IMPROVEMENT OF MUSCLE STRENGTH IN REHABILITATION BY THE USE OF SURFACE ELECTROMYOGRAPHY

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Introduction

One of the main objectives of physical rehabilitation is to restore muscle strength. Clinical test of muscle strength is either performed by mechanical means or by manual technique. However, these methods have limitations. Firstly, human muscle force in voluntary movement is usually contributed by a group of muscles rather than a single one. The performance of an individual muscle cannot be reflected solely by measurement of mechanical force. Secondly, surface electromyography (EMG) is also widely used in an effort to understand the neuromuscular adaptations accompanying motor learning and exercise (Kamen et al 1996). The use of surface EMG to monitor muscle performance has several advantages. It is non-invasive and real-time. Moreover, EMG acquired with advanced technology allows the study of individual muscle activity with high fidelity. Unlike EMG, force measurement device cannot detect very weak muscle contraction whereas EMG can. All these advantages justify more in-depth study of the surface EMG in the context of rehabilitation. This study aims at developing a protocol to monitor the improvement of muscle strength in rehabilitation by the use of surface electromyography (EMG). It is always a topic for discussion in other similar studies (Narici et al 1996, Hakkinen 1995, Weir et al 1994, Garfinkel el al 1992 and Sale 1988). Another objective is to explore the possible physiological mechanisms leading to the increase in muscle strength, which is always a common topic in the research field (Hamill et al 1995, Enoka 1994).

Methods

Eleven normal, healthy, lean (Bilodeau et al 1992, Solomonow et al 1990) and young (20 to 35 years old) male subjects completed the six-week strengthening program on their right quadriceps muscle. Training consisted of 30 maximal voluntary contraction (MVC) per day, 3 days a week (Garfinkel et al 1992). The maximal isometric strength of the quadriceps muscles was measured with the computerized dynamometer (NORM, Cybex, USA) with hip and knee at about 60° flexion. The testing position was exactly the same as that of strengthening. The subjects were accurately repositioned at subsequent session by following the set-up recorded in the computer. The extension torque of the knee was measured at maximal voluntary
contraction (MVC) of the right quadriceps muscles. The test for MVC follows the protocol recommended by De Luca (1997). Surface EMG was recorded on the right rectus femoris muscle at MVC and two pre-determined torque levels, 100 Nm and 150 Nm, of submaximal isometric contraction. The raw EMG was acquired and then processed by the use of a PC-based signal processing software (Global Lab, Data Translation). Integrated EMG (IEMG) and root mean square voltage (RMS) (Basmajian et al 1985) were calculated from the EMG data for subsequent data analysis. The test was repeated every two weeks by the same operator with the same set-up. Surface EMG of the rectus femoris muscle at MVC and two submaximal torque levels, 100 Nm and 150 Nm, were acquired according to the format recommended in the “Standards for reporting EMG data” of the Journal of EMG and Kinesiology (Solomonow et al 1996). Bipolar silver-silver chloride electrodes were used. Skin impedance was kept below 5 kΩ. The EMG signal was filtered at 5 to 350Hz, and sampled at 5 kHz. The gain is 1000 and the signal-to-noise ratio is 128 dB (Kumar et al 1996, Basmajian et al 1985). Moreover, since raw EMG detected by surface electrodes have been shown to be sensitive to many intrinsic and extrinsic factors (Enoka 1994) that cannot be perfectly controlled, the EMG should be normalized to facilitate comparison of the EMG data in the time-domain (Burden et al 1999). The EMG data was normalized twice (double normalization) in this study. It is because the surface EMG was acquired during the tests at two pre-determined submaximal levels of torque, 100 and 150 Nm, of isometric knee extension instead of the more common method that used percentage of MVC as the test protocol. Firstly, the EMG data was normalized with the EMG obtained at MVC in the same session. Secondly, since the muscle gained its strength during the six weeks of strengthening, the EMG data was then further normalized by a factor, which is the ratio of the torque at MVC at the current session to that in the initial session. The advantages of this double normalization would be discussed further in the next session.

“Friedman two-way analysis of variance by ranks” was used to test whether there was any significant difference in various EMG parameters during the six-week strengthening program. The level of statistical significance was set at P < 0.05. If Friedman test revealed significant difference, the “Wilcoxon signed ranks test” with Bonferroni’s Correction would be used to test which period in the six weeks showed statistically significant difference. The correlation between the relative change in MVC and the relative change in IEMG and RMS voltage at second week, fourth week and sixth week were tested by the Spearman rank correlation coefficient.

Results & Discussion

There was significant (p= 0.001) increase in the strength of the right quadriceps
muscles (mean = 22%). Both IEMG and RMS voltage at 150 Nm contraction had significant (p = 0.024) decreases after the strengthening program (fig. 2 and 3) though no strong correlation (r < 0.5) between the change in maximal torque and the change in the EMG could be found. Results show that less EMG (both IEMG and RMS value) is required to generate the same isometric torque (150 Nm) in the right quadriceps muscles. It implies that the muscle becomes more efficient after the six-week strengthening program. The most rapid decrease happens in first 4 weeks though it takes six weeks to be statistically significant.

Figure 1. Change of IEMG (mean) and RMS voltage (mean) at 150 Nm torque levels of isometric extension of the right knee during the six-week strengthening program in 11 subjects.

The major achievement of this study is the establishment of a test protocol at pre-determined submaximal level of torque instead of using percentage of MVC. This protocol is safer and easier to be administered in patient during rehabilitation. Comparison of EMG data between two sessions is possible after double normalization of the raw EMG data. The results of this study also support the view that an increase in muscle strength in a six-week strengthening program is attributed mainly to neural adaptation that includes metabolic and ultra-structural changes of the neuro-muscular system. The decrease in EMG at a reasonably strong (150 Nm in present study) submaximal contraction during strengthening is an indicator for improvement in mechanical force output though the relationship is not known. This can be applied in rehabilitation especially in monitoring progress in muscles whose strength cannot be easily measured by mechanical means.

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References


