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The Feasibility of Qualitative Assessment of Skeletal Muscle with Ultrasound

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Introduction

Ultrasound is capable of imaging tissues inside the body in a short time without invasion. As ultrasound has become smaller and more portable, it can be used in any location. Therefore, it has become one of the most useful devices in clinical practice and research in rehabilitation.

Skeletal muscle is an essential tissue for muscle output and physical exercise; further is often the subject of evaluation and treatment in rehabilitation. There is no doubt that the importance of skeletal muscle mass assessment is a major factor for muscle strength. However, the quantitative assessment of skeletal muscle with ultrasound (muscle thickness) has the problem of overestimating the muscle contractile tissue. On the other hand, the feasibility and usefulness of qualitative evaluation of skeletal muscle (muscle hardness, muscle echo intensity) with ultrasound has been demonstrated in recent years. One of the author's research areas is the analysis of muscle activity of the four quadriceps muscles. Therefore, this paper describes the qualitative evaluation of skeletal muscles with ultrasound based on previous studies and also outlines the author's research.

Muscle Hardness

There are two types of ultrasound methods for measuring muscle hardness: real-time elastography (RTE) and shear wave elastography (SWE). The principle of RTE measurement is based on the fact that the soft part of the tissue is easily deformed and the hard part is not so easily deformed when compressed [1,2]. It is a method to obtain the displacement at each depth from the reflected echo signals before and after applying pressure to the tissue with the probe, measure the strain based on the degree of displacement, further visualize the distribution of the strain [3].Since the values obtained by RTE are not absolute values, the strain ratio method is used to calculate the ratio of two different regions of interest in the image [4]. On the other hand, the measurement principle of SWE calculates muscle hardness from the reflected velocity of the shear wave excited by the probe [5] and is characterized by its ability to quantitatively measure muscle hardness. Therefore, SWE has become the golden standard for measuring muscle hardness using ultrasound. It has been reported that muscle hardness and isometric muscle output are strongly correlated (correlation coefficient 0.86-0.99) when the target muscles are abductor digiti minimi, interosseous dorsalis, and biceps brachii [6-8].Moreover, the reliability of muscle hardness assessment by SWE has been reported in various muscles, such as abductor digiti minimi, trapezius, and gastrocnemius [9-13]. In a previous study, the muscle activity of three muscles of the quadriceps femoris, excluding the vastus intermedius, were analyzed by SWE [12]. The quadriceps muscle is composed of four muscles, and it is unclear which muscle is most associated with muscle activity during knee extension. Therefore, the authors analyzed the muscle hardness of the four quadriceps muscles during relaxation and maximum isometric contraction in healthy adults and investigated the rate of change in muscle hardness [14]. The results showed that the rate of change in muscle hardness of the vastus intermedius was the highest. Since there is a proportional relationship between muscle hardness and isometric muscle strength [6], it was suggested that the vastus intermedius was most involved among the quadriceps muscles during knee extension at any given muscle contraction intensity. As the limitations of the study, it is considered that the effect of muscle contraction of the deep muscle vastus intermedius and adjacent muscles on the muscle hardness of other muscles cannot be ignored. Therefore, muscle hardness should continue to be carefully assessed in the future.

Muscle echo intensity

Muscle echo intensity (EI) is an established method to evaluate muscle quality using diagnostic ultrasound. Muscle EI is quantified using gray-scale ultrasound that entails the analysis of 256 gray levels from 0 to 255 and correlates with the amount of non-contractile tissue in skeletal muscle [15,16]. A predominantly white appearance suggests that there is a substantial amount of non-contractile tissue in the skeletal muscle, and a black appearance suggests that there is little non-contractile tissue [15].The validity of ultrasound measurements of muscle fiber mass and non-contractile tissues was proven in studies using magnetic resonance imaging for comparison [17,18]. Although it has been reported that the EI of the different quadriceps femoris muscles and their isometric peak torque are negatively correlated [19], a negative correlation between isokinetic strength and the EI has so far only been shown for the rectus femoris [16]. The relationship between the EI of the different quadriceps muscles and their isokinetic strength is unknown. Therefore, the authors investigated relationship between muscle echo intensity on ultrasound and isokinetic strength of the three superficial quadriceps femoris muscles in healthy young adults [20]. For muscle EI, short-axis images of the quadriceps muscle were taken. Moreover, we obtained the maximum force during isokinetic knee extension at 60°/s using an isokinetic dynamometer. As a result, in males and females, a significant negative correlation

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between echo intensity and muscle strength was found in the vastus medialis (VM) (r= −0.65 and r= −0.63, respectively). In both males and females, only the muscle EI of the VM was found to have a negative correlation with the maximum force during isokinetic knee extension at 60°/s. Our data lay the foundation for simplifying and rationally performing the measurement of muscle EI of the quadriceps femoris. And it would therefore be sufficient to only measure the VM to clarify a relationship between EI and maximum isokinetic force in the quadriceps. One of the limitations of muscle EI measurement is that the EI varies depending on the ultrasound model and settings. Therefore, it is necessary to standardize the measurement conditions and it is difficult to compare between models. As a solution to this problem, an attempt to calibrate muscle EI by dividing it by the EI of subcutaneous adipose tissue has been reported [21]. The other problem is that echoes attenuate in deeper layers, which limits the use of muscle EI as a qualitative index of muscle for deep muscles.

In this paper, we have discussed the feasibility of using ultrasound for the qualitative assessment of skeletal muscle. We hope that this paper will be of some help to you in using ultrasound. However, we should not forget that the values obtained by ultrasound are greatly influenced by the probe operation. The author believes that it is important to accumulate high quality data in the future.

Competing Interests

The author declare that there is no competing interests regarding the publication of this article.

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