Clinical Evaluation of a Wearable Personal Hydration Monitoring Technology

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1. Background

- Non-invasive, real-time volume status monitoring may help physicians to adjust ultrafiltration rates (UFR) during dialysis to minimize the complications of fluid removal while optimizing patient volume status.
- Geca™ is a patented wrist-worn wearable that uses diffuse near-infrared and infrared spectroscopy (NIRS) to non-invasively assess tissue hydration. Data is sent from the sensor to a mobile App through Bluetooth® and transmitted to the Cloud for processing.
- Previous studies have demonstrated accuracy in Geca™ monitoring for athletes, yet no studies have looked at use in a dialysis population.
- This study was completed to evaluate the current Geca™ device and software and its ability to predict large changes in hydration status of patients. Additionally, sensor location on the patient's body during treatment was examined to evaluate whether placement on the upper or lower extremities resulted in higher accuracy.

Fig 1. Geca wearable and app dashboard.

2. Participant characteristics

Demographic Information	Count / Mean
Age (Years)	65 (*SD* = 6.96)
Sex (Male: Female)	4: 2
Ethnicity (Black/African American: Hispanic/Latino: White)	3: 1: 2

3. Methods

6 outpatients from UCSD Dialysis unit

6 sessions each

Fig 2. Sensor placement.

Treatment Time	Data Recorded
Pre-treatment	Sensor placed on wrist or bicep. Secondary sensor placed on ankle (14 sessions).
During treatment	Recorded Geca sensor readings, UFR, symptoms and interventions.
Post-treatment	Post-dialysis weight taken on scale per routine.

- For model training we combined the dialysis data with data from healthy adults (n = 11) who wore the sensor during their daily routine. Fluid intake and weight were recorded throughout the day from these participants.
- Percentage weight change from dry weight served as an indicator of fluid volume change and was estimated using participants' starting and ending weights, UFR (for IHD) and fluid intake (for healthy adults).
- Signals were filtered and signal features aggregated within 1-minute windows.
- For model training, we split the data into train and test sets by participant and session. All participants were represented in both the train and test sets (62 and 26 sessions, respectively). The best model was selected from the root mean square error (RMSE) on 10-fold cross-validation, and was a random forest regressor.

4. Results: Location agreement

- For eight sessions in the test set, Geca sensor were placed on both the arm and ankle.
- When comparing predictions from recordings taken on the ankle and arm, the two locations had similar predictions (bias = 0.18), *SD* [-1.85, 2.21].
- Measurements taken on the arm were more accurate than those taken on the ankle (*RMSE* = 2.15 vs *RMSE* = 3.26, respectively).

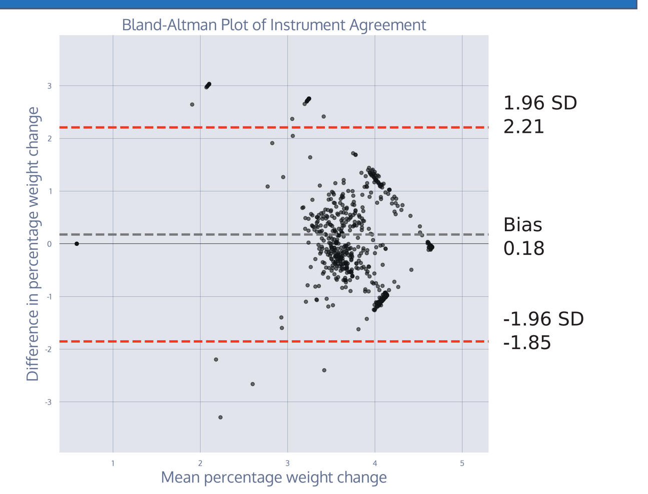

Fig 3. Bland-Altman plot of agreement between arm and ankle predictions.

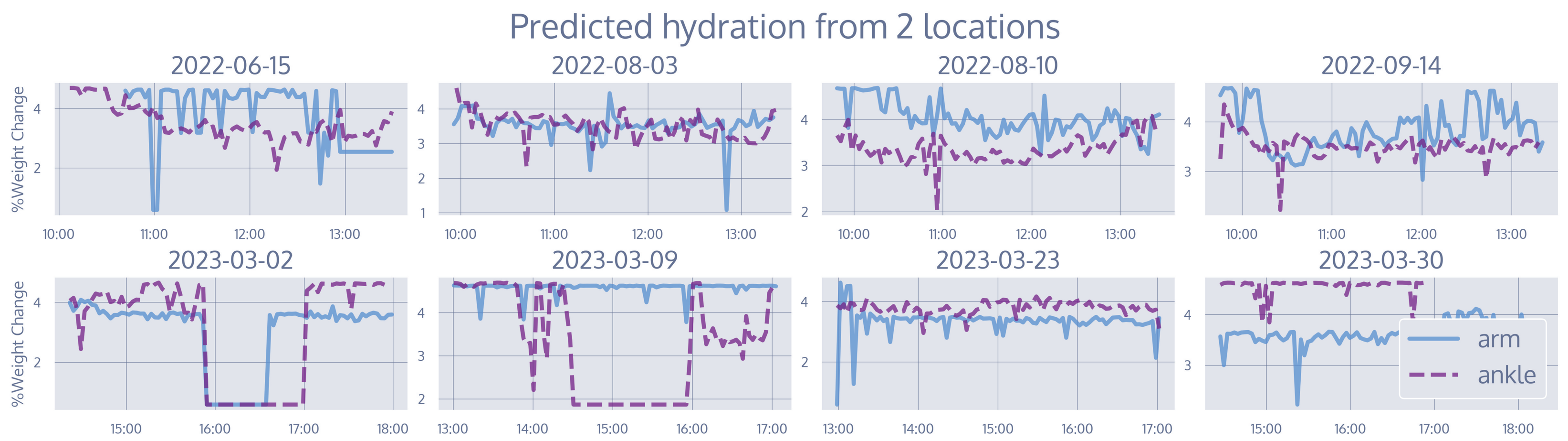

Fig 4. Correspondence between arm and ankle-based weight change predictions.

5. Results: Agreement with weight

- The average fluid loss at the end of IHD was 3,355ml. Percentage weight change ranged from 0.31 to 5.5% loss (*M* = 2.86, *SD* = 1.23). One session was discarded where the participant showed weight gain after dialysis.
- The best model predicted % weight change with an *RMSE* of 2.58 (R^2 = 0.28), compared to a baseline model based on median % weight change (*RMSE* = 3.05).
- Bland-Altman analysis of agreement between predicted versus actual % weight change (as estimated from UF rate, fluid intake and weigh-ins) found that sensor predictions had a mean bias of -0.55% weight change, 1.96 *SD* [-6.03, 4.93].

Fig 5. Bland-Altman plot of agreement between actual and predicted weight change.

6. Conclusion

- The Geca™ hydration sensor was able to be used during intermittent hemodialysis (IHD) without interfering with dialysis treatment. The novel wearable hydration sensor estimated patient fluids change with an average bias of -0.55% measured weight change.
- On average, the sensor had low bias but high variability in prediction accuracy, particularly on the arm.
- Measurements taken on the arm were more accurate than those taken on the ankle.
- More data is needed to improve fluid change estimates, particularly at fluid volume extremes. Additional modeling techniques that could increase accuracy include time-sensitive models and models that account for user demographics.

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