原著論文

Comparison of skinfold thickness measured by caliper and ultrasound methods

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Abstract

The purpose of this study was to determine the characteristics of skinfold thickness (Sthickness) measured by skinfold calipers (CP) and ultrasound (US) methods. Subjects were 54 healthy males and 56 females aged from 17 to 39 years. Measurements were taken at 14 sites of the body, i.e., right cheek, chest 1 (superior and lateral to the nipple), chest 2 (the level of the xiphoid process), abdomen, suprailiac, triceps, subscapula, back 1 (adjacent to and level with the vertebra prominence), back 2 (adjacent to the spinal column and level with and just below the arcus costalis), thigh 1 (the anterior aspect of the thigh midway), thigh 2 (the posterior aspect of the thigh), knee, calf (the posterior aspect of the calf at the level of maximal circumference) and chin sites. In examining the re-test reliability of Sthickness at each site for 32 subjects, intraclass correlation coefficients of greater than 0.89 were obtained in both methods. Individual differences in Sthickness were greater in abdomen, suprailiac, calf, triceps, back 1 in males, and knee and suprailiac in females than other variables. Sthickness at these sites may reflect individual differences in subcutaneous fat distribution. The skinfold ratio (CP/US) for each site was highest in back 1 (3.05 in males and 3.38 in females), and lowest in chin (1.35 in males and 1.78 in females). Although significant correlation coefficients between CP and US methods were found in all sites except for chest 2 in females, correlations were lower than 0.5 in cheek, chin, chest 1, suprailiac, knee in males, and chin, chest 1 and chest 2, thigh 2, and back 1 in females. It is important to note the differences in measurement error between CP and US methods.

Key Words : Skinfold thickness, Skinfold caliper, ultrasound method, coefficient of variance (CV)

1. Introduction

Obesity is one of the risk factors for the lifestyle-related diseases. The obesity is classified into two types, i.e., abdominal obesity and gluteo-femoral obesity. The former is one of the causes of metabolic disorders,[1,4] and is further classified into visceral fat obesity and subcutaneous fat obesity. Visceral fat obesity is a risk factor for diabetes and hypercholesterolemia.[1,4,8] Recently, body composition assessment by body fat distribution or visceral fat mass is considered to be important, in addition to percent body fat.

The CT (computed temography) is one of the methods for estimating visceral fat mass. The CT analyzer can display a cross-section of internal tissue in whole body, and can very accurately estimate fat mass. However, this method has limitations in terms of applicability and safety,[1,4] because it requires a considerably expensive instrument, a technical expert, enormous cost, measurement time and space, in addition to bringing with exposure of radiation.

In contrast, other method estimating visceral fat mass based on skinfold thickness (Sthickness) measured by skin-

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fold caliper (CP) and ultrasound (US) methods have also been developed by investigators.[3-5] Sthickness values at 14 sites are required to estimate visceral fat mass from subcutaneous fat mass,[3-5] but this method with more applicability and safety as compared with the CT method do not bring with exposure of radiation.[7, 9] Although the accuracy of measurement is lower than CT method, this method is significant in the point of prevention of lifestyle-related diseases because of the simplicity.

The CP and US methods have been mainly used to measure Sthickness. Although the CP method is an inexpensive and applicable method, tester's skills and experience are required to measure Sthickness accurately. Similarly although the US method can directly display subcutaneous fat tissue, much experience is required to find a dividing line between subcutaneous fat tissue and other internal tissue.[10,11] The accuracy of measuring Sthickness at the sites of triceps, subscapula and abdomen had been determined by many studies, however, there are few studies investigating the accuracy of other sites. Further, it is considered that the size of measurement error varies among body sites, and that this trend differs between CP and US methods. Therefore, assessing the Sthickness measured by CP and US methods will be necessary to estimate subcutaneous fat distribution or visceral fat mass accurately. The purpose of this study was to compare the Sthickness at 14 sites measured by CP and US methods.

2. Methods

2.1. Subjects

Subjects were healthy 54 males and 56 females aged from 17 to 39 years. Their physical characteristics were as follows: age, 20.5 ± 2.38 years; height, 179.2 ± 5.52 cm; weight, 65.8 ± 9.14 kg in males; age, 20.1 ± 1.37 years; height, 160.8 ± 6.58 cm; weight 52.3 ± 6.17 kg in females.

2.2. Measurement procedures

Considering previous studies,[3-5] Sthickness at 14 sites were measured by CP and US methods using Eiken caliper and B-mode ultrasonic instrument EUB-200 (Hitachi Medical Co.), respectively. Measurements were taken at the right cheek, chest 1 (diagonal fold just superior and lateral to the nipple), chest 2 (vertical fold on the midaxillary line at the level of the xiphoid process), abdomen, suprailiac, triceps, subscapula, back 1 (vertical fold just adjacent to and level with the vertebra prominence), back 2 (vertical fold just adjacent to the spinal column and level with and just below the arcus costalis), thigh 1 (vertical fold on the anterior aspect of the thigh midway between the superior aspect of the patella and anterior superior iliac spine), thigh 2 (vertical fold on the posterior aspect of the thigh), knee, calf (vertical fold on the posterior aspect of the calf at the level of maximal circumference, subject seated with lower leg dangling) and chin (Figure 1).

Two well-trained testers belonged exclusively to CP and US methods, respectively. The tester measured Sthickness of each site one time. Thirty-two subjects were measured Sthickness of each site twice to evaluate the re-test reliability.

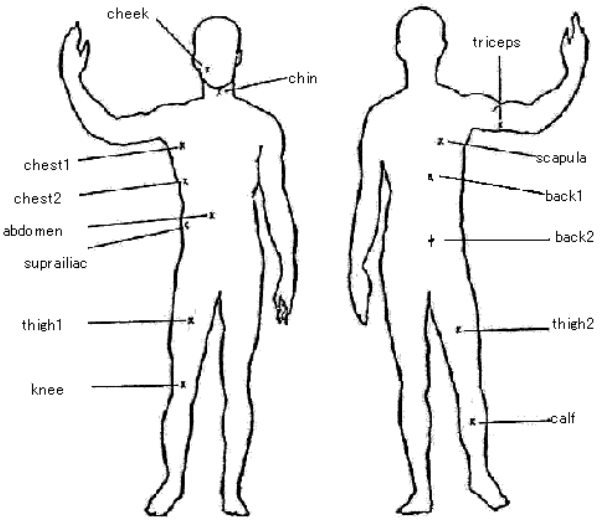

Figure 1 Measurement sites

2.3. Statistical analyses

Intra-class correlation coefficient (ICC) and coefficient of variance (CV) were calculated to evaluate re-test reliability and individual differences in Sthickness of each site, respectively. Gender differences in Sthickness were assessed by t-test. To determine the relationship between CP- and US-based Sthickness, the skinfold ratio (CP/US) and Pearson's correlation coefficients were calculated. Statistical significant level was set at $p < .05$.

3. Results

3.1. Re-test reliability

Intra-class correlation coefficients were higher than 0.95 in CP method, and higher than 0.89 in US method (Table 1). Insignificant mean differences between trials were found in both methods.

3.2. Characteristics of skinfold thickness

Table 2 shows mean and standard deviation, coefficient of variance (CV), and the results of gender differences in each Sthickness measured by CP and US methods. The highest mean CP-based Sthickness value was found in back 1 (9.8 mm) in males, and thigh 1 (16.2 mm) in females, while the highest US-based Sthickness value was found in thigh 2 (4.1 mm) in males and thigh 1 (7.2 mm) in females. The highest CV value in CP method was found in abdomen (54.8) in males and knee (53.7) in females, while that in US method was found in suprailiac (52.3) and knee (53.7) in females. This study evaluated each CV value based on the mean ± 1 SD. The CV values in CP method which were higher than the mean + 1 SD were found in abdomen, suprailiac and calf in males and knee in females, while those in US method were found in suprailiac, triceps and back 1 and suprailiac and knee in females. The CV values in CP method which is lower than the mean - 1 SD were found in subscapula, knee, back 1 and back 2 in males and thigh 1 and back 1 in females, while those in US method were found in chest 1 subscapula and back 2 in males and thigh 1 in females. Significant gender differences in Sthickness were found in all sites except for abdomen in CP method and subscapula in US method, and Sthicknesses were significantly greater in females than males.

Table 1 Re-test reliability in CP and US methods (n=32)

		First		Second		Reliability		
	Sites	Mean	SD	Mean	SD	ICC	F-value	
Caliper	Cheek	5.6	1.81	5.5	1.80	0.96	0.04	ns
	Chin	3.9	1.61	3.9	1.70	0.97	0.01	ns
	Chest1	5.0	1.47	4.7	1.40	0.95	0.76	ns
	Chest2	6.9	3.73	6.8	3.67	0.99	0.01	ns
	Abdomen	10.5	5.82	10.6	5.50	1.00	0.00	ns
	Suprailiac	7.9	3.65	7.8	3.43	0.99	0.02	ns
	Thigh1	14.8	6.82	15.1	6.82	1.00	0.03	ns
	Knee	8.5	2.90	8.4	2.88	0.98	0.02	ns
	Triceps	9.6	3.89	9.5	3.71	0.99	0.00	ns
	Scapula	10.5	3.43	10.4	3.50	0.99	0.01	ns
	Thigh2	19.3	6.86	19.1	6.93	1.00	0.01	ns
	Calf	11.6	3.94	11.5	4.23	0.99	0.01	ns
	Back1	12.3	3.44	12.2	3.30	1.00	0.01	ns
	Back2	9.5	3.77	9.5	3.79	1.00	0.00	ns
Ultrasound	Cheek	2.9	0.91	2.8	0.80	0.92	0.76	ns
	Chin	2.8	0.94	2.8	0.90	0.93	0.02	ns
	Chest1	3.6	1.07	3.6	1.05	0.91	0.01	ns
	Chest2	3.6	1.01	3.5	0.88	0.89	0.16	ns
	Abdomen	5.6	2.50	5.7	2.44	0.99	0.01	ns
	Suprailiac	3.8	1.86	3.8	1.82	0.98	0.02	ns
	Thigh1	5.8	2.49	5.8	2.41	0.98	0.00	ns
	Knee	4.1	1.54	4.4	1.79	0.95	0.45	ns
	Triceps	6.2	2.70	6.2	2.67	0.99	0.00	ns
	Scapula	4.9	1.10	4.9	1.13	0.92	0.00	ns
	Thigh2	6.2	2.11	6.1	2.17	0.98	0.03	ns
	Calf	4.5	1.65	4.6	1.66	0.98	0.02	ns
	Back1	4.2	2.45	4.2	2.42	0.99	0.00	ns
	Back2	4.0	1.55	4.0	1.64	0.98	0.01	ns

Note. Reliability was evaluated by intra-class correlation coefficient. F-value was obtained by the results of ANOVA.
ns: not significant

Table 2 Mean and standard deviation, CV, and the results of gender differences in skinfold thickness measured by CP and US methods.

		Total (n=110)			Male (n=54)			Female (n=56)			Gender diff.
	Sites	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV	t-value
Caliper	Cheek	4.9	2.92	59.0 a	3.0	1.40	46.1	6.8	2.81	41.4	*
	Chin	3.9	1.95	49.5	2.7	0.91	34.1	5.2	1.91	36.9	*
	Chest1	6.2	2.90	46.6	5.0	2.49	50.1	7.4	2.77	37.4	*
	Chest2	7.8	3.25	41.9	6.9	2.85	41.3	8.6	3.41	39.5	*
	Abdomen	8.9	4.05	45.8	8.1	4.45	54.8 a	9.6	3.53	36.9	ns
	Suprailiac	6.1	3.18	52.2	4.4	2.36	53.5 a	7.7	3.05	39.6	*
	Thigh1	12.4	5.45	43.8	8.5	3.46	40.7	16.2	4.20	25.9 b	*
	Knee	7.2	3.99	55.4 a	5.4	1.58	29.2 b	8.9	4.79	53.7 a	*
	Triceps	9.0	4.16	46.3	6.5	3.02	46.4	11.4	3.68	32.4	*
	Scapula	10.2	3.10	30.5 b	9.4	2.77	29.4 b	10.9	3.25	29.8	*
	Thigh2	12.4	5.39	43.4	9.2	4.08	44.2	15.5	4.66	30.0	*
	Calf	10.3	4.71	46.0	8.0	4.31	53.9 a	12.4	4.04	32.5	*
	Back1	11.6	3.55	30.7 b	9.8	2.93	29.8 b	13.3	3.29	24.8 b	*
	Back2	10.0	3.43	34.4	8.7	2.82	32.4 b	11.2	3.53	31.4	*
	mean ± SD in CV			44.7 ± 8.43			41.9 ± 9.49			35.2 ± 7.39	
Ultrasound	Cheek	2.6	1.17	44.2	2.1	0.85	40.7	3.2	1.19	37.5	*
	Chin	2.7	1.06	39.4	2.3	1.00	43.8	3.1	0.97	31.6	*
	Chest1	3.4	1.41	41.8	2.9	0.94	33.0 b	3.9	1.60	41.5	*
	Chest2	3.5	1.31	37.4	3.1	1.12	35.7	3.9	1.39	35.8	*
	Abdomen	4.3	1.83	42.8	3.7	1.60	43.1	4.8	1.89	39.0	*
	Suprailiac	2.9	1.76	60.3 a	2.0	1.05	52.3 a	3.8	1.86	48.7 a	*
	Thigh1	5.6	2.48	44.4	3.9	1.44	37.0	7.2	2.18	30.2 b	*
	Knee	3.9	2.09	53.8 a	3.1	1.08	35.1	4.7	2.50	53.7 a	*
	Triceps	5.3	2.46	46.6	4.0	2.08	52.2 a	6.5	2.14	32.7	*
	Scapula	4.1	1.33	32.7 b	3.9	1.30	33.4 b	4.3	1.35	31.8	ns
	Thigh2	5.4	2.35	43.2	4.1	1.67	40.9	6.8	2.18	32.2	*
	Calf	4.3	2.03	46.9	3.6	1.54	42.8	5.1	2.20	43.6	*
	Back1	3.9	1.75	45.0	3.5	1.69	47.7 a	4.2	1.76	41.6	*
	Back2	4.1	1.45	35.5 b	3.7	1.13	30.4 b	4.4	1.64	36.9	*
	mean ± SD in CV			43.9 ± 7.06			40.6 ± 6.94			38.4 ± 6.92	

Note. CV:Coefficient of variance, a: CV > (mean in CV) + 1SD, b: CV < (mean in CV) - 1SD, *:$p<0.05$, ns:not significant

3.3. Relationship between skinfold thicknesses measured by CP and US methods

Table 3 shows skinfold ratio (SR) and correlation coefficients between Sthicknesses measured by CP and US methods. The mean ± SD in SR were 2.25 ± 0.38 in total sample, 2.15 ± 0.41 in males and 2.33 ± 0.38 in females. The highest value was found in chin (3.05 in males and 3.38 in females), and the lowest value was found in back 1 (1.35 in males and 1.78 in females). Significant correlations were found in all sites except for chest 2 in females. The higher correlations ($r > .70$) were found in chest 2, abdomen, thigh 1, triceps, subscapula, thigh 2, calf, back 1 and back 2 in males, and in cheek, thigh 1, knee and subscapula in females.

4. Discussion

ICC of each site was greater than 0.95 in CP method and 0.89 in US method. Although the re-test reliability is considered to be high in both methods, it tended to be lower in US than CP methods. It has been reported that the measurement error of Sthickness by US method is smaller than that by CP method.[1,4,8] This result can be caused by the difference in the relationship between measurement scale and Sthickness size in two methods. The measurement scale is millimeters in both methods, but Sthickness measurement is greater in CP than US methods because of difference in measurement principle. Thus, the relative contribution of the difference of 1 millimeter to total variance in Sthickness is greater in US than CP methods, and this may also influence correlation coefficient and ICC. The lower ICC values in US method were found in the sites with thin Sthickness, such as cheek, chin, chest 1 and chest 2. Sthicknesses at triceps and subscapula are often used to estimate the body density by the estimation equation of Nagamine and Suzuki.6) Their ICC values in CP method were also high in this study. In estimating visceral fat mass using Sthickness at 14 sites, the accuracy of US method may influence the

Table 3 Skinfold ratio(CP/US) and correlation coefficients between CP and US methods.

	Total (n=110)				Male (n=54)				Female (n=56)			
Sites	mean	SD	r		mean	SD	r		mean	SD	r	
Cheek	1.92	0.76	0.72	*	1.62	0.74	0.31	*	2.21	0.67	0.74	*
Chin	1.57	0.67	0.52	*	1.35	0.58	0.42	*	1.78	0.68	0.41	*
Chest1	1.96	0.82	0.42	*	1.81	0.76	0.43	*	2.10	0.85	0.27	ns
Chest2	2.28	0.75	0.68	*	2.26	0.60	0.71	*	2.31	0.86	0.62	*
Abdomen	2.14	0.67	0.69	*	2.19	0.62	0.85	*	2.09	0.72	0.54	*
Suprailiac	2.34	0.88	0.69	*	2.52	1.02	0.40	*	2.17	0.69	0.66	*
Thigh1	2.28	0.55	0.89	*	2.19	0.44	0.87	*	2.37	0.64	0.76	*
Knee	1.95	0.57	0.83	*	1.89	0.59	0.45	*	2.01	0.56	0.85	*
Triceps	1.78	0.59	0.80	*	1.70	0.51	0.90	*	1.85	0.66	0.59	*
Scapula	2.59	0.61	0.74	*	2.54	0.63	0.75	*	2.64	0.60	0.73	*
Thigh2	2.42	0.96	0.67	*	2.34	0.86	0.70	*	2.50	1.05	0.39	*
Calf	2.45	0.83	0.72	*	2.30	0.86	0.70	*	2.60	0.78	0.67	*
Back1	3.22	0.96	0.60	*	3.05	0.96	0.78	*	3.38	0.94	0.43	*
Back2	2.52	0.66	0.69	*	2.38	0.52	0.77	*	2.65	0.75	0.62	*
Total mass	2.15	0.26	0.92	*	2.08	0.26	0.91	*	2.21	0.24	0.86	*
Mean	2.24				2.15				2.32			
SD	0.38				0.41				0.38			

Note. *:$p<0.05$, ns: not significant

estimation of visceral fat mass.

Comparing the characteristics of Sthickness measured by CP and US methods from the viewpoints of gender differences and individual differences, there were significant gender differences in all sites except for abdomen in CP method and subscapula in US method. Individual differences in Sthickness varied among body sites, and they were greater in abdomen, suprailiac, calf, triceps and back 1 in males, and in knee and suprailiac in females. These results mean that there are individual differences in subcutaneous fat distribution and body fat distribution.[11] In both methods, CV values of Sthickness were greater in suprailiac in males and knee in females, and they were smaller in subscapula and back 2 in males and thigh 1 in females. However, the CV values for the other sites were different between CP and US methods. Furthermore, comparing gender differences in CV of Sthickness among body sites, size of gender difference in CV varied among body sites, and the relationship of size of its difference among body sites also differed between the two methods. Therefore, it is suggested that there are gender differences in subcutaneous fat distribution and this difference is influenced by Sthickness at the sites showing large CV value, and that there are some possibilities of differing how to produce the measurement error between CP and US method.

Significant correlations between CP and US methods were found except for chest 2 in females, but its values were lower than 0.5 in cheek, chin, chest 1, suprailiac, knee in males, and chin, chest 1, chest 2, thigh 2 and back 1 in females. Since the females are different from males in subcutaneous tissue characteristics at the chest and their fat tissue at breasts grow more than males, there is a possibility that this makes the measurement difficult by CP method, which required to pinch the subcutaneous tissue.[10]

The SR (CP/US) was highest in back 1 (3.05 in males and 3.38 in females), and lowest in chin (1.35 in males and 1.78 in females). Although measurement error in US method is caused by unskillful operation and the difficulty of judging a dividing line between subcutaneous fat tissue and other internal tissue, it is reported that measurement error is smaller in US than in CP methods.[1,10] Assuming that the US-based Sthickness is more accurate, results in this study mean that the CP method overestimates Sthickness three times over in maximum as compared with the US method. Since the tester pinches subcutaneous fat tissue in CP method, the measurement is often considered to be double of actual thickness. However, as seen in Table 3, there are various body sites which the measurement value becomes double and over, or double and below, and these characteristics also differ between males and females. In reality, it is impossible to pinch only subcutaneous fat tissue, and there are the cases that the tester pinches subcutaneous fat tissue with including other internal tissue, or that the tester cannot pinch efficiently.[8] Saitoh et al.[7] reported that there is a sig-

nificant difference ($p<0.01$) between male's body density values calculated from CP-based Sthickness and doubled US-based Sthickness. These results may be one of the causes by the difference of measurement principles.

As mentioned above, the body sites where gender differences or individual differences were found in Sthickness and the relationship of Sthickness size among body sites are different between CP and US methods. Since Sthickness measured by CP method is not always double value of that by US method, it will be necessary to develop estimation equation of subcutaneous fat mass measured by CP- and US-based Sthicknesses, respectively. In addition, further studies should be made on the differences in visceral fat mass, subcutaneous fat mass and body fat distribution estimated by Sthickness values.

In conclusion, major findings of this study are as follows. Re-test reliability of Sthickness at 14 sites measured by CP and US methods is satisfactorily high. Individual differences in Sthickness are greater in abdomen, suprailiac, calf, triceps and back 1 in males, and in knee and suprailiac in females than other variables. These body sites influence individual differences in subcutaneous fat distribution. Correlations between Sthicknesses measured by CP and US methods are rather low in cheek, chin, chest 1, suprailiac and knee in males, and in chin, chest 1, chest 2, thigh 2 and back 1 in females, and it is important to note the differences in measuring error between CP and US methods.

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