System for measuring muscle hardness using an ultrasound imaging device

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Abstract: The purpose of this study is to develop a system for measuring muscle hardness using an ultrasound imaging device. The system was applied to measuring muscle hardness before and after stretching. An ultrasound probe holder that has three force sensors was constructed. The holder could measure the force of the probe on the skin while acquiring an ultrasound image. Two images were obtained with and without a compression force of 1 kgf. Subjects were instructed to stand on a stretching board. Stretching was performed three times, and images were obtained again. The thickness of the muscle was measured from the image, and the strain was calculated. The Young’s modulus of the muscle was calculated from the stress and strain. The Young’s modulus decreased after stretching. It was concluded that the developed system could be applied to measuring muscle hardness.

Keywords: Muscle Hardness, Stretching, Ultrasound Imaging

1. Introduction
Muscle hardness is one of the evaluation indices of muscle fatigue. Ultrasound elastography, which shows the elasticity of tissue in color, has recently been used for measuring muscle hardness.¹ However, ultrasound elastography equipment is too large to carry. Development of a portable system for measuring muscle hardness will expand the opportunities to measure muscle fatigue. The purpose of this study is to develop a system of measuring muscle hardness that uses a portable ultrasound imaging device and force sensors. The system has been applied to measuring muscle hardness before and after stretching.

2. Method
An ultrasound image device probe holder with three force sensors was constructed. The probe holder could measure the force of the probe on the skin while acquiring an ultrasound image. The hardness of the gastrocnemius medialis muscle was measured before and after stretching.

2.1 Subjects
Five healthy male subjects (A–E) participated in the experiments. The subjects were from 21 to 24 years old. Ethics committee approval was obtained, and all subjects gave informed consent according to the Declaration of Helsinki.

2.2 Measurement system
A schematic illustration of the measurement system is shown in Fig. 1. The probe of the ultrasound imaging device, Mirucube (Global Health, Yokohama), was fixed to a probe holder with three force sensors, MCSR-5L (Toyo Sokki, Yokohama). The probe is pushed to an object through the sensors when the sensors are compressed using a handle. The probe holder could measure the force of the probe on the skin while acquiring an ultrasound image. The force signals were sampled at 1 kHz with an AD converter, cRIO-9215 (National Instruments, Austin, TX), and visually fed back to the experimenter on the screen of a personal computer.

2.3 Measuring muscle hardness
Each subject lay on a bed in a prone position. The probe was longitudinally placed on the gastrocnemius medialis muscle. Two images were obtained with and without a compression force of 1 kgf on the skin. The subjects were instructed to stand on a stretching board, H-7295 (Toei Light, Saitama), while stretching the knee, and the passive ankle joint range of motion (ROM) was measured. They were instructed to stand on a stretching board whose angle was 3 degrees lower than the ROM. Two minutes of stretching was performed three times with a one-minute break between the stretching. After stretching, subjects lay on a bed, and the images were obtained again in the same way.

The thickness of the muscle was measured from the image, and the strain was calculated as the difference of thickness with and without stress. The Young’s modulus of the muscle was calculated with the stress divided by the strain to determine the muscle hardness.
3. Results
Figure 3 shows typical examples of ultrasound images of the gastrocnemius medialis muscle under static pressure (Subject A). The left panel, a, shows the image before stretching; the right one, b, was made after stretching. The distance, A–B, shows the thickness of the skin and subcutaneous tissue, and B–C shows that of the gastrocnemius medialis muscle. The thickness of the muscle under static pressure decreased after stretching.

Figure 4 shows the muscle hardness before and after stretching. Dotted and diagonally lined bars indicate the results in this study and those in a previous study, respectively. The muscle hardness decreased after stretching and was harder than that measured in a previous study.

4. Discussion
In a previous study, muscle hardness decreased after stretching. The result of the present study agreed with that of the previous study; stretching might decrease muscular tension or tonus. In this study, muscle hardness was measured under pressure from the probe. As a result, stretching might cause greater deformation.

The method of stretching in this study was the same as that in a previous study. However, muscle hardness was measured under no pressure in the previous study. In this study, the part that was compressed by the probe received tension from the surrounding tissues, such as the skin. As a consequence, the muscle was harder than in the previous study.

5. Conclusion
It was concluded that the developed system could be applied to measuring muscle hardness before and after stretching.

Reference