Skin-to-Fat Water in Diabetes Mellitus Assessed by Tissue Dielectric Constant (TDC): Variations with Respect to Depth, Anatomical Site and HbA1C

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Background and Objectives

BACKGROUND: Worldwide, there are about 285 million people who have been diagnosed with Diabetes Mellitus (DM) and about 1/3 of them have skin changes[1-2]. Prior research has indicated alterations in skin-to-fat tissue water especially prevalent in foot dorsum skin but specific mechanisms have not been clarified. Literature is consistent with the theory that hyperglycemia-induced non-enzymatic glycation of structural and regulatory proteins may play a role in the pathogenesis of diabetic complications. In this scenario, excess supply of glucose in the blood plasma leads to a non-enzymatic chemical reaction between the carbonyl group of glucose and the amino acid of proteins[4]. This glycation of structural and regulatory proteins might play a role in the pathogenesis of diabetic skin complications.

Purpose

The purpose of this study is to test the hypothesis that in persons with DM the dermal collagen glycation displaces bound water and thereby decreases skin tissue water. If true then a measurable relationship between skin water and HbA1c should be present. Hence, we are testing if there is a positive relationship between skin-to-fat tissue water as measured by TDC, and HbA1c values in persons with DM. Further because of already demonstrated differences in TDC values between genders these measurements are being conducted in both male and female subjects.

Protocol

BIOIMPEDANCE MEASUREMENTS were done to obtain total body composition using the Ironman InnerScan Body Composition Monitor (**Figure 3c**). The Ironman is a non-invasive, battery operated device that measures the electrical impedance value of the body while the subject is in the standing position. The subject's gender, birth date, and height are entered into the device after which the subject removes shoes and socks and step onto the scale and grip two attached handles for a period of about 20 seconds (**Figure 2**). Relevant measured parameters include: weight, body fat percent, body water percentage, muscle mass, visceral composition, BMI.

TDC MEASUREMENTS were obtained using the MoistureMeter-D, Delfin Inc. (Figure 1). The MoistureMeter is a non-invasive, battery operated hand-held device utilizing gold plated brass open-ended coaxial probes (**Figure 3a, b**). The probe measures TDC at a frequency of 300 MHz. For the purpose of this study probes used had an effective penetration depths of 0.5 mm, 1.5 mm, 2.5 mm and 5.0 mm. For reference, pure water has a TDC value of 76 at 34°C. The sites measured were the anterior forearm 6 cm distal to the antecubital fossa, 10 cm superior to the medial malleolus and dorsum of the foot between the junction of the 1st and 2nd toes. All measurements are conducted on the dominant side of the subject. Each TDC measurement was done in triplicates and averaged.

Measurement Methods

FIG 1

FIG 1. TDC Measurements

Tissue Dielectric Constant is directly related to H_2O in the measuring volume. The unit is the Moisture Meter-D (Delfin Tech). A coaxial probe contacts skin for about 10 seconds. The probe, connected to a control and display device, measures TDC at 300 MHz so the TDC value depends on free and bound H_2O. TDC was measured to effective depths of 0.5 mm, 1.5 mm, 2.5 mm and 5.0 mm. As reference, pure H_2O has a dielectric constant value of 76 at 34°C.

FIG 2

FIG 2. Body Composition

Bioimpedance was used to estimate total body & segmental composition parameters including total body %H_2O & %Fat and muscle mass (MM) & arm & leg %Fat & MM. The method depends on passing a small electrical current, measuring the impedance and using a model representation of the body components.

Algorithms to estimate body parameters from the model are usually company private.

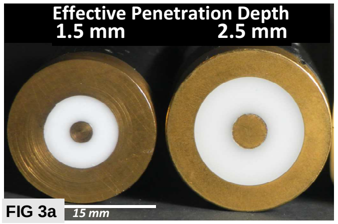


FIG 3a

FIG 3b

FIG 3c

Descriptive Parameters

TABLE 1

	range	mean ± standard deviation
Age (yr)	31-86	65.9 ± 14.7
BMI (kg/m²)	19.1-36.6	27.1± 5.1
HbA1c (check)	5.5-12.9	8.1± 1.8
Glucose (mmol/L)	92-349	171.3 ± 61.7
Total Body Water (%)	40.6-60.4	48.6 ± 5.4
Total Body Fat (%)	15.6-43.8	32.4 ± 7.5
BP Systolic (mmHg)	98-180	121.2 ± 20
BP Diastolic (mmHg)	50-100	72 ± 11.9

Results and Analysis

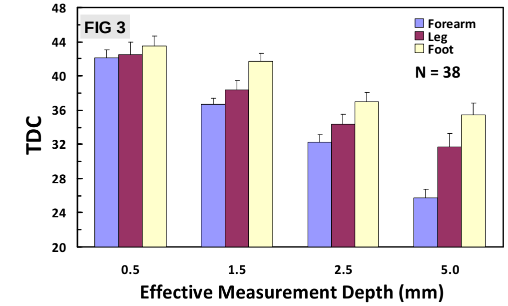
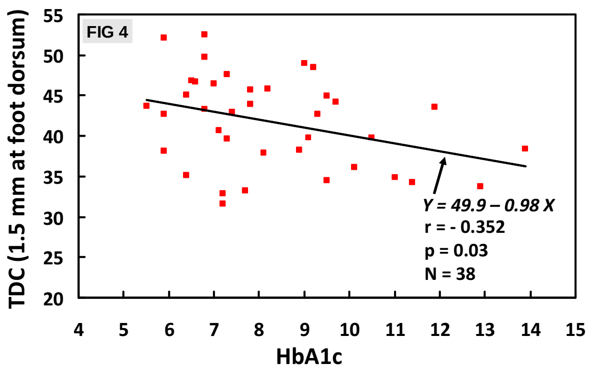


Figure 3. TDC by Site and Depth. Comparisons among depths showed that TDC values monotonically decreased from the most shallow at 0.5 mm to the deepest at 5.0 mm (p<0.001). TDC values at each depth were significantly (p<0.001) different from each of the others. TDC values tended to be highest at the foot, middle at the leg and least at the forearm. However statistical significance of these differences depended on the measurement depth being highly significant at 5.0 mm (p<0.001) and not significant at 0.5 mm. However no significant negative correlation between TDC values and HbA1c was found at any depth or site except for the foot dorsum as shown in FIIG 4.



Conclusion

This study's focus was to test the hypothesis that HbA1c and skin-to-fat tissue water were related as measured at different depths and different sites of persons with DM. A trend for a negative correlation between TDC values and HbA1c was statistically significant only for foot dorsum for a measurement depth of 1.5 mm.(**FIG 4**). About 12% of TDC variation could be explained by HbA1c variation. However, this dependence is unlikely to be of clinical importance and may be related to a similarly found negative foot TDC-HbA1c correlation (p<0.05) with total body fat. The TDC depth and site data provide hither-to-fore unavailable baseline information on patients with diabetes.

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