ultrasound for evaluation of muscles activities in recent years, new methods provided for measuring muscle thickness [27] and tracking fascicle orientation [28] from the ultrasound images automatically.

The first use of ultrasound in this field has been reported to measure the size of biceps brachii muscle in the late 1960s [29]. After that, this method was used to evaluate other muscles activity. High correlation between muscle dimensions (measured with ultrasound) with strength and EMG data has been reported for several muscles in the lower extremity such as: soleus [30], quadriceps [19,24,25,31,32], rectus femoris [33], tibialis anterior [16,34], vastus lateralis [32] and for the upper extremities like to: transverse abdominus [8,16,22], internal oblique abdominus [8,16], brachialis [16,35], biceps brachii [16,18,35] and forearm and hand muscles [36,37] in healthy subjects. Correlation between these two factors is high for people with cerebral palsy in vastus lateralis muscle [32]. Recently, ultrasound has been used to measure the muscle onset [13,38].

Increasing of the cervical multifidus muscle thickness during isometric neck extension, has been reported recently [21]. On the other side, Rahnama et al. stated that the anterior-posterior dimension of this muscle becomes larger during isometric shoulder contraction while its lateral dimension gets thinner [2]. Also studies suggest that the relationship between muscle thickness with the amount of its activity (strength and EMG) depends on the level of contraction [9,16].

Lee et al. obtained a high reliability for evaluation of cervical multifidus muscle in the fourth to sixth cervical vertebrae (C_4–C_6) by comparing the relationship between ultrasound and magnetic resonance imaging data in healthy subjects [21]. Also reliability and repeatability of ultrasound data to measuring the size of this muscle C_4 level have been reported in both healthy subjects and people with neck pain during rest and muscle contraction [39,40].

Notwithstanding development of ultrasound in the field of measurements of muscle dimensions automatically [27,28] and the high correlation between ultrasound data with muscle activity, this relationship has been reported qualitatively in numerous articles and used for the comparison between people. While many biomechanical studies need to quantification of muscles contraction in different activities that lead to the activation of different parts of muscles [41]. This quantification will lead to better understanding of normal and abnormal muscle function [41]. About the cervical multifidus muscle and given its importance role, finding the mathematical equations and predictive models for the relationship between its thickness changes with contraction level can be effective on detecting this muscle function, as well as which joint activities and strength levels can be better to recognize the change of cervical multifidus muscle dimensions.

In our previous study, using of biomechanical modeling of neck and shoulder muscles showed that the activity of cervical multifidus muscle is different in six shoulder joint activities [42]. At present study, the relationship between thickness of cervical multifidus muscle with isometric strength of shoulder joint in its six direction has been investigated in the people with and without neck pain on both the right and left sides using response surface methodology (RSM). After that the predictive models presented for this relationship in activities and people separately.

2. Materials and methods

2.1. Data recording

In this study, research data of Rahnama et al. were used [43]. The maximum voluntary contraction (MVC) in six movement directions of shoulder joint were recorded by a dynamometry (a ZEMIC load cell model H3-C3-100 Kg-3B) for subjects on the right side by a custom chair. Ultrasound images of cervical multifidus muscle at the C_4 level was recorded by an ultrasound system (Accuvix V20 prestige, Samsung Medison, Korea) with an 8 MHz and 4.5 cm linear array transducer on both sides to find the muscle dimensions. A custom-designed software (SonoSynch) was used to pick up all load cell data and ultrasound images in a synchronized way [44]. Using of this software, synchronic data for 0, 25%, 50%, 75% and 100% of MVC and their identical images were recorded for data analysis. The length of cervical multifidus muscle dimensions (one-dimensional) including the anterior-posterior dimension or muscle thickness (APD) and lateral dimension (LD) are extracted from ultrasound images. Then multiplied linear dimension or muscle size (MLD = APD × LD) and the shape ratio (SHAP = LD/APD) were calculated from these lengths. Fig. 1 shows the schematic work of the present study.

2.2. Data analysis

2.2.1. Determining dependent and independent variables

The RSM was used for data analysis. The effects of isometric contraction of shoulder joint in its six direction on the cervical multifidus muscle dimensions were assessed by RSM. To this end, measured strength (dynamometry data) was considered as the independent variable and cervical multifidus muscle dimensions as the dependent variable.

To assess the impact of contraction level on the relationship between these two factors, data were clustered in two groups of over 50% and less than 50% of MVC for each subject and equations for each class calculated separately.

2.2.2. Data normalization

Recorded strength by the dynamometry (STR) and ultrasound data (Including: APD, LD, SHAP, and MLD) in every six activities and for both sides and groups were normalized using the following equation:

$$N\_x_i = \frac{x_i - x_{rest}}{x_{MVC} - x_{rest}} \quad i = 1, \ldots, 5 \tag{1}$$

Where N_x_i is the normalized data, x_i is the basic data, x_{rest} and x_{MVC} are the value of x in the 0 and 100% shoulder muscles MVC respectively, and i represents the strength levels (0, 25, 50, 75 and 100% of MVC).

2.2.3. Presenting the predictive models by RSM for subjects separately

To find the relationship between these two factors per subjects and without considering the type of activities, data blocking was used [45]. In general, a block is a definite variable that explains variation in the response that is not caused by the independent variables. Given that it is not always possible to enter all the variables in the test, the block effect is used to minimize bias and variance of the error because of nuisance factors and to evaluate the effect of the independent variables on the response. For this purpose, performed activity on the shoulder joint has been considered as the block effect (BE) and second-order model of RSM was used. This