최대 수의적 등척성 수축을 하는 동안 장요측 수근 신근에서 최대 수의적 등척성 수축력과 근 구조와의 상관관계

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Correlation between MVIC and Muscle Architecture in the Extensor Carpi Radialis Longus Muscle during Maximum Voluntary Isometric Contraction

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Purpose: This study examined the correlation between the maximum voluntary isometric contraction (MVIC) and the muscle architecture in the extensor carpi radialis longus muscle during MVIC.

Methods: The muscle area, volume and density were measured using a ultrasound imaging system to obtain the muscle architecture during the MVIC. For the mechanical muscle strength measurements, the MVIC was obtained using a dynamometer.

Results: There was a significant correlation between the MVIC and the muscle area (r=0.498, p<0.01) and muscle volume (r=0.602, p<0.001). There was a significant correlation between the MVIC and density (r=−0.429, p<0.05). The area showed significant correlations with the muscle volume (r=0.699, p<0.001) and density (r=−0.429, p<0.05). In addition, there was a correlation between the volume and muscle density (r=−0.555, p<0.01).

Conclusion: There is close relationship between the MVIC and the muscle architecture in the extensor carpi radialis longus muscle during the MVIC.

Key Words: MVIC, Area, Volume, Density

I. Introduction

The voluntary muscle function and structure of the whole muscle activity is a fundamental component of human physical capabilities. In an effort to understand the importance of the capacity in selected activities, many studies have examined the torque and structure, comparing these torques to the strength values and imaging analyses (Grabiner et al, 2005; Gross et al, 1998; Hodges et al, 2003; Hughes et al, 1996; Kotake et al, 1993; Pavol et al, 2002; Schultz et al, 1992; Wojcik et al, 2001; Zheng et al, 2006). Several methods have been developed to evaluate the muscle morphology and function (Cooper et al, 1988; Oka, 1996; Reimers, 1999).

Mechanomyography and a dynamometer, which mainly reflects the mechanical properties of a

muscle, have proven to be useful tools for interpreting the muscle mechanical activities and their varying characteristics in both dynamic and static muscle contractions (Hu et al, 2007; Mademli & Arampatzis, 2006; Stafilidis & Arampatzis, 2007; Vedsted et al. 2006). Some studies recommended a maximum voluntary isometric contraction (MVIC) method to measure the muscle torque because it represented the absolute demands required for a specific task while others advocated a dynamic method because it reduced inter subject variability and provided information on the pattern of muscle activation during a task (Burden et al, 2003; Knutson et al, 1994; Winter & Yack, 1987; Yang & Winter, 1984). Prior work has shown that the use of a MVIC method can provide a reliable measure of the muscular demands during a specific lower extremity task or exercise (Earl et al, 2001; Knutson et al, 1994).

A study of the neuromuscular structure and morphological imaging employs three techniques: An ultrasound imaging system (sonography), computerized tomography (CT) and magnetic resonance imaging (MRI)(Monetti, 1997). Currently, sonography examinations have the advantages of low cost, non-invasive and easy access, and the possibility of a dynamic examination (Monetti, 1997). Sonography has been used since the early 1990s to measure the changes in muscle thickness, muscle fiber pennation angle, muscle fascicle length, and muscle cross-sectional area during isometric and dynamic contractions (Fukunaga et al, 1997; Hodges et al, 2003; Ito et al, 1998; Maganaris et al, 2002; Narici et al, 1996; Reeves et al, 2004; Zheng et al, 2006). A musculoskeletal ultrasound tissue assessment is normally focused on the static or quasi-static examination muscles, tendons and other tissues (Van Holsbeeck & Introcaso, 2001). Ultrasound imaging has also been used to assess the movement of muscles (Hodges et al, 2003). The dynamic changes in the muscle cross-sectional area can also be obtained directly from the ultrasound images by improving the ultrasound technique (Zheng et al, 2006). A recent study definedthe mechanical (muscle strength) and morphological (density, pennation angle, muscle thickness) properties (Mademli & Arampatzis, 2006; Stafilidis & Arampatzis, 2007) but gave no conclusion for the correlation between the mechanical properties and morphological properties of a muscle. Therefore, this study examined the relationship between the MVIC and muscle architecture in the extensor carpi radialis longus (ECRL) muscle during the MVIC.

Ⅱ. Methods

1. Subjects

Twenty seven subjects (12 male and 15 female) were enrolled in this study. The subjects were collected arbitrarily in a group (n=27; age, 21.63± 1.86 years; height 167.37±9.11 cm; weight, 58.11± 9.86 kg)(Table 1). The subjects were normally active and volunteered to participate in the study.

Table 1. Subjects' characteristics

	Age(years)	Height(cm)	Weight(kg)
Mean±SD	21.63±1.86	167.37±9.11	58.11±9.86

2. Methods

The subjects were seated comfortably in a chair. Their elbows were flexed at 80~100°. Their right forearms were placed and fixed on a support with their palms down during the test. Their ECRL muscle maximum torques was measured using a dynamometer (JLW Instruments Inc., CS200 Dynamometer, USA). The MVICs were performed three times at one minute intervals. The participants were instructed to perform each MVIC as quickly and powerfully as possible. The average of the three trials was used as the MVIC criterion. These instructions and methods were used for all subsequent measurements of the MVIC strength. The experimental measurements were taken using an ultrasound imaging system (sonography) (Medison Co., SONOACE 6000, Korea). Sonography was performed from the muscle belly of the right ECRL during isometric contractions of 100% MVC(Figure 1). The sonograph of the cross-sec-

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tional area of the ECRL was recorded using a B-mode ultrasound scanner with a 7.5 MHz linear transducer. The right ECRL morphology and thickness was measured at the cross section areas. In order to quantify the muscle aspect, the muscle aspect parameters, such as the muscle area, volume, and density, were defined and calculated using digital image analysis. To calculate the mean mid-belly cross sectional area, the volume of a three-sliced section of a muscle image, which was equidistant (3 cm) from either end of the complete image, was divided by three times the slice thickness(Figure 2). Image analysis was performed using integrated software, image pro plus 4.1(Media Cybernetics, USA) after resizing the collected images to 332 310 pixels through photoshop CS (Adobe, USA). Using this software, the density of the muscles was averaged at the mid belly cross sectional areas (Maurits et al, 2004)(Figure 3).
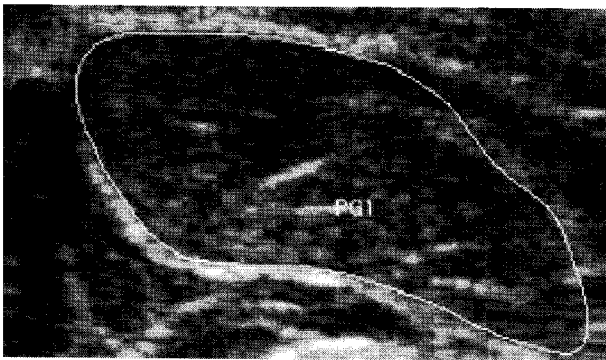

Figure 1. Measurement of the ECRL cross section area

Figure 2. Measurement of the ECRL cross section area

$$V = 1/3 \cdot d \cdot \left[a + \sqrt{(a \cdot b)} + b \right]$$

V : volume, d = 3cm (between a and b)
volume of the entire ECRL = summing up all of the inter-cross section area volumes
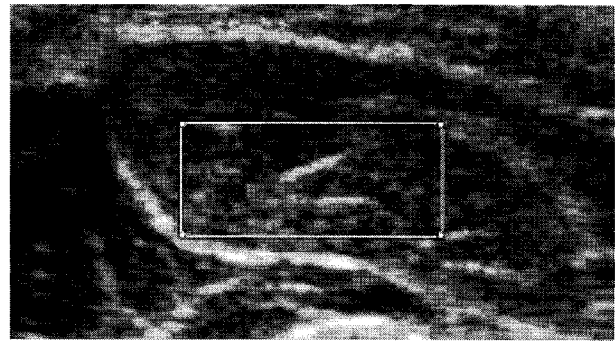

Figure 3. Measurement of the ECRL cross section area
Pixel value : 1-255, 0 : Pure Black, 255 : Pure White
Density = Total pixel values / Total pixel number

3. Statistical Analysis

The Pearsons correlation coefficient was used to estimate the correlation between the MVIC, muscle area, volume and density. All analyses were carried out using SPSS v 12.0 with the level of significance set to 0.05.

III. Results

Figure 4, 5 and 6 show the relationship between MVIC and the sonography measures. There was a good correlation between the MVIC and muscle volume (r=0.602, p<0.001)(Figure 5), suggesting a strong relationship between the muscle strength and the architecture during MVIC activity. There was a significant correlation between MVIC and the muscle area (r=0.498, p<0.01)(Figure 4). In addition, there was a significant correlation between MVIC and density (r=p<0.05)(Figure 6). A comparison with MVIC showed that the volume value had a larger slope than the area.
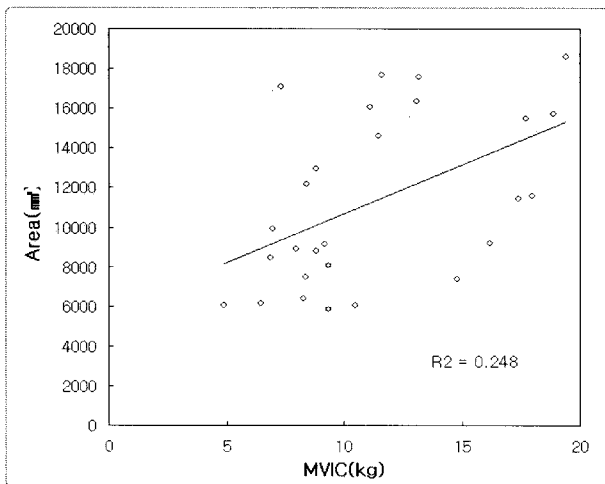
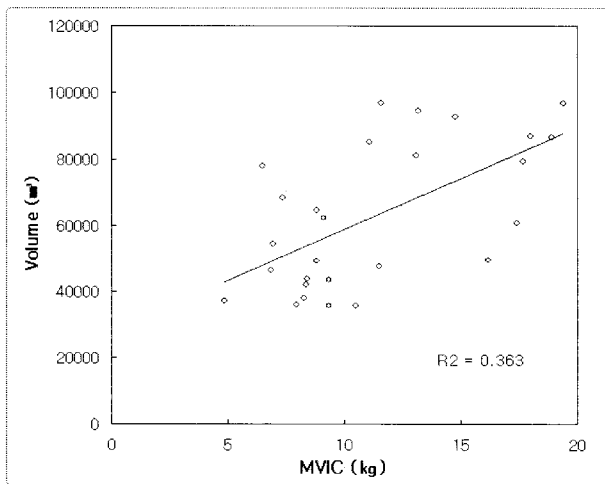**Figure 4.** Relationships between MVIC and Area
r = 0.498
p < 0.01

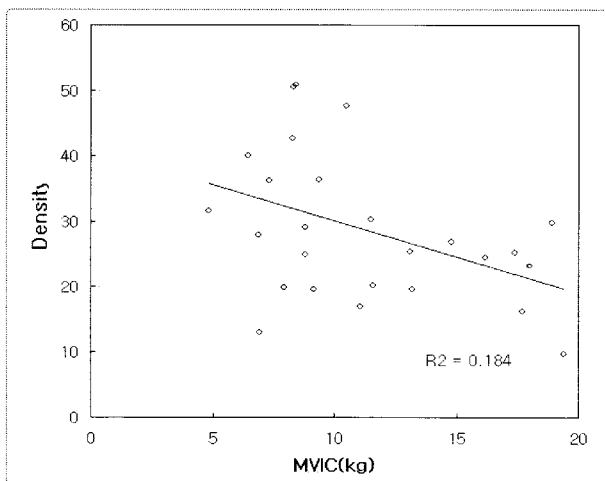**Figure 5.** Relationships between MVIC and Volume
r = 0.602
p < 0.001

Figure 6. Relationships between MVIC and Density
r = -0.429
p < 0.05

Significant correlations were found in the sonography measurements during maximum voluntary muscle contraction (Figure 7, 8, 9). The correlation between the muscle volume and muscle area was higher (r=0.699, p<0.001)(Figure 7), suggesting a strong relationship between the muscle size and architecture during the MVIC activity. The correlations between the muscle density versus muscle area and volume were similar, with r values ranging from -0.512 (p<0.05) (Figure 8) to -0.555 (p<0.01)(Figure 9).
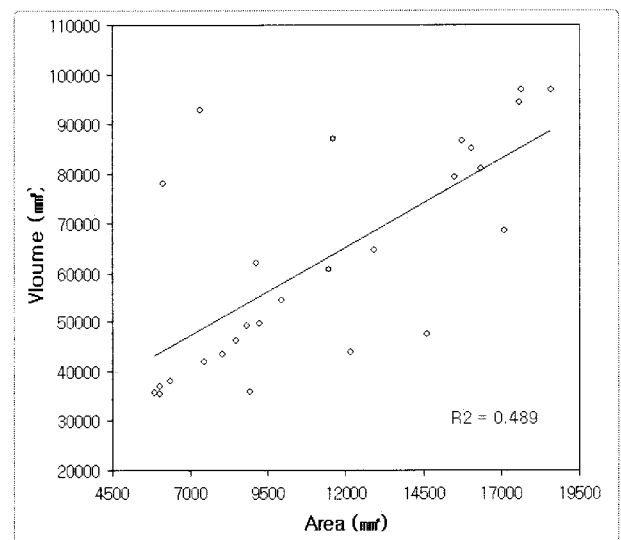

Figure 7. Relationships between Area and Volume
r = 0.699
p < 0.001
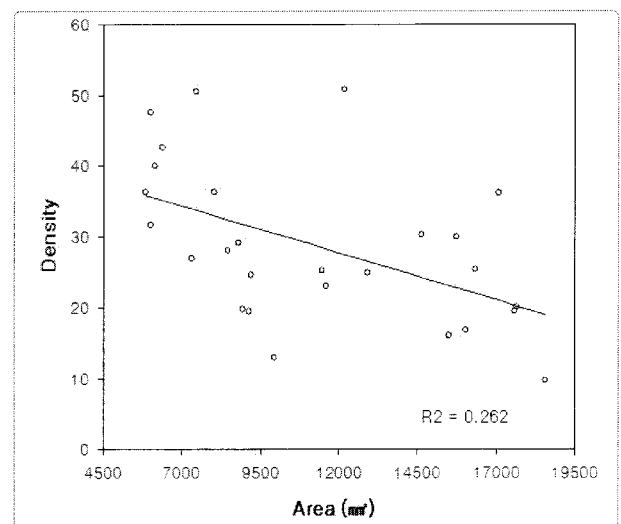
Figure 8. Relationships between Area and Density
r = -0.512
p < 0.01

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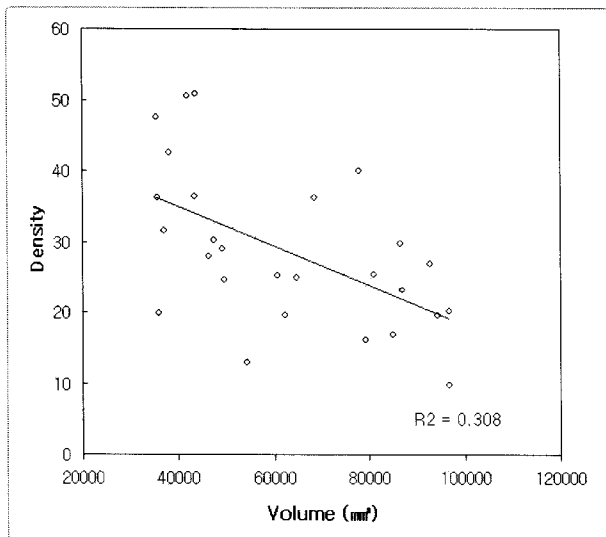
27

Figure 9. Relationships between Volume and Density
r = -0.555
p < 0.01

IV. Discussion

In this study, 27 healthy adults were examined using a dynamometer and ultrasound (US) imaging to obtain reference values of the muscle parameters. For a mechanical muscle aspect, the MVIC was measured in ECRL. In order to quantify the muscle aspect, the muscle area and volume were defined and calculated by sonography. The muscle density was measured by sonography to obtain the muscle quality aspect of the muscle.

In order to achieve the MVIC, all motor units must be recruited (Sbriccoli et al, 2003). Therefore, MVIC reflects the mechanical torque of a muscle (Vedsted et al, 2006). In this study, the MVIC values were easily reproducible and the reliable indices were similar to those obtained from other studies (Strimpakos et al, 2004). There was a significant correlation between the MVIC and the ultrasound imaging measurements. The volume of a specific muscle can be assumed to be constant during muscle contractions (Kardel, 1990). De Haan et al.(1988) concluded that longer muscles with similar cross sectional areas would have higher energy consumption during isometric contractions at the same percentage of MVIC due to the larger number of musclesin series sarcom-

eres. Therefore, among the various possible indicators of Henneman's size principle, the conduction velocity was recently validated under muscle activity force (Farina et al, 2007). For this reason, the muscle area and volume increased with increasing MVIC (Figure 4, 5). The correlation between the MVIC and muscle volume became higher, suggesting a strong relationship between the mechanical aspects of a muscle and the structural aspect of a muscle during the maximum muscle contraction.

The muscle shape parameters are structural measures of a muscle used to infer functional properties. Muscle structure research considers the size and arrangement of muscle fibers to be important determinants of the whole muscle function (Delp et al, 2001; Fukunaga et al, 1997; Kawakami et al, 2000). The movement of individual muscles can be observed using ultrasound, which can detect morphological changes in the underlying soft tissues. Previous studies aimed at differentiation between normal and pathological muscle between myopathies and neuropathies were based largely on quantifying the parameters including muscle thickness, density or inhomogeneity (Dock et al, 1990; Maurits et al, 2003; Maurits et al, 2004; Pillen et al, 2003; Schmidt & Voit, 1993; Scholten et al, 2003). Neurogenic disorders produce a characteristic pattern with increased inhomogeneity and the juxtaposition of hypo- and hyper-echoic areas, which reflect the grouping of fiber types into atrophic fibers (hyper-echoic, bright areas) and hypertrophic fibers (hypo-echoic, black areas)(Knut et al, 2007). Muscular dystrophies are characterized by an extensive homogeneous echo hyper-density, resulting in a loss of visibility of the bone and fascial echoes (Knut et al, 2007). An abnormal muscle shows more hyper-density than the normal muscle. Therefore, there was a significant correlation between the MVIC muscle area and muscle volume with density (Figure 6, 8, 9).

Sonography can show the muscle size, abnormalities of the muscle mesenchyma, and muscular hyperkinesias (Reimers, 1999). This study measured the area, volume and muscle density using

sonography, and used a dynamometer to obtain the MVIC. It is evident that these relationships are important factors in the architecture and morphology of muscles, which require due consideration in a patient's assessment. The potential applications of the characteristic muscle need to be confirmed with more experiments on subjects with different genders, ages, and pathological conditions.

V. Conclusion

MVIC measurements can provide information on the muscle structure and morphology, all of which reflect the strength of the entire muscle function through the muscle cross section area, volume and density. Sonography can also provide information on the muscle architecture from each measurement. These results revealed a strong correlation between the mechanical properties and the muscle architecture.

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