The Influence of Ageing and Diabetes on Skin and Subcutaneous Fat Thickness in Different Regions of the Body

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KEY WORDS: age, skin thickness, subcutaneous fat

ABSTRACT

Diabetes and ageing are associated with skin damage and a reduction in skin blood flow. In the present investigation, 50 male and female subjects were examined to assess the thickness of subcutaneous fat and skin thickness in the hand, upper thigh, foot, triceps, scapula, lower back, and ball of the foot in relation to body fat, ageing, and diabetes. The results of the experiments showed a significant negative correlation between age and skin thickness ($P < 0.0001$) and age and subcutaneous fat thickness ($P < 0.001$). The greatest skin thickness was on the back and least was on the back of the hand. The thinnest skin was in people with diabetes. For subcutaneous fat, the back and foot had thicker subcutaneous fat than did the hand. People with diabetes had the thinnest fat layer on the foot although they had the greatest body fat, implying a shift with diabetes and age from subcutaneous fat to visceral fat. The only exception was the abdominal area where subcutaneous fat increased with diabetes. The reduced fat pad on the foot and thinner dermal skin layer should predispose older and especially people with diabetes to foot ulcers and poor healing.

INTRODUCTION

Both ageing and diabetes cause a reduction in resting blood flows and the response of the skin blood flow to a local heat source or a global heat stress.[1-5] Global heat stress is mediated by the autonomic nervous system through sympathetic cholinergic post-ganglionic pathways.[4] The vasodilatation is mediated by the release of principally nitric oxide in older individuals whereas other substances such as prostcylcin[6,7] and vasoactive intestinal peptide (VIP)[8] help mediate the response in younger individuals. In contrast, the response to local heat initially induces the endothelial cells of the blood vessels to release substance P and the pro-inflammatory neuropeptide calcitonin gene-related peptide,[9,10] but after a few seconds to a minute, nitric oxide dominates as the factor that causes additional and sustains skin blood vessel vasodilatation.[9,11] It is believed that age and diabetes both

Table 1. Skin and Subcutaneous Fat Thickness in Various Areas of the Body.

	Controls		Old		Diabetes		Overweight	
	Skin	Fat	Skin	Fat	Skin	Fat	Skin	Fat
Lower back (right)	0.08 ± 0.02	0.82 ± 0.21	0.05 ± 0.01	0.71 ± 0.21	0.04 ± 0.01	0.65 ± 0.13	0.07 ± 0.02	1.01 ± 0.07
Hand (2nd-3rd MC)	0.05 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.05 ± 0.01	0.05 ± 0.01
3rd MC bone	0.05 ± 0.01	0.06 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.06 ± 0.01	0.05 ± 0.01
Sub scapula	0.08 ± 0.01	0.7 ± 0.21	0.05 ± 0.01	0.66 ± 0.22	0.04 ± 0.01	0.61 ± 0.34	0.05 ± 0.02	0.95 ± 0.08
Triceps	0.07 ± 0.11	0.75 ± 0.02	0.05 ± 0.21	0.70 ± 0.01	0.04 ± 0.23	0.69 ± 0.01	0.06 ± 0.25	0.86 ± 0.02
Umbilicus	0.07 ± 0.02	0.73 ± 0.22	0.05 ± 0.01	0.85 ± 0.18	0.04 ± 0.01	1.06 ± 0.15	0.06 ± 0.01	1.09 ± 0.12
Quadriceps	0.07 ± 0.02	0.81 ± 0.19	0.05 ± 0.01	0.79 ± 0.12	0.04 ± 0.01	0.76 ± 0.34	0.06 ± 0.01	0.92 ± 0.10
Ball of foot	0.07 ± 0.02	0.14 ± 0.03	0.05 ± 0.01	0.09 ± 0.04	0.04 ± 0.01	0.08 ± 0.22	0.07 ± 0.02	0.13 ± 0.02

MC = metacarpal.

alter either the ability of the cells to produce nitric oxide or the sensitivity of nitric oxide receptors, causing a reduced blood flow response to thermal and other stimuli.[12-16] But there appears to be no loss of vasoconstriction of the skin with ageing or diabetes, only a reduction in vasodilatation,[12,13] indicating that ganglionic failure is probably not a predominant cause of age-associated reductions in the skin blood flow response to global heating since ganglionic damage would certainly affect both vasoconstriction and vasodilatation. Therefore, other factors must be involved in the response of the circulation of the skin due to ageing and diabetes.

Other factors are associated with the ageing process as well. There is some evidence that skin thickness decreases with ageing due to loss in the thickness of the dermal layer.[17] Thus, in response to a local heat stress, with a thinner dermal skin layer, there would be less circulatory cross sectional area[15] as well as poorer perfusion of the remaining skin circulation due to nitric oxide impairment in older individuals. Further, if body fat redistributes in older people, making it thinner in subcutaneous tissue and greater in abdominal tissue,[18-20] then heat dissipation would also be altered in the skin. But little has been done to examine different regions of the body, examine the skin in people with diabetes, or confirm this single report. Therefore, the purpose of the present investigation was to study the relationship between skin thickness, subcutaneous fat thickness in people with diabetes and in older, younger and overweight people.

PATIENTS AND METHODS

Subjects

Four groups of subjects participated in these experiments. One group (young, n = 15) had an average age of 25.7 ± 2.89 years, average height of 173.1 ± 13.1 cm, and average weight of 71.1 ± 12.4 kg. An older group (n = 15) had an average age of 66.9 ± 18.3 years, an average height of 162.2 ± 9.2 cm, and an average weight of 62.2 ± 7.5 kg. The group with

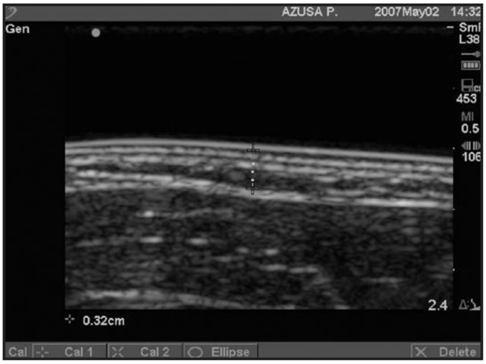

Figure 1. An ultrasound picture of the skin and subcutaneous fat.

diabetes (n = 10) had an average age of 60.1 ± 5.7 years, an average height of 168.0 ± 10.0 cm, and an average weight of 99.6 ± 23.7 kg. The average length of time since the onset of diabetes was 7.8 ± 3.5 years. Finally, an overweight group (n = 10) had an average age of 45.6 ± 15.7 years, an average height of 171.5 ± 11.6 cm, and an average weight of 107.1 ± 20.1 kg. All methods and procedures were explained to each subject and they then signed a statement of informed consent. All protocols were approved by the Institutional Review Board of Loma Linda University.

Determination of Fat and Skin Thickness

Measurement of skin and fat thickness was accomplished on a 2-D ultrasound system manufactured by Sonasite incorporated (Brothel, Washington). The device, Sonasite 180 plus, provided a weak ultrasound signal at a frequency of 10 million Hertz. The ultrasound signal reflected from the muscles below the probe created a 2-dimensional picture to measure the thickness of skin and subcutaneous fat. Because of physical problems in measuring the thickness of skin near the surface of the probe, a 1-cm standoff was used (Cone Instruments, Cleveland, Ohio). The probe was placed at an angle of 90° with respect to the skin and at angle of 37° a linear ray probe was used. This probe had 95 separate ultrasound elements to provide a high-resolution picture. To assure accuracy, the measurements were done by one single investigator. For reliability measures, 22 subjects whose average age was 25.7 ± 6.3 years old and whose average weight was 75.3 ± 60.4 kg were examined. Approximately half the subjects were male and half were female. The technique used to measure the reliability of the ultrasound was to have subjects come into the lab on 3 separate trials. On each trial, skin and fat thickness were measure 7 and 14 cm away from the spinal cord on the lower back bilaterally. The average skin thickness measured was 0.08 ± 0.01 cm and the average fat thickness was 0.84 ± 0.01 cm. The range of skin thickness was small, changing less than 0.01 cm in thickness. However, fat varied from 0.68 to 1.09 cm in thickness. On repeat measures, the coefficient of variation for skin thickness was 2.2 ± 3.3% and for fat thickness was 4.3 ± 5.1%. There was no significant difference between the fat thickness and skin thickness on any of the 4 areas of the back ($P > 0.05$). Skin thickness and subcutaneous fat thickness in the present investigation were measured on the lower back at L4 at 7 cm lateral to the spine, on the ball of the foot, on the back of the hand near the wrist between the second and third metacarpal and above the third metacarpal bone, above the triceps, and above the medial head of the quadriceps. A typical ultrasound picture for the back is shown in Figure 1. The subcutaneous fat layer is marked.

Statistical Analysis

Statistical analysis involved the calculations of means and standard deviations. To compare data, related *t*-tests, unrelated *t*-tests, and analysis of variance (ANOVA) were employed. The level of significance was $P \leq 0.05$.

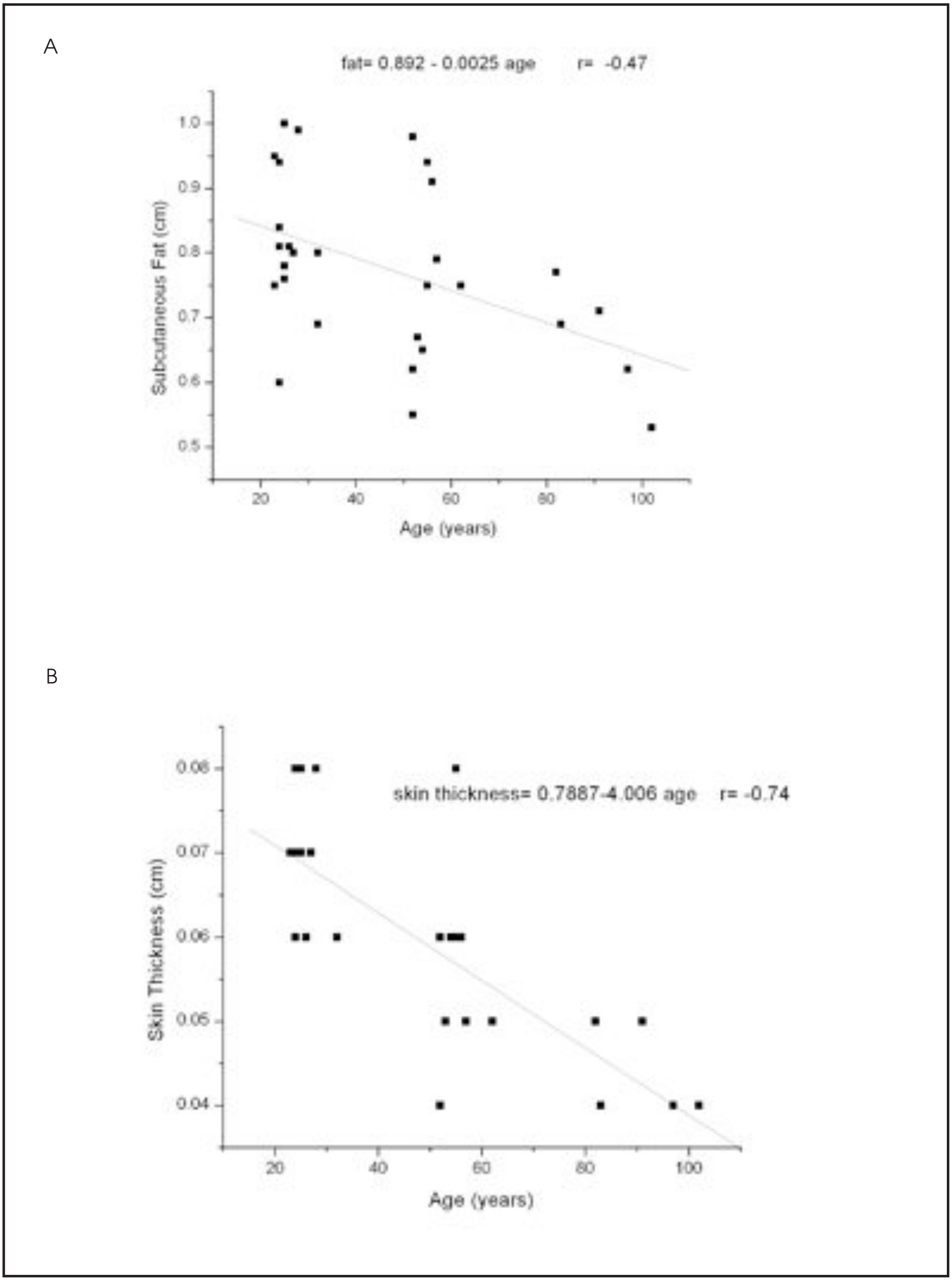

Figure 2. The thickness of the subcutaneous fat layer in relation to the age of the 2 groups of subjects in A and the relationship between the skin thickness and age of the subjects in B. Each panel shows also the regression equation relating the 2 variables. The slope of the regression was significantly different than zero in both cases ($P < 0.001$). The correlation coefficient (r) is also shown and was significant in both cases ($P < 0.01$).

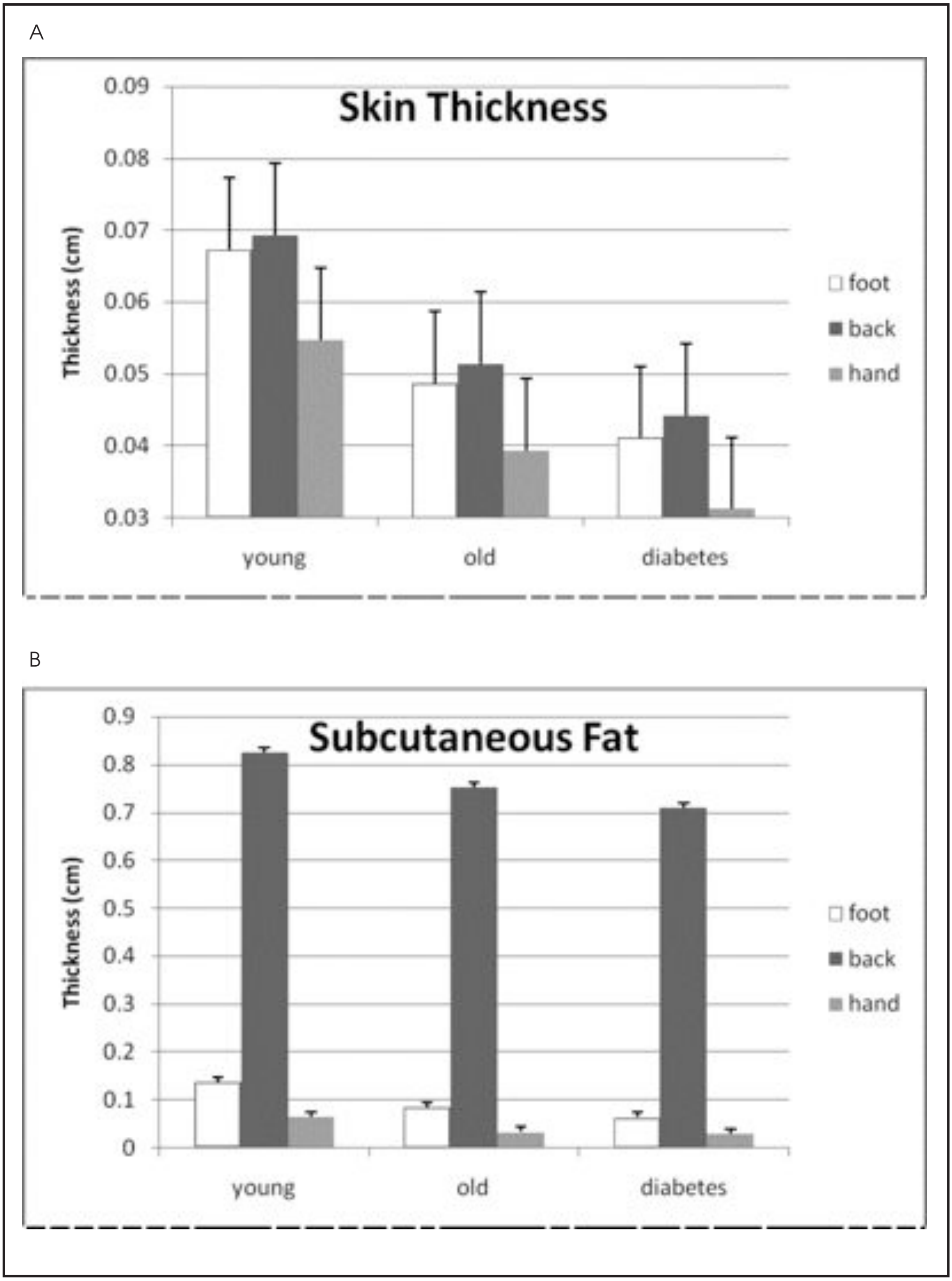

Figure 3. The thickness (A) and subcutaneous fat thickness (B) for the hand, back, and ball of the foot in the younger, older, and diabetes subjects.

RESULTS

The individual results are typified for the young and old group where data has been pooled together for the back measurements for ease of presentation (Figure 2). The average subcutaneous fat of the younger group was 0.82 ± 0.16 cm and for the older group was 0.71 ± 0.11

cm thick; these differences were significant ($P < 0.01$). As seen in Figure 2A, the correlation was -0.47, a significant negative correlation ($P < 0.01$) for this group. The regression equation is shown. Skin thickness was likewise significantly reduced with age ($P < 0.01$) and the slope of the regression line in Figure 2B was significantly less than zero ($P < 0.001$) as was the regression coefficient ($P < 0.01$). For the entire group of 30 subjects, skin thickness averaged 0.06 ± 0.013 cm. In the older subjects, the ultrasound showed the skin to be hyper echoic compared to the younger group with the appearance of much more skin density.

Looking at the average group results in Figure 3, also for the back, the skin thickness was greater for the youngest subjects in all 3 areas of the body compared to the older and diabetic group of subjects (ANOVA $P < 0.05$). The greatest skin thickness was on the back and the thinnest on the back of the hand. The older subjects had thinner skin at each area and the subjects with diabetes had even thinner skin at each area.

Table 1 shows the results of the skin and fat measures at each area of the body, some of which are shown graphically in Figure 3 as a basis for comparison. As seen in this table, there was a general reduction in skin and fat thickness in older people and people with diabetes. For all areas except the umbilicus, subcutaneous fat decreased with age and diabetes; for the umbilicus, subcutaneous fat increased with age and diabetes. Being overweight increased subcutaneous fat in all areas compared to the younger, thinner subjects. The reductions in skin and subcutaneous body fat in the older and diabetic groups compared to the young group was significant ($P < 0.05$). Figure 3 directly compared 3 areas of the body.

For subcutaneous fat (Figure 3B), the back showed significantly more subcutaneous fat than observed in the other 2 areas of the body (ANOVA $P < 0.001$). Here again, the older subjects had less subcutaneous fat at each area and the subjects with diabetes had even less subcutaneous fat. Because the subjects with diabetes were heavier than the age-matched older subjects, a correlation was calculated between subcutaneous fat and the body mass index (BMI) in the younger group for all 3 areas of the body. The correlation was 0.68, significant at $P < 0.05$. Thus, it would be expected that the subjects with diabetes would have more subcutaneous fat and not less.

DISCUSSION

Ageing has been associated with a reduction in skin blood flow and numerous changes in the structure of the skin including changes in skin collagen, skin thickness, and the response of the skin vasculature to local and global heat stress.[17,21] In the present investigation, we also found that the skin was thinner with ageing. The thinner skin in older people has been reported to be due to a thickening in the stratus corneum and a thinning in the dermal layer. A thinning in the dermal layer implies less vasculature in the skin in older rather than younger people. This was also true in people with diabetes. Thinner skin should make the skin more susceptible to damage such as burns and injuries and, as is the case for people with diabetes, make the skin harder to heal. The subcutaneous fat layer was also reduced here with ageing as has been reported elsewhere.[18-20] This may be critical for the foot especially due to even greater thinning in people with diabetes on the foot since the reduction in the thickness of foot padding would make the foot more susceptible to lesions during gait. When added to the thinner dermal layer in the skin, this would make the skin even harder to heal. It has been assumed that the reduction in blood flow with ageing and diabetes is solely due to impairment in nitric oxide synthase, a vascular endothelial mediator of vascular smooth muscle dilatation.[1,15,16] But thinner skin would certainly mean less blood vessel density and also account for some of the reduction in skin blood flow. Making matters worse, the high correlation between subcutaneous fat and BMI and the greater BMI in the subjects with diabetes would imply that their fat layer should even be thinner if they had normal weight. Thus someone with diabetes, but thin, would even be more susceptible to foot injuries during gait.

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