

Metabolic Monitoring at Home with a Smartphone-coupled Breath Sensing Device

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Summary:

Human metabolism can be monitored through non-invasive breath analysis suitable for home use. We developed a handheld breath acetone detector for smartphone-guided metabolic monitoring that provides accurate and reproducible measurements with strong stability across time and humidity. Individual metabolic responses of volunteers during exercise and dietary interventions were captured with high agreement with mass spectrometry. This work establishes a validation framework for translating breath detectors from laboratory prototypes into healthcare applications.

Keywords: nanotechnology, electronic device, sensor, mobile health, metabolism

Background, Motivation and Objective

Overweight and obesity affect a large proportion of the global population and are major risk factors for chronic diseases such as diabetes, cardiovascular disorders and cancer [1,2]. Effective management increasingly relies on personalized metabolic monitoring to guide lifestyle interventions, including diet and exercise [3]. Breath analysis offers a non-invasive approach to monitor fat metabolism through acetone, a volatile byproduct of ketogenesis that reflects the systemic metabolic state [4]. Its suitability for frequent and convenient sampling makes it attractive for home-based monitoring. However, most existing sensing approaches remain confined to laboratory environments, and translation into reliable, user-friendly handheld devices is still lacking [5]. Key challenges include achieving sufficient sensitivity, selectivity and long-term stability under varying environmental conditions, as well as ensuring reproducible breath sampling. Here, we aim to bridge this translational gap by developing and validating a handheld breath acetone sensing system designed for accurate, reproducible and user-guided metabolic monitoring in real-world settings.

Description of the New Method or System

We present a fully integrated handheld device (Fig. 1) for non-invasive metabolic monitoring via breath acetone detection, designed for unsupervised home use. The system combines a modular mouthpiece with volume-guided breath

sampling using a pressure sensor to ensure reproducible end-tidal sampling. Selective detection is achieved through a sorption column coupled to a chemoresistive sensor, enabling reliable acetone quantification. Automated sampling and regeneration cycles allow rapid and repeatable measurements. A smartphone interface provides real-time user guidance and data visualization, while cloud connectivity enables longitudinal tracking. This integration of controlled sampling, selective sensing and user feedback advances the translation of breath analysis from laboratory setups to practical everyday applications.

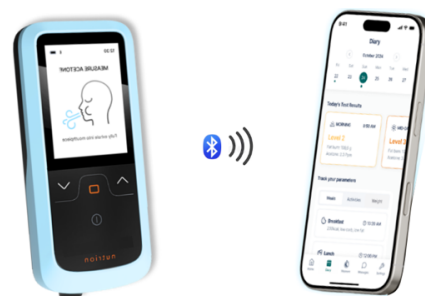


Fig. 1: Smartphone-guided metabolic monitoring at home with a fully integrated breath acetone device. Smartphone app with Bluetooth connection for sampling control, result display and trend analysis.

Results

The device demonstrated accurate and stable acetone quantification across the physiologically relevant range, with low inter-device variability

(5.6% at 1 ppm) and high repeatability (mean coefficient of variation (CV) of ~2.5%). Long-term measurements over 8 months showed no observable drift (inter-day variability 6.1%), and humidity robustness was confirmed with $\leq 4.2\%$ bias up to 90% relative humidity. Pressure-guided sampling enabled reproducible end-tidal breath collection (CV ~3%), supporting reliable operation under user-controlled conditions. Validation against proton transfer reaction time-of-flight mass spectrometry (Fig. 2) showed excellent agreement across 0.2–43 ppm ($R^2 = 0.990$; $r = 0.995$; ~7.5% bias at 2 ppm), confirming analytical accuracy in human breath.

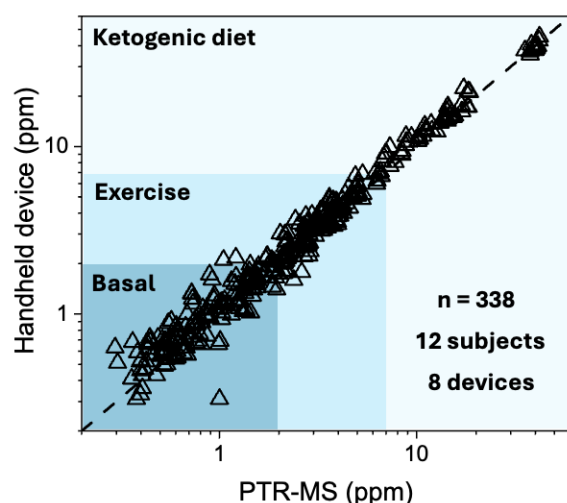


Fig. 2: Correlation between breath acetone concentrations measured by the sensor and PTR-MS. A total of $n = 338$ breath samples were analyzed from 12 subjects using 8 devices during exercise and dietary interventions ($R^2 = 0.990$).

Longitudinal home monitoring during dietary interventions (Fig. 3) demonstrated the ability to resolve individual metabolic adaptations over three weeks. Breath acetone remained low during habitual diet, increased substantially during ketogenic diet with subject-specific peak levels up to ~39 ppm, and decreased again during intermittent fasting, in agreement with PTR-MS measurements. The device closely tracked reference measurements and captured pronounced inter-individual differences in both magnitude and dynamics. These results highlight the capability of the system to monitor real-world metabolic changes over time, providing information complementary to blood ketones and continuous glucose measurements.

Conclusion

We present a validated handheld breath acetone sensing platform enabling accurate, non-invasive metabolic monitoring in real-world settings. By integrating controlled sampling, selective

detection and digital guidance, the system reliably tracks individual metabolic dynamics over time, supporting personalized health applications such as dietary guidance, exercise optimization and preventive monitoring.

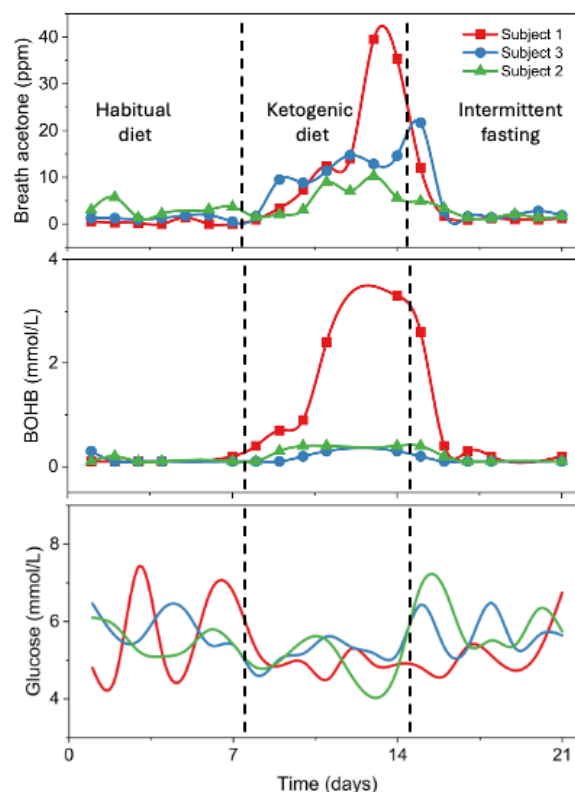


Fig. 3: Longitudinal monitoring of (a) breath acetone measured by the sensor, (b) capillary blood BOHB and (c) ISF glucose during habitual diet (days 1–7), ketogenic diet (days 8–14), and intermittent fasting (days 15–21) for three subjects.

References

- [1] Nyberg, S. T. et al. Obesity and loss of disease-free years owing to major non-communicable diseases: a multicohort study. *Lancet Public Heal.* 3, e490–e497 (2018); doi: 10.1016/S2468-2667(18)30139-7
- [2] Phelps, N. H. et al. Worldwide trends in underweight and obesity from 1990 to 2022: a pooled analysis of 3663 population-representative studies with 222 million children, adolescents, and adults. *Lancet* **403**, 1027–1050 (2024); doi: 10.1016/S0140-6736(23)02750-2
- [3] Güntner, A. T. et al. Challenges and opportunities of wearable molecular sensors in endocrinology and metabolism. *Nat. Rev. Endocrinol.* **22**, (2025); doi: 10.1038/s41574-025-01175-z
- [4] Musa-Veloso, K., Likhodii, S. S. & Cunnane, S. C. Breath acetone is a reliable indicator of ketosis in adults consuming ketogenic meals. *Am. J. Clin. Nutr.* **76**, 65–70 (2002); doi: 10.1093/ajcn/76.1.65
- [5] Güntner, A. T. et al. Breath sensors for health monitoring. *ACS Sensors* **4**, 268–280 (2019); doi: 10.1021/acssensors.8b00937