MATERIALS

Accessibility of B-mode Ultrasonic Measurement of Subcutaneous Fat Thickness to the 22 Sites Needed for Clothing Design

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Abstract Information about subcutaneous fat distribution over the entire body is important for clothing design as applied anthropology. The measurement of subcutaneous fat thickness by ultrasonic tomogram overcomes the limitations of skinfold calipers measurement, but its accessibility varies depending on easiness of identifying the fat-muscle interface at the measuring sites. This study examined accessibility of ultrasonic tomograms at 22 body sites in 58 young adult females. Individual differences in the tomographic image at such sites as the triceps, plural echoes from the fat layer at such sites as the trochanter, and the "dead time region" at such sites as the wrist, make the identification difficult. The 22 sites were classified into three groups according to their accessibility to measurement. Seventeen sites were confirmed to be measurable, including the sites such as the buttock and thigh which are indispensable to the study of the apparent characteristics of the human body and obesity/leanness as a basis for the designing of comfortable clothing. The sites such as posterior neck and posterior sulcus were not considered to be accessible.

Keywords Subcutaneous fat thickness, B-mode ultrasonic method, Accessibility, Body sites, Clothing design

Introduction

The distribution of subcutaneous fat governs the apparent characteristic of the human body and seems to influence the intensity of the sense of garment pressure (MATSUYAMA *et al.*, 1987), the key points of garment comfort. Thus, thickness and the patterning of subcutaneous fat are important data for clothing design as applied anthropology. The measurement of subcutaneous fat thickness for this purpose require covering the

whole of the body. Several methods so far applied, however, have certain limitations or problems. In the skinfold measurement, which is the most widespread method and is recognized as providing a result highly correlated with relative body fat (NAGAMINE, 1972), it is difficult to form a complete fold on an obese and stiff body, and the reading accuracy of the calipers changes depending on the degree of compression of the measuring sites, which varies with sex, age or site (HIMES *et al.*, 1979; KUCZMAR-

SKI *et al.*, 1987). The use of X-rays or advanced technology, including computed tomography, is still restricted to laboratory and clinical use.

The ultrasonic method is an uncompressed measurement, and is thus free from some limitations such as pain and so on. Within the category of ultrasonic techniques, there are two types of method (Fig. 1), namely, the A-mode (amplitude) and the B-mode (brightness). Because of the earlier development of instruments for the A-mode, this was the method first used for thickness measurement. (HAYMES *et al.*, 1982; KATCH, 1984; TOYOKAWA, 1984a, b; JONES *et al.*, 1986). Studies using the B-mode are still relatively few. KATSUKI *et al.* (1965) developed a sectioning method for the B-mode, and dealt with the extremities of the body to examine body composition. The same method was used by IKAI and

FUKUNAGA (1968, 1969). Measurements by B-mode instruments for clinical use and by skin-fold calipers have been correlated (MATSUMOTO

Fig. 1. Two kinds of ultrasonic graph of abdomen taken at the same time. The A-mode graph corresponds to the vertically lined part of the B-mode image.

Fig. 2. Twenty two sites examined for accessibility in B-mode ultrasonic measurement of subcutaneous fat thickness. 1. anterior chest, 2. anterior axilla, 3. umbilicus, 4. abdomen, 5. lateral chest, 6. iliac crest, 7. posterior waist, 8. trochanter, 9. posterior neck, 10. subscapular, 11. posterior sulcus, 12. buttock, 13. triceps, 14. lateral forearm, 15. wrist, 16. anterior thigh, 17. medial thigh, 18. lateral calf, 19. medial calf, 20. ankle, 21. cheek, 22. chin. The arrows indicate the standardized direction of the probe.

et al., 1985) and further compared each other in predicting body density (FANELLI *et al.*, 1981; KUCZMARSKI *et al.*, 1987). The correlation coefficients reported from these investigations vary from 0.677 to 0.99. Problems in the identification of the fat-muscle interface can arise in actual application, since it is not always easy to identify the waves correctly when individuals differ in the images (ISHII, 1986) and when ultrasonic waves reflect from some portions of the site other than fat-muscle interfaces. None of the previous investigations have reported on the identification of the boundaries of the fat layer at the sites needed for clothing design.

Methods

The apparatus used was an electronically scanning ultrasonic tomograph (Model EUB 26, Hitachi Medico). Probe frequency was 3.5 MHz. No stand-off was used. A tomogram was displayed on a cathode-ray tube and recorded by Polaroid photograph. Subcutaneous fat thickness was determined from the photograph to an accuracy of 0.1 mm using a digitizer connected to a personal computer. Compression with the probe was avoided at all sites

with a caution not to press hard. The correlation coefficient of the ultrasonic values and values directly measured by a vernier calipers for pieces of fresh pork loin fixed in gelatin was 0.994. The accessibility of B-mode ultrasonic measurement to the 22 sites (14 sites on the trunk including the head and 8 sites on the extremities, Fig. 2) was examined on the tomograms of 58 Japanese females aged from 21 to 26 years. The subjects did not show any noteworthy tendency to obesity/leanness.

Results

Problems in discriminating subcutaneous fat boundaries

The problems in discriminating subcutaneous fat boundaries were as follows:

1) Individual differences in the image of the layer: In the tomograms, the pattern of fat and other tissues sometimes varied between individual subjects, especially for subscapular, triceps (Fig. 3) and anterior thigh sites. Images of the medial calf and medial thigh, however, were similar in all the subjects. Generally, individual difference of pattern was greater for sites where muscle and tendon formed a complicated tangle.

Fig. 3. Cases A and B show individual difference of pattern in image at triceps.

Fig. 4. An image of multiple strata in subcutaneous fat tissue of abdomen.

Fig. 5. Image at the cheek, where no strong reflection indicating the fat-muscle interface can be identified.

2) Plural echoes in the subcutaneous fat layer: Sometimes more than two relatively strong echoes appeared from a shallower layer. Sites at which plural echoes frequently appeared were umbilicus, abdomen (Fig. 4), iliac crest, trochanter and buttock. HAYMES *et al.* (1976) studied abdomen, iliac crest, subscapular and triceps sites by the A-mode ultrasonic method and found plural echoes from interfaces in the fat layer on the iliac crest. Using X-ray computed tomography, MATSUYAMA *et al.* (1984) observed double strata of the subcutaneous fat on the trunk of adult males and females. It is important to discriminate the fascia from these interfaces contained in the fat.

3) The dead time region and other problems: A "dead time region" is created by a lowering of receiver sensitivity just after the transmission of an ultrasonic pulse (KIKUCHI, 1980). If the subcutaneous fat layer is thinner than several millimeters, it can be lost to observation in this region. At a site such as the ankle, where the fat layer was often thinner than the depth of the dead time region, it was difficult to observe the

Table 1. Accessibility of B-mode ultrasonic measurement of subcutaneous fat thickness to 22 body sites*

sites	accessibility		
	easy	moderately difficult	difficult
1. Anterior chest	55	3	0
2. Anterior axilla	58	0	0
3. Umbilicus	55	3	0
4. Abdomen	58	0	0
5. Lateral chest	58	0	0
6. Iliac crest	57	1	0
7. Posterior waist	58	0	0
8. Trochanter	51	7	0
9. Posterior neck	0	0	58
10. Subscapular	54	4	0
11. Posterior sulcus	0	55	3
12. Buttock	54	4	0
13. Triceps	45	13	0
14. Lateral forearm	58	0	0
15. Wrist	0	58	0
16. Anterior thigh	54	4	0
17. Medial thigh	58	0	0
18. Lateral calf	58	0	0
19. Medial calf	58	0	0
20. Ankle	0	2	56
21. Cheek	0	0	58
22. Chin	0	0	58

* Figures indicate number of cases observed

Fig. 6-1. Typical images of the sites which are easy to access. The arrows in each image indicate the boundary of the subcutaneous tissue.

Anterior chest

Lateral chest

Umbilicus

Iliac crest

Abdomen

Buttock

boundary of the fat layer. For such site, probing using a gelatinous stand-off is preferable. On the cheek (Fig. 5) and the chin, no intense echo showing the boundary of the fat layer was detected. For a site such as the posterior sulcus, where the subcutaneous fat was relatively thin and accompanied by stiff connective tissue, which reflects a strong wave, it was difficult to identify

the boundary.

How to discriminate the boundary

An image of muscle contracting and relaxing provided a useful clue for discriminating the fascia, especially for triceps. When contact pressure of an ultrasonic probe is increased, the layers are compressed. Reduction of thickness

Lateral forearm

Medial thigh

Lateral calf

Medial calf

Fig. 6-2. Typical images of the sites which are easy to access (continued).

Fig. 7-1. Typical images of the 7 sites which are moderately difficult to access. The arrows in each image indicate the boundary of the subcutaneous tissue.

Anterior axilla

Posterior waist

Trochanter

Subscapular

Triceps

seems to differ between fat and muscle. Pressing on the measuring site is helpful for sites including the anterior chest, anterior axilla, trochanter, triceps, and wrist. Consequently, presence of the individual differences in the tomographic image and the plural echoes did not necessarily prevent the correct identification of the subcutaneous fat layer by a trained person.

Accessibility of measuring sites

From the above observations, 22 sites were classified into three groups in accordance with the degree of accessibility to measurement. Table 1 shows the results of the examinations of the accessibility.

Group A: Sites which permitted easy and stable measurement. The ten sites included were the anterior chest, umbilicus, abdomen, lateral chest, iliac crest, buttock, lateral forearm, medial thigh, lateral calf, and medial calf.

Group B: Sites at which measurement is possible but moderately difficult. For the seven sites which were the anterior axilla, posterior waist, subscapular, trochanter, triceps, wrist, and anterior thigh, measurement should be done by

a trained person. For ankle site, probing using a stand-off was preferable.

Group C: Sites at which measurement is difficult. The four sites included were the posterior neck, posterior sulcus, cheek, and chin.

Figs. 6-1 to 7-2 show sample tomograms of the seventeen sites confirmed to be measurable (groups A and B). The A and B groups included sites such as the buttock and thigh, where measurement of subcutaneous fat thickness was often difficult by skinfold method but is indispensable for obtaining apparent characteristics and obesity/leanness as a basis for the designing of comfortable clothing.

抄 録

全身 22 部位における B モード超音波法測定による皮下脂肪層の同定

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全身の皮下脂肪分布に関する情報は、着心地のよい、体にあった衣服の設計条件を追求するためには重要なものである。そこで本研究では、医療用 B モード超音波法による皮下脂肪厚測定を、人体の多様な部位に適用する場合の、測定部位同定について検討した。すなわち、同定を困難にしている、①断層像個人差、②脂肪組織から反射される複数のエコー、③受信機の過渡現象などの問題について、若年成人女子 58 名を被検者とし、上胸部、腋前面、臍側部、下腹部、側胸部、腸稜部、腰背部、大転子、肩甲骨下角、股部、上腕後面、前腕外側、手首、大腿前面、大腿内側、下腿外側、下腿内側、足首、頬骨部、オトガイ部、頸椎部、胸椎部の 22 部位について検討し、測定のしやすさに従って分類した。ここに掲げた 22 部位のうち、前者 18 部位では、皮下脂肪層の同定が可能であると確認されたが、後者 4 部位では確実な同定は困難であった。前者には、衣服設計の観点から不可欠であるにもかかわらず従来の方法では測定の困難な部位が含まれているので、今後貴重なデータが得られることになろう。

Anterior thigh

Fig. 7-2. Typical image of the sites which are moderately difficult to access (continued).

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