

Longitudinal Cough Frequency Monitoring in Subjects with Persistent Cough: Daily Variability and Predictability Over 30 Days

Kian Fan Chung¹, Peter Small², Carlos Chacour³, Mindaugas Galvosas⁴, Lola Jover⁴, Woo-Jung Song⁵, Matthew Rudd⁶

1. Imperial College London - London (United Kingdom); 2. University of Washington, Department of Global Health; Research and Development Department, Hyfe Inc. - Seattle (USA); 3. Clínica Universidad de Navarra, Pamplona; ISGlobal, Barcelona Institute for Global Health, Barcelona; Centro de Investigación Biomédica en Red de Enfermedades Infecciosas - Madrid (Spain); 4. Research and Development Department, Hyfe Inc. - Wilmington (USA); 5. Asan Medical Center - Seoul (South Korea); 6. University of the South, Sewanee; Research and Development Department, Hyfe Inc. - Wilmington (USA)

Objectives

Current methods of monitoring cough are intrusive and limited to 24 hours. We used a novel non-contact, AI-powered continuous passive cough monitor to quantify cough over protracted periods and describe the limitations of 24 hour monitoring to identify cough trends.

Methods

Hyfe identifies and timestamps coughs thus providing continuous hourly cough counts. The CoughPro and CoughTracker apps use the smartphone's microphone and a two-layer AI system: (1) peak-detection, (2) cough classification, to detect and classify "cough-like" sounds on-device in a privacy preserving way. The retrospectively analyzed dataset was comprised of 97 users, who monitored for 30 days, with >20 daily monitoring hours and a cough frequency >5 coughs per hour. The data, gathered between January and August 2023, included only cough timestamps and smart app (CoughPro and CoughTracker) usage times, with no additional user information.

Outcome measures

We calculated daily cough frequencies by dividing total daily coughs by monitoring time and applied bootstrapping to hourly counts to establish 95% confidence intervals for each day. In assessing cough predictability, we calculated One Day's Predictability as the percentage of other days with cough frequencies within that day's 95% confidence interval. Overall Predictability, the mean of these percentages across 30 days, reflects the predictability of 24 hour monitoring. High values indicate a stable and predictable cough pattern, while low values suggest variability from day to day, and thus that 24 hour monitoring is inaccurate.

Results

The mean (median) daily cough rates varied from 6.5 to 182 (6.2 to 160) coughs per hour, with standard deviations (interquartile ranges) varying from 0.99 to 124 (1.30 to 207) coughs per hour among all subjects. There was a positive association between cough rate and variability, as subjects with higher mean cough rates (OLS) have larger standard deviations. The accuracy of any given day for predicting all 30 days is the One Day Predictability for that day, defined as percentage of days when cough frequencies fall within that day's 95% confidence interval. Overall Predictability was the mean of the 30 One Day Predictability percentages and ranged from 95% (best predictability) to 30% (least predictability).

Limitations: The clinical data was not available for most of the subjects. Although the cough detection algorithms have been extensively tested, their performance has not been validated for this use case.

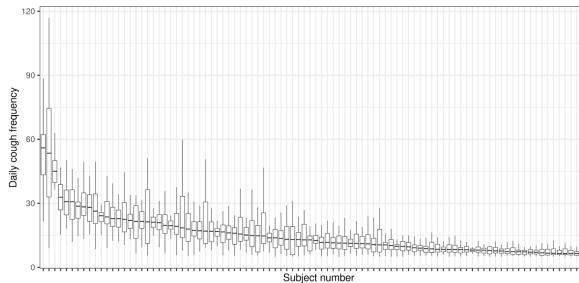


Figure 1. Daily cough rates for 96 individuals over 30 days
Significant variation in cough frequencies is observed within this group, both among different individuals (dots) and within the same individual over time (boxes).

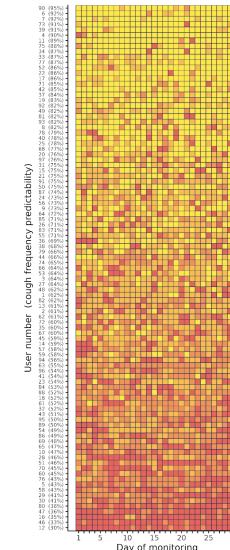


Figure 3. Cough frequency predictability for all users, with each row denoting an individual user and each cell representing one day

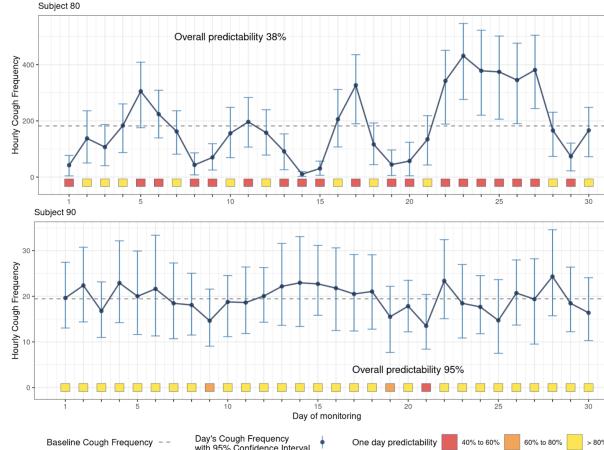


Figure 2. User with low predictability (top panel) and high predictability (bottom panel)

Daily cough frequencies (dots) with the 30-day average (dashed line), the 95% confidence interval for the cough frequency on each day (vertical bars). The coverage percentage for each day is indicated at the bottom, using a color code.

Coverage
More than 80%
Between 60% and 80%
Between 40% and 60%
Less than 40%

The color coding of each cell reflects the predictability coverage for that particular day: from yellow (greater than 80%) to red (less than 40%).

Take-Home Points

1. Coughing frequencies **vary significantly between and within individuals**, for those with a cough frequency of >5 coughs/hr.
2. One 24-hour measurement of cough **does not reliably reflect long-term trends** in up to half of those with persistent cough.
3. This work provides **methodological direction** for subsequent definitive studies.

Contact:
Peter M. Small, M.D.
Chief Medical Officer
peter@hyfe.ai

