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Development of measurement system for cross-sectional image of muscle using ultrasonography and 3D position sensors
3 次元位置センサを用いた超音波筋横断面画像測定システム開発の試み

Kiyotaka Fukumoto[1‡], and Yoshinobu Ebisawa[1] ([1]Grad. School Eng., Shizuoka Univ.)
福元清剛 [1‡]，海老澤嘉伸 [1] ([1] 静岡大学大学院工学研究科)

1. Introduction

As Japan approaches its future as a super-aged society, the increasing number of elderly requiring assistance and long-term care is becoming a major social issue. In approximately 24% of cases, assistance or long-term care is necessitated by events that decrease the ability for activities of daily living (ADL). Maintenance and improvement of the ability to perform ADLs is therefore important in order to avoid the need for assistance and long-term care of the elderly. A certain amount of muscle is considered necessary to perform ADLs, and the thigh and calf muscle areas are a focus of attention.

We have developed a system using ultrasonography that enables muscle area to be safely measured in elderly requiring long-term care without placing a load on the joints or muscles [1]. With this system, an ultrasound probe is attached to the end of a mechanical arm that has four links and joints, and can be moved freely along the body surface. Four rotary encoders are attached to each joint. Link lengths and measured angles are used to compose a cross-sectional image.

However, participants are not able to change their posture, for example, from supine to standing posture, because the mechanical arm can measure only in the vertical plane. As a result, a long time is required for measurement. We have therefore developed a novel ultrasound measurement system that replaces the mechanical arm with 3D position sensors.

2. System components

A. Measurement unit

Figure 1 shows an overview of the developed ultrasound measurement system. The ultrasound probe of an ultrasound imaging device (LOGIQ e; GE Healthcare UK Ltd., England) is attached to the center of a T-shaped attachment (Mechatronics Co., Japan), and two position sensors (3D Guidance trakSTAR; Ascension Technology Corp., USA) are fixed to both ends of the attachment (**Fig. 2**). Measurement can be freely performed within a range of about 78 cm from the transmitter. X, Y, and Z positions and three angles obtained from the sensors

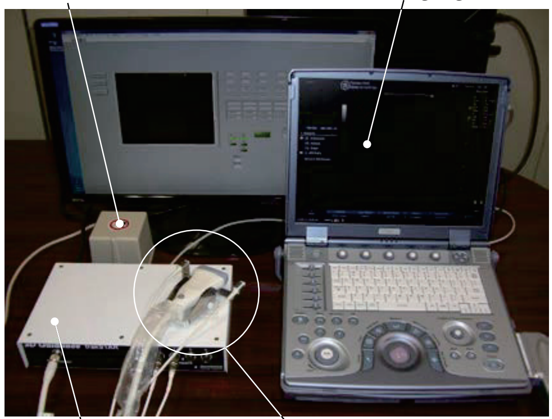

Fig. 1 Overview of the developed ultrasound system

Fig. 2 Attachment with ultrasound probe and position sensors

are transferred to a personal computer (PC) via a controller using a USB port. In this system, two positions and one angle are used to compose ultrasound images. Coordinates and the angle of the probe center are calculated by averaging the positions and angle obtained from two sensors.

Depth of the ultrasound image is set to 8.0 cm from the body surface so that the center of the thigh can be measured. Ultrasound images (fragmental image) from an analog RGB connecter of the ultrasound device are transferred to the PC via a capture board (UFG-05 1E; ARGO Co., Ltd., Japan).

In the measurement of the fragmental images, the probe is in direct contact with and scans along the

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fukumoto@sys.eng.shizuoka.ac.jp

body surface. The center of the probe is in contact perpendicular to the measurement site. The fragmental images and angle and coordinate corresponding to each image are used to compose complete cross-sectional image of the site.

B. Image-composition software

The spatial compound method [2] is used to compose the cross-sectional image after shifting and rotating the fragmental images to coincide with the coordinates and angle of the center position of the probe. Mean brightness, which is calculated from overlapping pixels among the fragmental images, is used to determine the brightness of pixels in the composite image.

3. Experiments

A. Evaluation of measurement accuracy

Measurement errors at the probe center were evaluated by measuring an object of known size. The probe, which was attached to the T-shaped attachment with the 3D position sensors, contacted with and scanned along the surface of the object. Coordinates of the probe center were calculated in every frame. Repeatability was determined by performing the same experiment 10 times.

Table 1 shows mean measurement error and repeatability, respectively. Measurement errors for X and Y axes were 0.41 mm and 1.19 mm, and repeatability was ±0.44, and ±1.26 mm, respectively. An innate measurement error of approximately 1.4 mm was seen for the position sensor. The error was suggested to affect the accuracy of the developed system in this experiment.

Table 1 Mean measurement error and repeatability

Unit (mm)	X axis	Y axis
Error	0.41	1.19
Repeatability	±0.44	±1.26

B. Measurement of cross-sectional images in the field

To evaluate the feasibility of the developed system in a field survey, we measured 13 elderly participants (10 males, 3 females; mean age, 68.0 ± 3.7 years). After providing a thorough explanation of the study in advance, written, informed consent was obtained directly from each participant. The study was approved by the Research Ethics Committee of Shizuoka University. The right thigh was measured at 50% of its length from the greater trochanter, and the right calf was measured at the thickest site. To examine whether the system allows changes in participant posture, the participants were measured in a standing posture immediately after being measured in a supine posture on a bed. We also investigated pain and discomfort during measurements.

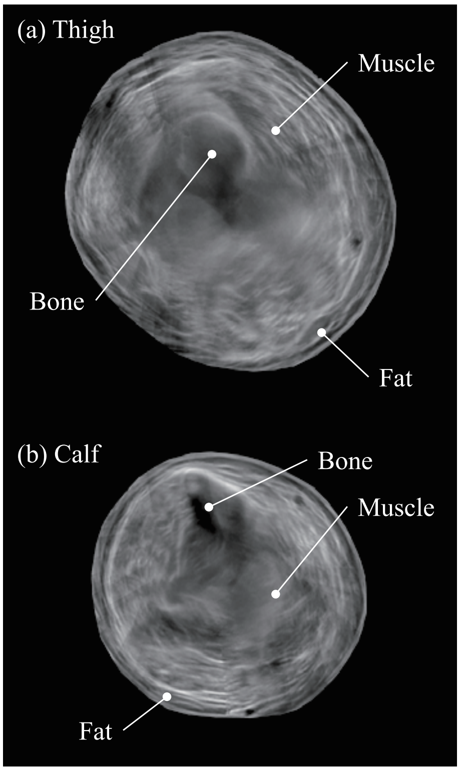

Fig. 3 Examples of cross-sectional images for the thigh and calf

Figure. 3 shows examples of cross-sectional images for the thigh and calf. The muscle, fat, and bone were able to be discriminated from both images. In all participants, cross-sectional images were able to be obtained from the thigh and calf in both supine and standing postures. In addition, all no participants reported pain or discomfort during measurements.

4. Conclusions

We have developed a novel ultrasound measurement system using 3D position sensors. This system ia able to measure cross-sectional images of the thigh and calf in elderly. Although image quality is inferior to the results of computed tomography and magnetic resonance imaging, this technique enables measurement of cross-sectional images in the field.

Acknowledgment

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