Listening to Your Lungs: Continuous Respiration Volume Monitoring Using In-Ear Audio

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1 INTRODUCTION

Respiration volume—the amount of air inhaled or exhaled during breathing—is a critical biomarker for assessing respiratory and cardiovascular health, physical fitness, and the progression of chronic diseases such as asthma or COPD. In both clinical and daily-life scenarios, continuous tracking of this metric could enable early detection of health deterioration, real-time monitoring of ventilatory capacity, and performance optimization. However, existing solutions are either bulky (e.g., spirometry or plethysmography) or obtrusive (e.g., chest straps, airflow masks), limiting their practicality for everyday use [3].

Meanwhile, consumer earphones are increasingly equipped with in-ear microphones and are routinely worn during everyday activities. This presents a unique opportunity to repurpose earphones into a health-sensing platform. Prior studies have explored earable sensing for heart rate [1] and respiratory rate [2] but not for respiration volume—a more informative and clinically relevant measure. In this work, we propose the first system to enable **continuous, in-situ respiration volume monitoring using off-the-shelf earphones**, without the need for specialized equipment.

2 CHALLENGES

Our system leverages in-ear audio to estimate respiration volume across varying physical conditions and breathing intensities. The core insight is that breathing sounds, generated by turbulent airflow in the respiratory tract, propagate through tissues and bones and can be captured in the ear canal by in-ear microphones. However, it poses significant challenges to enable the design:

1) Faint and variable signals. Breathing sounds reaching the ear canal are often extremely weak—especially during low-intensity breathing—and can vary significantly between users and conditions. Extracting meaningful volume-related features from these signals is non-trivial.

2) Interference from other body-conducted noise. In-ear microphones also capture other body-conducted sounds, such as footsteps, which may overwhelm the subtle breathing signal, particularly during movement or exercise.

3) Lack of labeled data. High-quality, paired recordings of in-ear audio and ground-truth respiration volume are scarce and require substantial effort to collect. This limits the ability to train supervised models and makes generalization across users and conditions more difficult.

These challenges demand a robust, data-efficient approach that can extract respiratory features from weak, noisy signals and operate across diverse real-world scenarios.

3 APPROACH AND RESULTS

We develop and evaluate a system that leverages in-ear audio to estimate breathing volume continuously across varied conditions and intensities. Our solution is designed to work with minimal supervision, generalize across users, and function during both rest and movement. We validate the approach using data collected from 18 participants under diverse physical states and compare estimated respiration volumes to gold-standard reference measurements.

The system achieves a mean absolute percentage error (MAPE) well below the clinical threshold of 20%, and maintains strong correlation with ground truth across a wide range of breathing volumes and activities. Additionally, the system shows promising performance on related metrics such as tidal and minute volume and benefits from lightweight, user-specific calibration when available.

Our findings suggest that earphones (already widely adopted) can be repurposed for non-invasive, continuous respiratory volume monitoring in naturalistic settings, opening up new opportunities for passive wellness tracking, chronic disease management, and fitness optimization in everyday life.

REFERENCES

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