# Human Hydration Monitoring using Microwaves: System Assessment Using Fasting Volunteers

Brendon C. Besler, David C. Garrett, Sarah Thorson, Elise C. Fear
Department of Electrical and Computer Engineering
University of Calgary
Calgary, Canada
brendon.besler@ucalgary, fear@ucalgary.ca

***Abstract*—A novel system for hydration monitoring using microwaves estimates changes in forearm permittivity to assess hydration status. Previous work with athletes undergoing acute water loss showed promising results. Initial results from volunteers fasting during Ramadan are presented here.**

***Keywords—nutrition and hydration, microwave sensors, dielectric measurements, microwave imaging.***

## I. Introduction

Hydration is important for proper physiological function in humans. Even at mild levels, dehydration can cause physical and cognitive impairments in healthy adults [1]. Currently there is no clinical gold standard for measurement of hydration [2]. While methods for continuous hydration assessment are emerging, these approaches have not been fully validated [3]. Microwave techniques provide a promising method of hydration assessment due to the strong relationship between tissue permittivity and water content. Our group has developed a microwave hydration assessment system that uses antennas in contact with the forearm to estimate the tissue permittivity and monitor changes in hydration. A study using athletes undergoing acute water loss during a practice session has provided preliminary validation of this method [4].

In this work, the microwave hydration assessment system is tested with volunteers fasting during the month of Ramadan. Typically this involves abstaining from food and drink from sunrise to sunset. Studies have shown that participation in Ramadan fasting can cause changes in body composition [5]. People fasting during Ramadan can lose as much as 2% total body weight during a day, predominately from water loss [6]. To test if the microwave hydration assessment tracks these changes, we measure volunteers three times per day during and after Ramadan.

## II. Methods

A custom measurement setup consisting of two antennas designed to operate in contact with human skin was previously implemented [7]. These ultra-wideband antennas are shielded and dielectric-loaded [8]. The antennas radiate from 1.8-20 GHz, with signals above 7 GHz being attenuated beyond the sensitivity of the measuring device when propagating through tissues. The antennas are positioned at the midpoint of the forearm of each volunteer and tightened to be in good contact with the skin. Both antennas are connected to a vector network analyzer (Agilent N5230-A PNA-L) to record the complex scattering parameters from 10 MHz to 10 GHz.

Average permittivity is estimated by measuring the time-of-flight of signals transmitted through the forearm [9]. The measured signals are transformed into the time domain and the pulse arrival time found from the maximum of the pulse envelope. Permittivity is estimated by using the difference in arrival times from tissue and air measurements collected with the antennas separated by the same distance.

Volunteers were recruited though the University of Calgary Muslims' Student Association. This study was approved by the University of Calgary Conjoint Health Research Ethics Board (CHREB, ID: REB18-0700).

During the study, each volunteer was measured three days while fasting during Ramadan and three days post-fasting. Each measurement day consisted of three measurement sessions: morning, afternoon, and evening. Five microwave

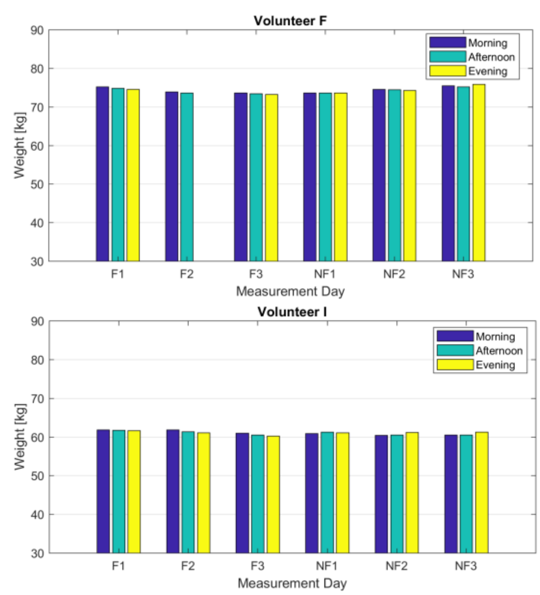


Fig. 1. Weight of select volunteers while fasting (F) and after fasting (NF).

measurements were taken during each session. Volunteers were weighed each session to provide an estimation of the amount of water lost.

## III. Results

During Ramadan, the weight of all volunteers consistently decreased every day, while after Ramadan the weight fluctuated arbitrarily as food and drink were consumed throughout the day. This decrease in weight during Ramadan is consistent with observations in previous studies [6]. Examples of this decrease are shown in Fig. 1.

The permittivities of select volunteers are shown in Fig. 2. While decreases in permittivity are consistently seen for Volunteer I during Ramadan, Volunteer F does not have a consistent decrease while fasting.

Next, the change in permittivity between the first and last measurements each day was compared to the weight loss each day. In the previous athlete study there was a strong correlation between a reduction in permittivity and weight loss ($R^2$=0.6). Here this simple metric yields a weak relationship between change in permittivity and weight loss ($R^2$=0.168).

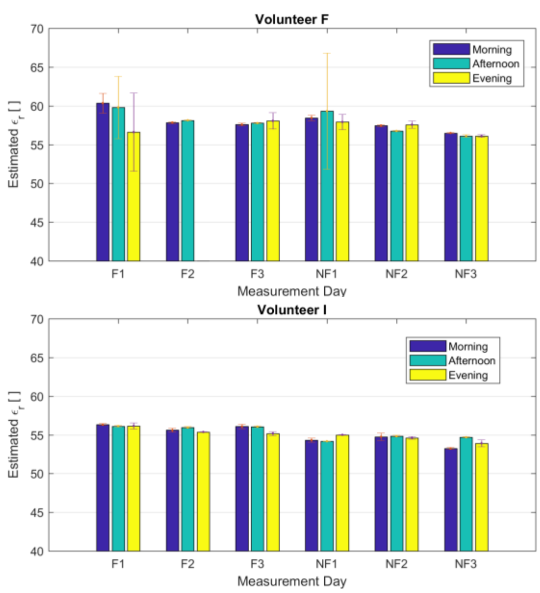


Fig. 2. Estimated tissue permittivity of select volunteers while fasting (F) and after fasting (NF). Error bars represent an estimate of variance.

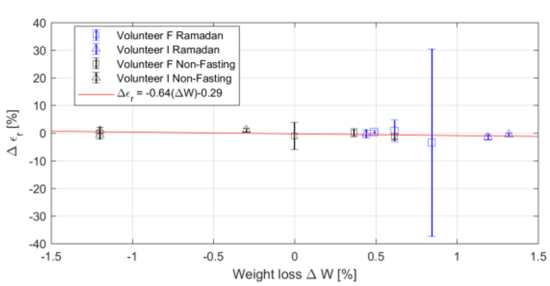


Fig. 3. Estimated tissue permittivity vs weight loss of select volunteers while fasting and after fasting. Error bars represent an estimate of variance.

## IV. Conclusion

While some volunteers show a relationship between change in permittivity and weight loss, this relationship was weak when multiple volunteers were considered. Further analysis of the remaining volunteers is required. Due to the correlated nature of the biometric parameters, more rigorous statistical analysis such as generalized estimating equations (GEE) may be able to control for confounding factors such as forearm circumference or blood pressure.


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