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-
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 skinfold calipers have been correlated (MATSUMOTO

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**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.

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**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.](image-url)
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

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

<table>
<thead>
<tr>
<th>sites</th>
<th>accessibility</th>
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<tbody>
<tr>
<td></td>
<td>easy</td>
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<tr>
<td>1. Anterior chest</td>
<td>55</td>
</tr>
<tr>
<td>2. Anterior axilla</td>
<td>58</td>
</tr>
<tr>
<td>3. Umbilicus</td>
<td>55</td>
</tr>
<tr>
<td>4. Abdomen</td>
<td>58</td>
</tr>
<tr>
<td>5. Lateral chest</td>
<td>58</td>
</tr>
<tr>
<td>6. Iliac crest</td>
<td>57</td>
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<td>8. Trochanter</td>
<td>51</td>
</tr>
<tr>
<td>9. Posterior neck</td>
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</tr>
<tr>
<td>10. Subscapular</td>
<td>54</td>
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<tr>
<td>11. Posterior sulcus</td>
<td>0</td>
</tr>
<tr>
<td>12. Buttock</td>
<td>54</td>
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<tr>
<td>13. Triceps</td>
<td>45</td>
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<tr>
<td>14. Lateral forearm</td>
<td>58</td>
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<td>17. Medial thigh</td>
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<td>20. Ankle</td>
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<tr>
<td>21. Cheek</td>
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<tr>
<td>22. Chin</td>
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</tbody>
</table>

* Figures indicate number of cases observed
Accessibility of B-mode Ultrasonic Measurement

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
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.
References


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