COMPARISON OF MAXIMAL VOLUNTARY CONTRACTION IN THE ELDERLY AND YOUNG

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Abstract: Back strength is an important parameter in low back pain studies. This study was to compare back extensor muscle strength such as maximal voluntary contraction (MVC), in elderly and young subjects using electromyography (EMG) and strength measurements. From three trials of isometric back strength measurement, average and maximum back strength values were obtained and compared. From the EMG experiment, muscle activities such as amplitude and frequency parameters were obtained and compared. However, it is often difficult to determine the true MVC as there can be errors caused by the experimenter and equipment. To obtain a more accurate estimation, several experiments were performed to find out the level of uncertainty.

Keywords: Back Strength, Maximal Voluntary Contraction, Low Back Pain, Uncertainty, Standard Reference Data.

1. INTRODUCTION

Low back pain (LBP) is one of the most prevalent health problems in the general population. About two-thirds of the adult population suffers from LBP at some time [1, 2]. The onset LBP and spinal injuries are often preceded by flexed posture trunk extension tasks, and therefore, trunk extensor muscle function is believed to play an important role in the normal functioning of the spine. To address this, a variety of functional assessment techniques have been developed, including surface EMG and trunk dynamometry, and both are currently being used for clinical assessment of trunk muscle function in patients with low back disorders [3]. The assessment of lumbar impairments is generally done using range of motion, trunk muscle strength and endurance measurements [4, 5]. EMG analysis is promoted as a measure of muscle fatigue [6] but still require to perform MVC to determine the submaximal load level selected in the endurance test [7]. In many back pain studies, back muscle fatiguability test have been performed. In most of these studies, subjects were asked to contract their muscle at a certain force level for a period of time while muscle fatiguability was evaluated. In these studies MVC was used to standardize the target force level. As such, it is important that an accurate MVC be obtained and used [8].

Protecting spinal column is absolutely important. The fact is that traction is the only known conservative method used to restore normal curves to the spine. Lumbar traction has been used in the rehabilitation therapy for the treatment of LBP since the time of Hippocrates. Historically, it had also been used in the management of neurological conditions [9]. The lumbar traction can be applied in a variety of ways, with the patient in a range of postures [10]. The objective of traction is to produce a separating force over the intervertebral discs to counteract the shrinkage caused by compressive loading and restore its mechanical functioning, thereby relieving symptoms. These traction forces are necessary to reduce abnormal spinal curvatures, correct abnormal postures, and will provide increased stability to damaged spines.

Many studies have been performed to analyze the effects of such procedures, in which unloading of the intervertebral discs has been induced by a variety of means. These include gravitational inversion, manual traction, mechanical traction and self-traction. Some degree of success from the use of spinal traction has been suggested, although the benefits have not been always confirmed [11- 15]. The proper application of spinal traction will ensure safety and effectiveness of care [16]. The lack of standardization in terms of load and its magnitude constitutes a confounding factor in attempting to understand the effects of spinal unloading. Presently in hospitals, the traction strength has been calculated as 1/2 of the patient weight, but it does not reflect the personal characteristics' of the patient. This error creates many health problems. Our work is aimed to develop intelligent spinal traction and spinal traction guideline by developing spinal tractor using Korean lumbar spinal shape and its characteristics. It is essential to have back strength and EMG data to develop spinal traction guideline.

This study was to measure back extensor muscle strength such as MVC, in elderly and younger subjects using EMG and strength measurements. From three trials of isometric back strength measurement, average and maximum back strength values were obtained and compared. From the

EMG experiment, muscle activities such as amplitude and frequency parameters were obtained and compared.

2. MATERIALS AND METHODS

The subjects consisted of 85 individuals (45 elderly and 40 younger) including male and female. The purpose and procedures of the study were explained in details and the subjects gave their informed consents. The subjects were compensated for their participation. The back strength of the subjects has been measured using spring type back dynamometer from 3 trails with 5 min rest between each trail. During trails, subjects asked to pull the dynamometer handle hard to their maximum capacity without bending their knees with 30 degree upper body bend. At the same time, EMG experiment also performed to measure the back muscle strength. A wireless type EMG measurement system (The Noraxon Telemyo 2400T G2 Telemetry System, Noraxon, USA Inc., USA) was used to capture the EMG signals of the erector spinae with a sampling frequency rate of 1000 Hz.

All the surface EMGs were collected on both right and left side. EMG data were captured from the two muscles for a 5-s period in each trail. The disc shaped (10 mm diameter) 3M red dot electrode was used. The skin was abraded and cleansed with alcohol before placing the electrodes. The electrodes were applied using standard placement procedure. The raw EMG signals from the experiment were processed for frequency and amplitude parameters using MyoResearch XP Master Edition 1.04.01. The raw EMG signals were filtered at 10-500 Hz with band pass type FIR filter in hamming window. The filtered signals were: full wave rectified for frequency parameters and smoothed based on RMS algorithm with a 50 ms window for amplitude parameters. The back strength and back muscle strength results were statistically analyzed with significance criterion of $p < 0.05$ for all statistical analyses. The data were statistically analyzed, to compare the significant difference between elder and younger.

3. RESULTS AND DISCUSSION

Back Strength: The elderly and younger subjects, 3 trails average and maximum back strength values are grouped, based on height and weight (Fig 1 & 2). Elder's height and weight range: 142.8~174.0 cm & 44.0~75.2 kg, respectively. Younger's height and weight range: 155.1~189.3 cm & 48.2~109.7 kg, respectively. For comparison, the subjects were grouped based on height and weight. Height groups were: 155.0~159.9 cm, 160.0~164.9 cm, 165.0~169.9 cm and 170.0~174.9 cm. Weight groups were: 40.0~49.9 kg, 50.0~59.9 kg, 60.0~69.9 kg and 70.0~79.9 kg. For elder's, the back strength value was higher at 170.0~174.9 cm height group and 70.0~79.9 kg weight group. For younger's, the back strength value was higher at 170.0~174.9 cm height group and 60.0~69.9 kg weight group.

The younger subjects back strength values were consistently higher than elderly subjects ($p < 0.05$), in both height and weight groups. In both elderly and younger subjects, the tallest subjects having more back strength. But in terms of weight groups, not heavier subjects having higher back strength. The elderly male and female subject's average back strength value was 79.9 kg and 49.5 kg, respectively. The younger male and female subject's average back strength value was 143.3 kg and 65.6 kg, respectively. The elderly subjects back strength value was 38.4% lower than ($p < 0.05$) younger subjects. The elderly female subjects back strength value was 68.1% lower than ($p < 0.05$) elderly male subjects. The younger female subjects back strength value was 54.2% lower than ($p < 0.05$) younger male subjects. The elderly male subjects back strength value was 44.3% lower than ($p < 0.05$) the younger male subjects. The elderly female subjects back strength value was 24.5% lower than ($p < 0.05$) the younger female subjects.
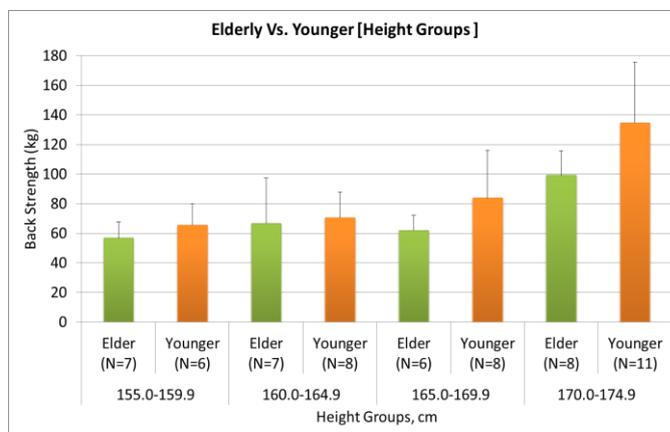

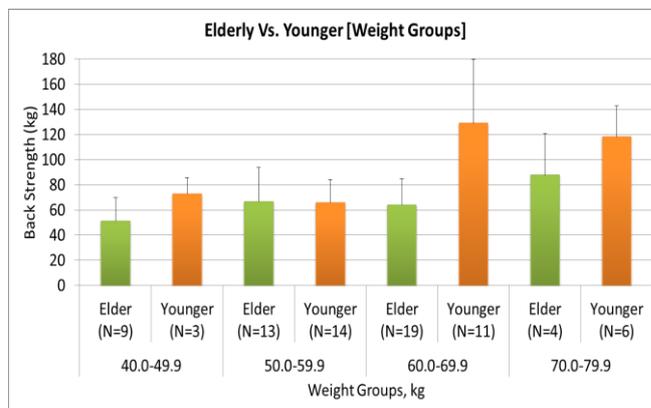Figure 1. Back strength comparison based on height groups

Figure 2. Back strength comparison based on weight groups

Back Muscle Strength: Muscular strength is an essential component of fitness for anyone involved in a physical activity program. By definition, muscle strength is the ability or capacity of a muscle or muscle group to exert a maximal force against resistance, one time through a full range of motion. Muscle fatigue is the decline in ability of a muscle to generate force, and it reduces muscle strength. EMG has been used to identify the level of local muscle fatigue. The use of sEMG techniques, in particular, has played a major role in understanding back muscle activity

during specific postures and movements in both control and patients with LBP [6, 16-19].

Mean power frequency (MPF), and median frequency (MF) are two most commonly used single indexes of the power spectral alterations. The MPF is defined according to the standard definition of a mean in statistics, on the basis of a continuous distribution, in this case the power spectrum. The MF is defined as the frequency that divides the power spectrum into two parts with equal areas. Fatigue causes a decrease of the frequency content of the EMG signal usually described as a decline of the mean or median frequency of the power spectrum [20-22]. Conversely, the association between progression of fatigue and an increase in root mean squared (RMS) values of EMG signal is associated with ambiguity and controversy [23]. In general, RMS is expected to decrease as the firing rates of motor units decrease during fatigue, whereas the shift of MF or MPF to lower frequencies would theoretically result in an increase in RMS voltage, since the power spectral density within the EMG range has increased (i.e., more signal energy is passing through to the electrodes). Many different methods exist to process and present EMG amplitude data. A few of these methods include peak root mean squared (pRMS), mean root mean squared (mRMS) and integrated EMG (iEMG).

Trunk function studies generally focus on measurements of lumbar erector spinae (ES) extensor muscle activity, since the highest levels of EMG activity during trunk extension tasks are associated with these muscles. The multifidii or multifidus (MI) muscles are capable of producing extension, lateral flexion, and rotation. EMG studies confirms that multifidii muscles seem to act more as stabilizers rather than prime movers of the vertebral column and it was found that the multifidii play a role in the controlling intersegmental motion. In this study, we have considered lumbar erector spinae and multifidii muscles, and evaluated back muscle strength by comparing the EMG frequency and amplitude values. The elderly and younger subjects 3 trials average frequency and amplitude values are presented (Fig. 3-6).
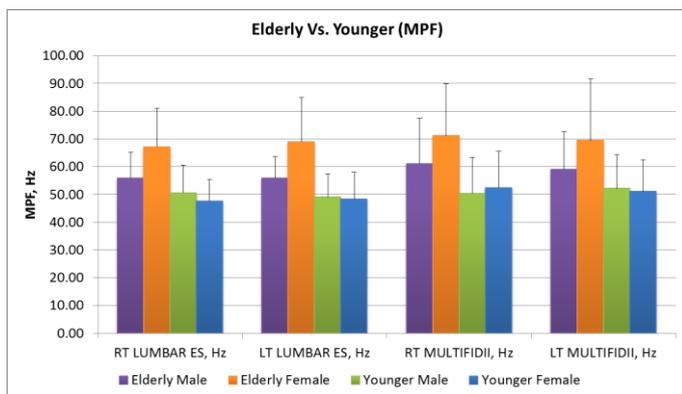

Figure 3. Mean Power Frequency Comparison

There was a rise in mRMS and pRMS value, and decrease of MPF and MF value (i.e., classical EMG signs of muscle fatigue), for younger subjects comparing with elderly subjects. This indicates that the back muscles are more susceptible to fatigue in younger subjects than in elderly. There was a rise in mRMS and pRMS value, and

decrease of MPF and MF value, for elderly male subjects comparing with elderly female subjects. This indicates that the back muscles are more susceptible to fatigue in elderly male than in elderly female.
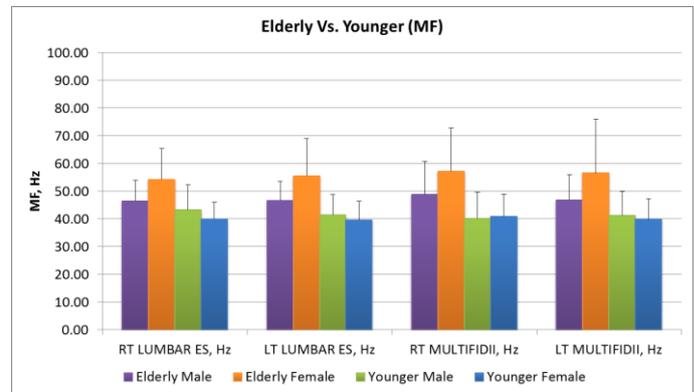

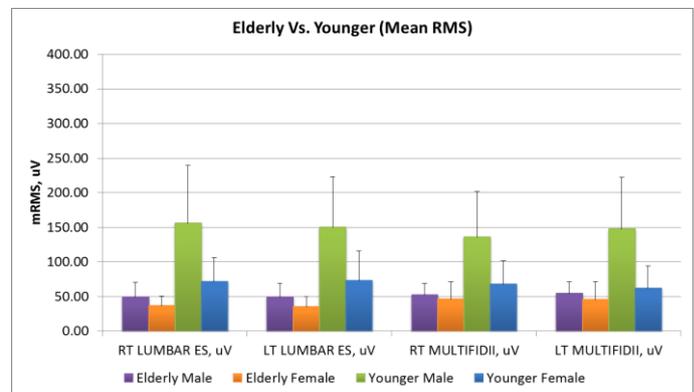Figure 4. Median Frequency Comparison

Figure 5. Mean Root Mean Square Comparison

Different trend observed in younger subjects. There was a rise in mRMS and pRMS value, and increase of MPF and MF value, for younger male subjects comparing with younger female subjects (i.e., controversial to the classical EMG signs of muscle fatigue). This indicates that the back muscles are more susceptible to fatigue in younger female than in younger male with respect to the EMG frequency results. With respect to the EMG amplitude results, the back muscles are more susceptible to fatigue in younger male than in younger female.
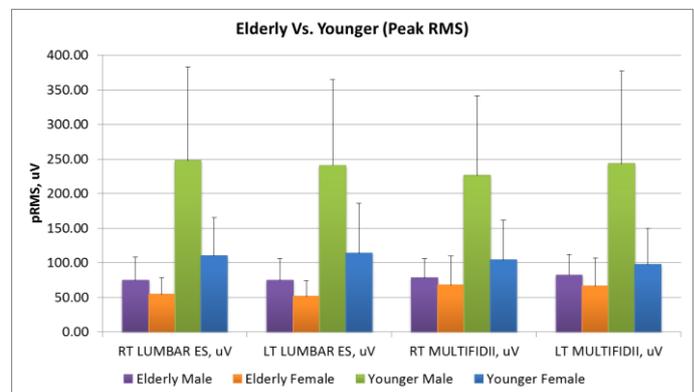

Figure 6. Peak Root Mean Squared Comparison

Significant difference was found (p<0.05) between ES and MI muscles MPF values, for both younger and elderly. The ES MPF value was lower than MI, regardless of side. Significant difference was not found between ES and MI muscles MF values, for both younger and elderly. The ES MF value was lower than MI, regardless of side. This indicates that ES muscles are more susceptible to fatigue than MI muscles.

Significant difference was not found between ES and MI muscles mRMS values, for both younger and elderly. There were different muscle activity trend observed between sides of two muscles. The right side ES mRMS value was higher than right side MI, and the left side MI mRMS value was higher than left side ES. Significant difference was not found between ES and MI muscles pRMS values, for both younger and elderly. Similar with mRMS results, the right side ES pRMS value was higher than right side MI, and the left side MI pRMS value was higher than left side ES. This indicates right side ES muscles are more susceptible to fatigue than right side MI muscles, and the left side MI muscles are more susceptible to fatigue than left side ES.

4. CONCLUSIONS

To develop intelligent spinal traction and spinal traction guideline by developing spinal tractor, it is essential to have back strength and back muscle activity data along with Korean lumbar spinal shape and its characteristics. The younger and elder's back strength was measured using spring type dynamometer. For back muscle activity measurement, sEMG experiment was performed. The younger's back strength values were consistently higher than elders, in both height and weight groups. The younger male's back strength values were higher than younger females, and similar trend were observed in elderly males. From the sEMG experiment, it was observed that: the younger's back muscles were more susceptible to fatigue than elders; the elderly male's back muscles were more susceptible to fatigue than elderly females; the younger female's back muscles were more susceptible to fatigue than younger male's with respect to EMG frequency results; the younger males back muscles were more susceptible to fatigue than younger females with respect to EMG amplitude results.

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