

## **Title: Normative Lower-to-Upper Limb Tissue Dielectric Constant Ratios with Possible Application to Lower Extremity Edema**

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**Background:** Lower extremity edema occurs in many conditions including congestive heart failure, lymphedema, diabetes-related, kidney and liver disease, chronic venous insufficiency with venous hypertension. Clinical edema assessment methods are often subjective and variable. Our goals were to introduce a simple noninvasive measurement procedure potentially useful to characterize lower extremity edema by providing normative values from which edema thresholds might emerge. A non-invasive way to assess local skin water is by measuring skin tissue dielectric constant (TDC) since TDC depends strongly on skin-to-fat water content.

**Objective:** Our research goal was to determine and present such TDC normative ratios, initially for healthy young persons, as a first step in developing normative reference values and ranges to potentially aid in the early detection and tracking of lower extremity edema.

**Methods:** TDC measurements were made using a hand-held, commercially available device that records TDC values by touching skin for 5-7 seconds. For reference, the value for pure water at 32°C is 76. Measurements were done in triplicate, bilaterally at three lower limb sites and at two upper limb sites. Measurements were done in 22 women ( $24.9 \pm 2.5$  years) and 22 men ( $25.3 \pm 1.8$  years) after each signed an IRB approved consent form. Absolute TDC values for each site and gender were determined and lower limb / upper limb ratios (LL/UL) were determined for each site. All values are mean  $\pm$  SD.

**Results:** TDC values did not significantly differ between dominant and non-dominant sides at any site for either gender. However, TDC values were greater for males at forearm ( $33.3 \pm 3.2$  vs.  $27.5 \pm 3.0$ ,  $p < 0.001$ ) and foot dorsum ( $32.3 \pm 4.9$  vs.  $28.1 \pm 2.8$ ,  $p < 0.001$ ). There were no gender related differences at the other measured sites with the largest TDC value measured at the hand ( $42.1 \pm 7.9$ ). The LL/UL ratios were normally distributed and varied depending on sites included in the ratio. However, the LL/UL ratio that had the least variance among subjects and also did not differ between genders, was the foot/forearm ratio. For measurements in 44 subjects (88 legs) the foot/forearm ratio was  $1.003 \pm 0.146$  with a median value of 1.004.

**Conclusion:** Our current findings suggest that measurement of the foot/forearm and leg/forearm TDC ratios provide useful assessment parameters for detecting early lower extremity edema when that ratio exceeds a specified threshold greater than determined in the present healthy group. At this time, the optimum threshold value is somewhat arbitrary but a reasonable selection would be a value that is greater than the currently determined mean value plus 2SD. This would define a threshold for edema as a foot/forearm ratio greater than 1.300 and a similar value for the leg/forearm ratio threshold.