Hyfe's cough insights for
Research

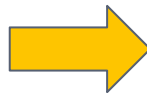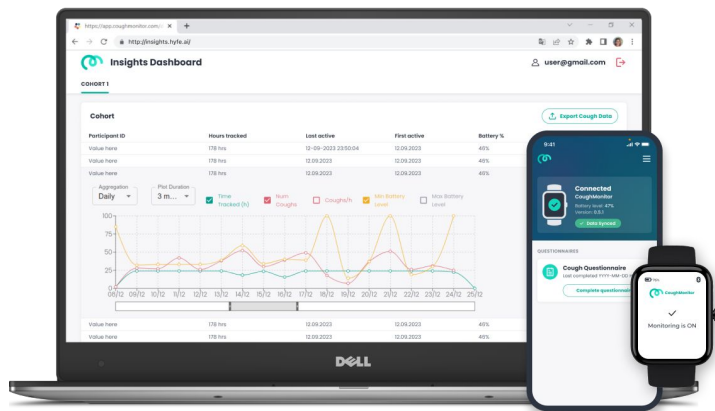**Trusted By**
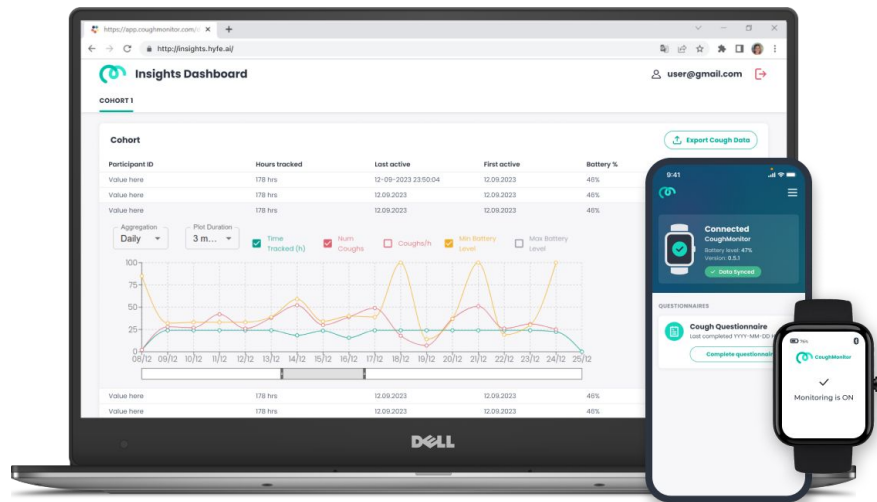
#1

Introduction to

Hyfe's CoughMonitor Suite

Hyfe uses AI to monitor **cough frequency** over time

Like a step counter, but for cough:
- Passive
- Continuous
- Fully automated
- Fully privacy-preserving

Generating longitudinal, continuous cough–frequency data, making it visible for the first time.

Hyfe's **CoughMonitor Suite** is comprised of:

ID206

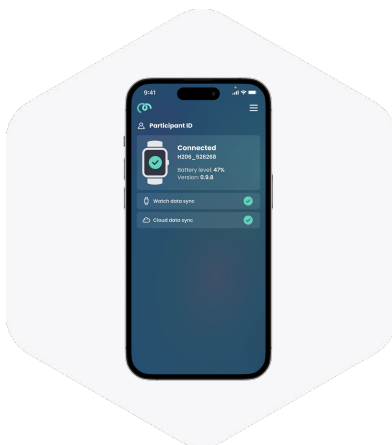A watch that detects and timestamps coughs.

Companion App

A phone app that **collects customizable PROs** and transfers data to the cloud

Insights Dashboard

A web-based dashboard for viewing data and analysis

Plus full end-to-end execution services including study protocol support, database setup, logistics, site training, helpdesk, site performance monitoring, statistical analysis, etc., as required
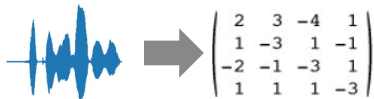
AI-powered cough detection: how it works

1. Step: Peak detection & feature extraction

2. Step: Cough classifier

1st algorithm monitors environmental sound levels and identifies "explosive" sounds, e.g. a dog bark, door slam, or a cough.

Algorithm simplifies each explosive sound to a mathematical matrix representing the key 'features'.

2nd algorithm reviews the 'features', and categorizes them as either **cough** or **non-cough**.

Each **cough** is time-stamped.

$$\begin{pmatrix} 2 & 3 & -4 & 1 \\ 1 & -3 & 1 & -1 \\ -2 & -1 & -3 & 1 \\ 1 & 1 & 1 & -3 \end{pmatrix}$$

Cough

Non-cough
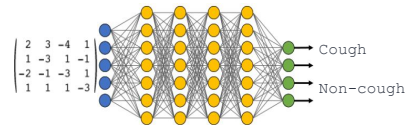
To protect users' privacy, both peak detection and cough classification happen on-device.

Hyfe's CoughMonitor technology is analytically validated in real-world environments
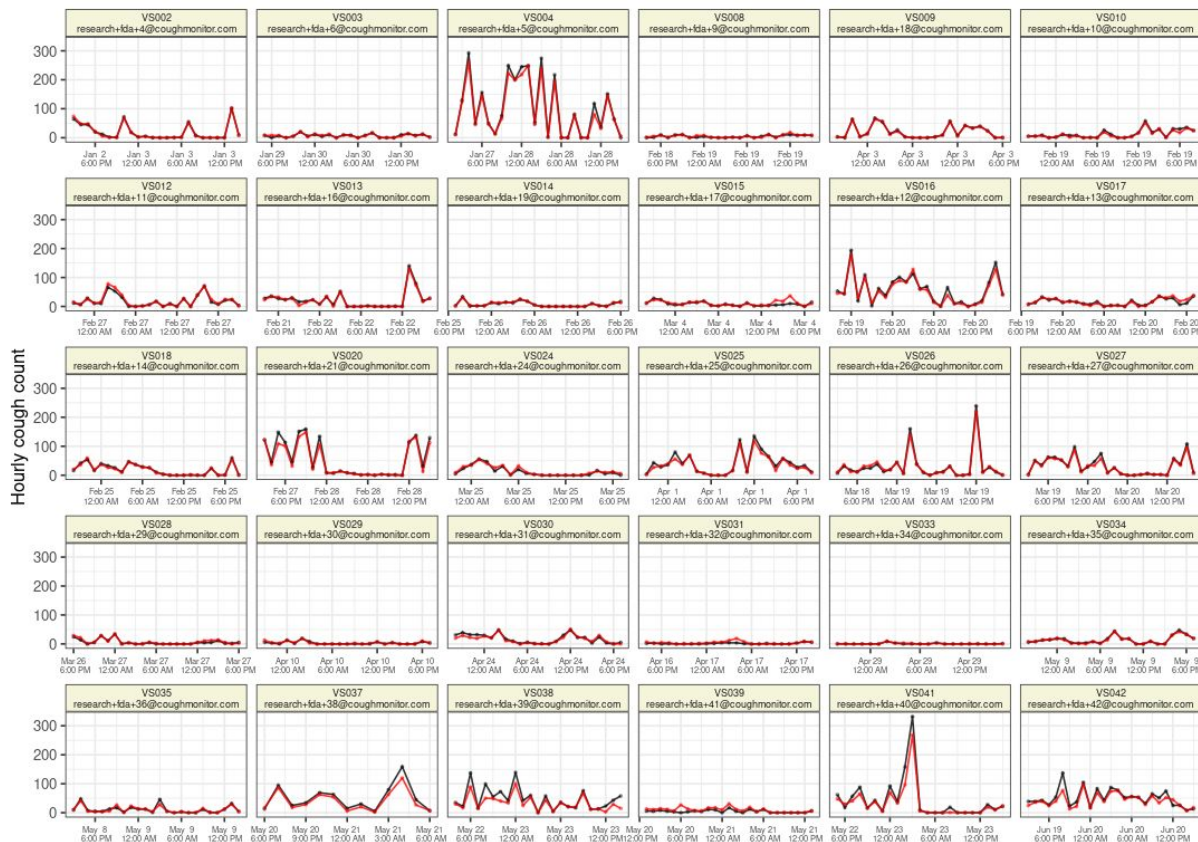
30 patients in their normal daily life, monitored for 24h

Hyfe in red
Continuous audio labeled by trained humans **in black**

Transparent, thorough labeling
- Published SOP
- Labeled twice, all discrepancies confirmed by a doctor

Results: Lin's Concordance Correlation Coefficient with ground truth (human annotations) for hourly counts of coughs is 0.974

Unpublished data, Hyfe Inc. 2025

Dashboard shows near real time cough data

Aggregation: Hourly ▾

Reset Zoom

Sync Count
Time Tracked
Num Coughs
Cough Rate
Battery Min
Battery Max
Not Wearing
Wearing
Not Charging
Charging

2025-Jun-24   2025-Jun-25   2025-Jun-26   2025-Jun-27   2025-Jun-28   2025-Jun-29   2025-Jun-30   2025-Jul-01
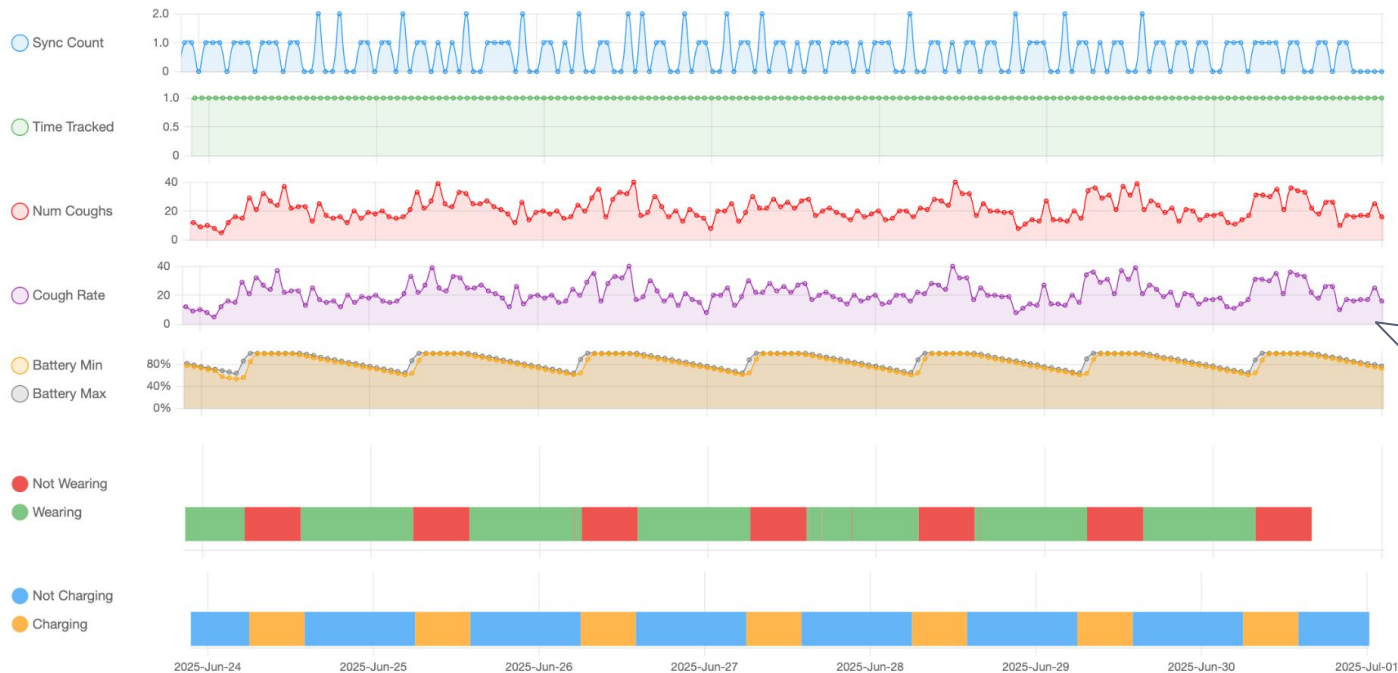
Cough data can be blinded or not, per user type

Adherence (wear time/battery) visible to sites with customizable alerts

Option to download raw data from the dashboard

HYFE INC.
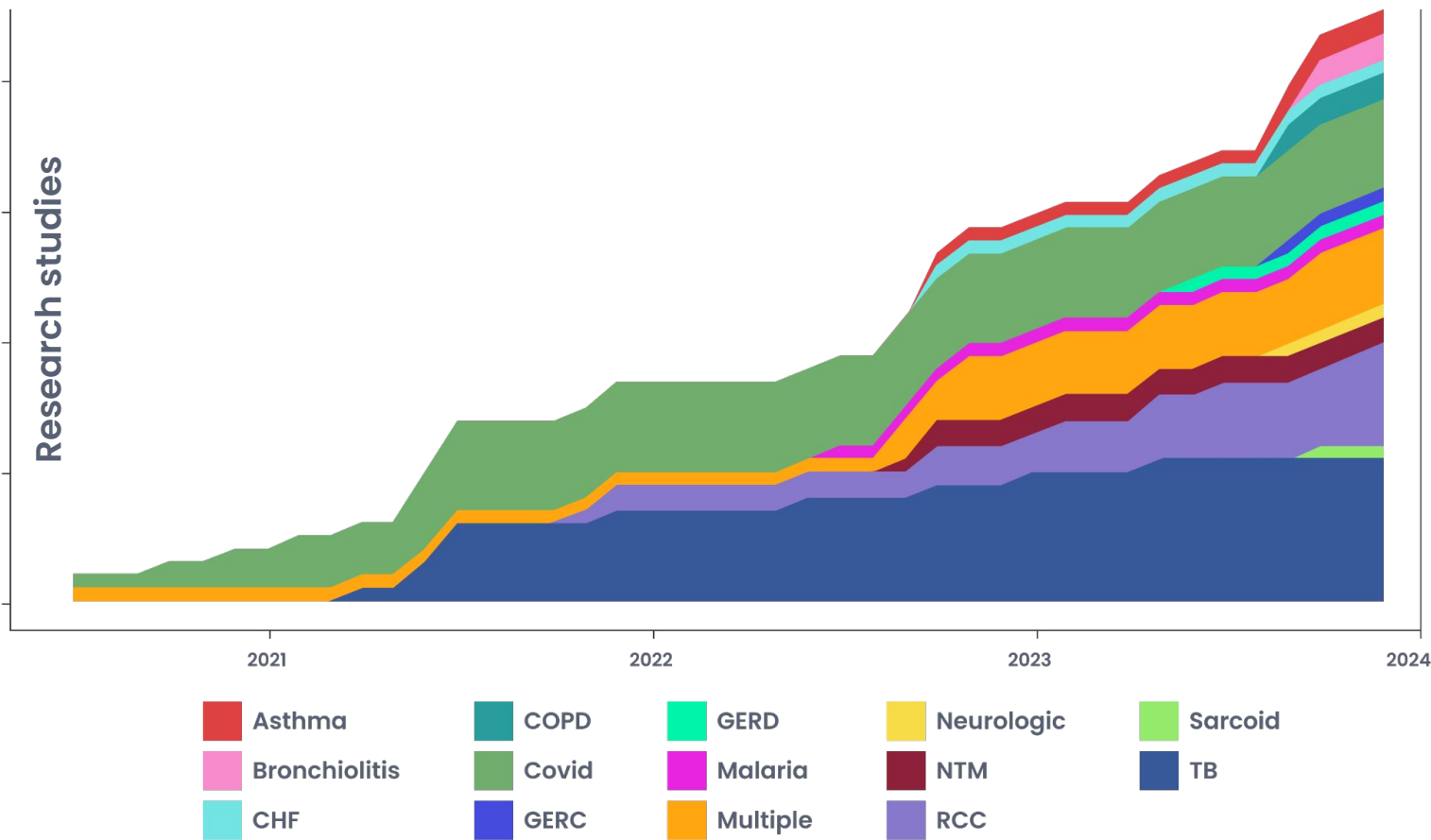
01

CoughMonitor Suite summary
Accurate insights-rich data; low patient burden

✓ **Validated** Observed Lin's Concordance Correlation Coefficient with ground truth (human annotations) was 0.974

✓ **Continuous** during *day and at night* while charging, resulting in 7/7 data for days, weeks, even months

✓ **Unobtrusive** watch is discrete, light, waterproof and comfortable - designed for everyday wear for long periods of time

✓ **Fully automated** data collection requires very minimal patient interaction

✓ **Privacy-preserving** all *processing completed on the watch* so no audio sent to the cloud

Hyfe is the **Global Leader** in Cough Science

Research studies

50+ studies

17+ indications

19+ publications

Legend:
- Asthma
- Bronchiolitis
- CHF
- COPD
- Covid
- GERC
- GERD
- Malaria
- Multiple
- Neurologic
- NTM
- RCC
- Sarcoid
- TB

2021   2022   2023   2024
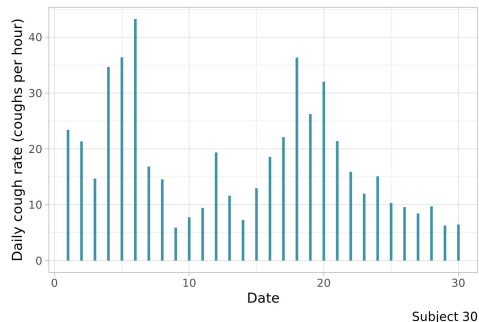
Insights from continuous cough monitoring

1. Consequences of 24h snapshots

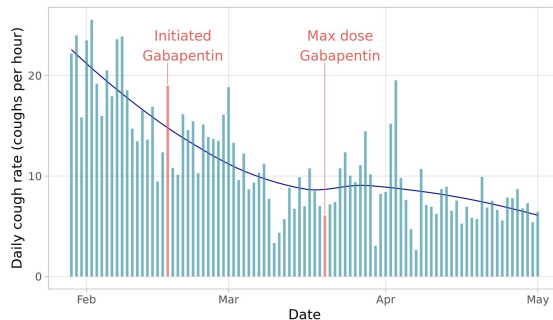Cough is inherently variable. Trends are only revealed by extending the observation window

Variable cough rate impedes subject recruitment

Subject 30

High cough rates on some days and low cough rates on others, purely by chance

Undermines subject recruitment and efficacy analyses

Inaccurate estimate of treatment effects

Longitudinal monitoring reveals a 35% reduction in cough rate after starting Gabapentin

24h snapshots incorrectly estimate the change more than half the time[2] – and can even falsely indicate *an increase*.

Slow detection of adverse side-effects
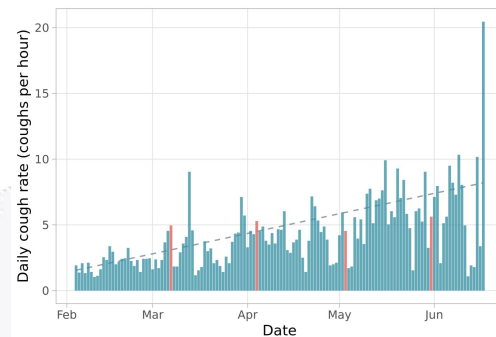
Glacial trend: cough rate increasing by 1 cough/hour every *3 weeks* (grey dashed line)

24h snapshots (e.g. red bars, at 1 month intervals) miss the trend

[2]J.C. Gabaldón-Figueira, E. M. Keen et al., *ERJ Open Res.* 2022

2. Cough monitoring fills the gap between perceived and objectively measured symptom

1. Cough PROs (patient-reported outcomes) are **not the same** as objective cough frequency.
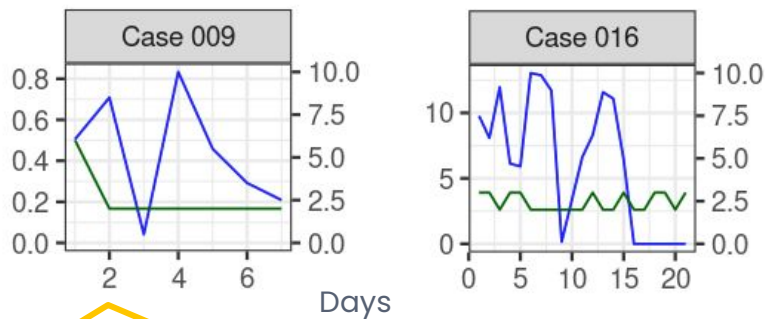
The subjective cough score (in green), and objective cough rate (in blue) would ideally match. But often they don't. Highlighting the gap between perceived and objectively measured symptoms!

Lee SE, et al. Feasibility and Utility of a Smartphone Application-Based Longitudinal Cough Monitoring in Chronic Cough Patients in a Real-World Setting. Lung. 2023

3. Baseline cough rates

Some people's daily cough rates cluster near their longer term mean frequency
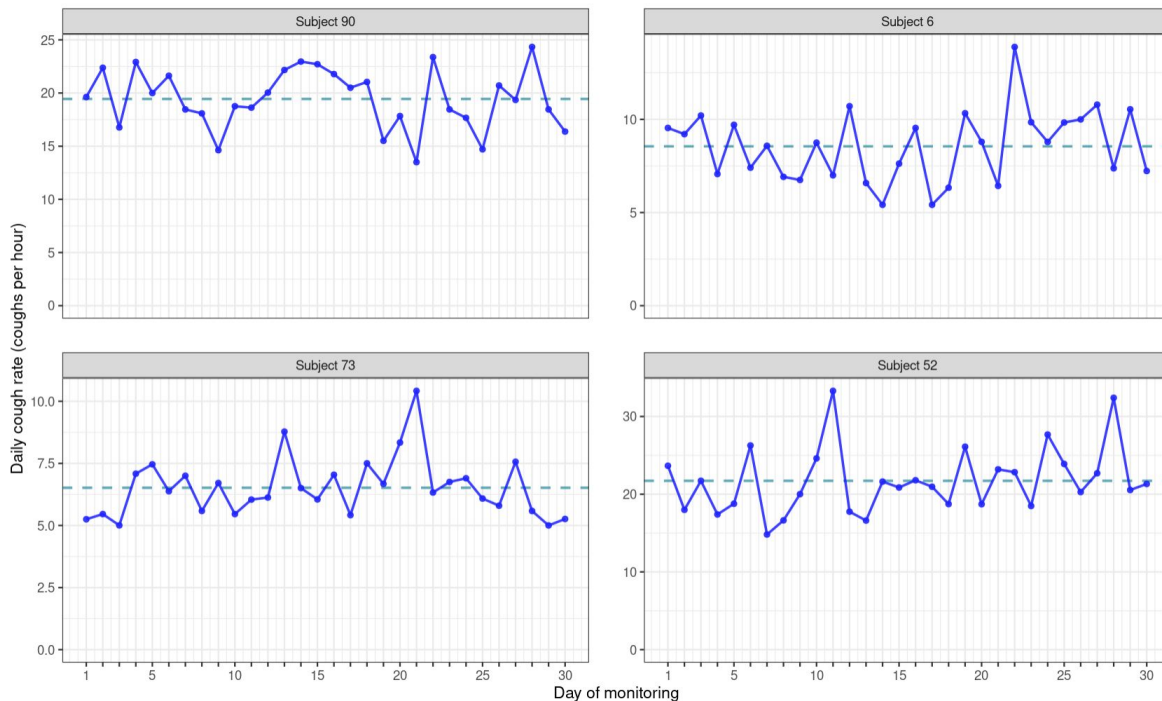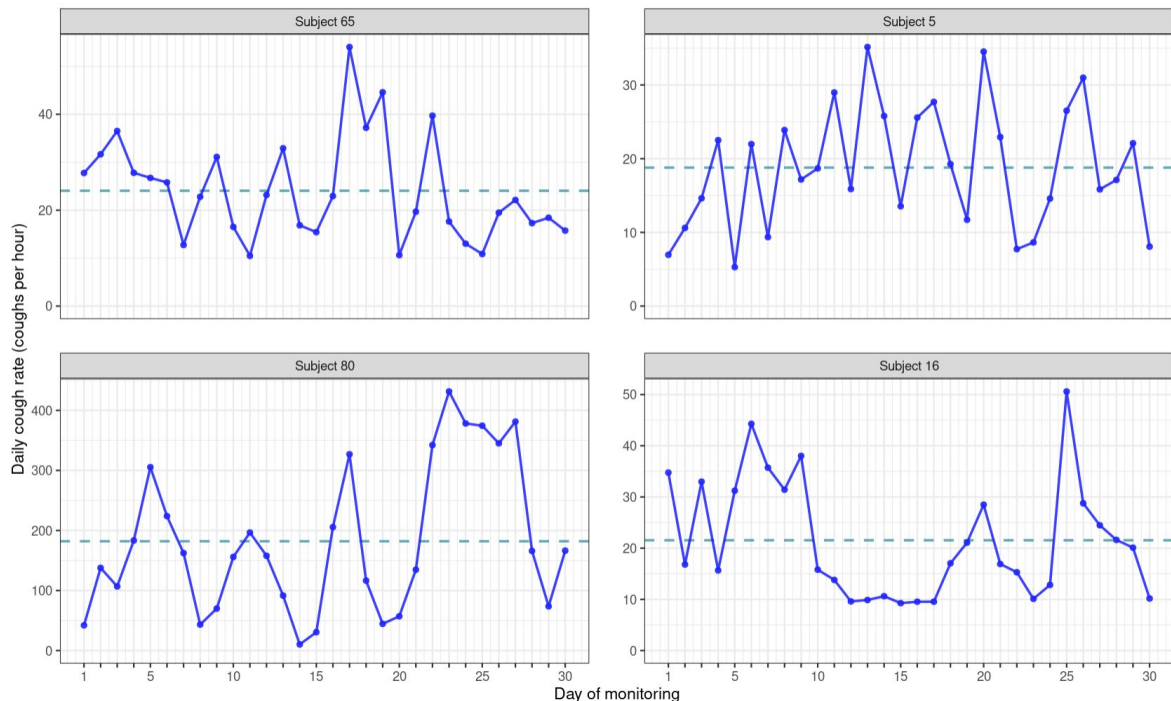

30 days of data from 4 problematic coughers, with 20+ hours of monitoring per day

These stable coughers have consistent daily cough rates (in blue) that vary predictably about their average rates (dashed lines)

These means define their baseline rates well

Chung KF, et al. Longitudinal cough frequency monitoring in persistent coughers: Daily Variability and Predictability. Lung. 2024

4. Cough Variability

Daily cough rates can be volatile, so mean cough rates do a poor job of predicting any single day's rate for many coughers.

30 days of data from 4 problematic coughers, with 20+ hours of monitoring per day

These volatile coughers have inconsistent daily cough rates (in blue) that vary unpredictably about their average rates (dashed lines)

These averages don't describe their coughing well – these coughers don't have stable baseline rates

Chung KF, et al. Longitudinal cough frequency monitoring in persistent coughers: Daily Variability and Predictability. Lung. 2024

4. Cough Variability

High degree of cough rate variability within and between individual coughers
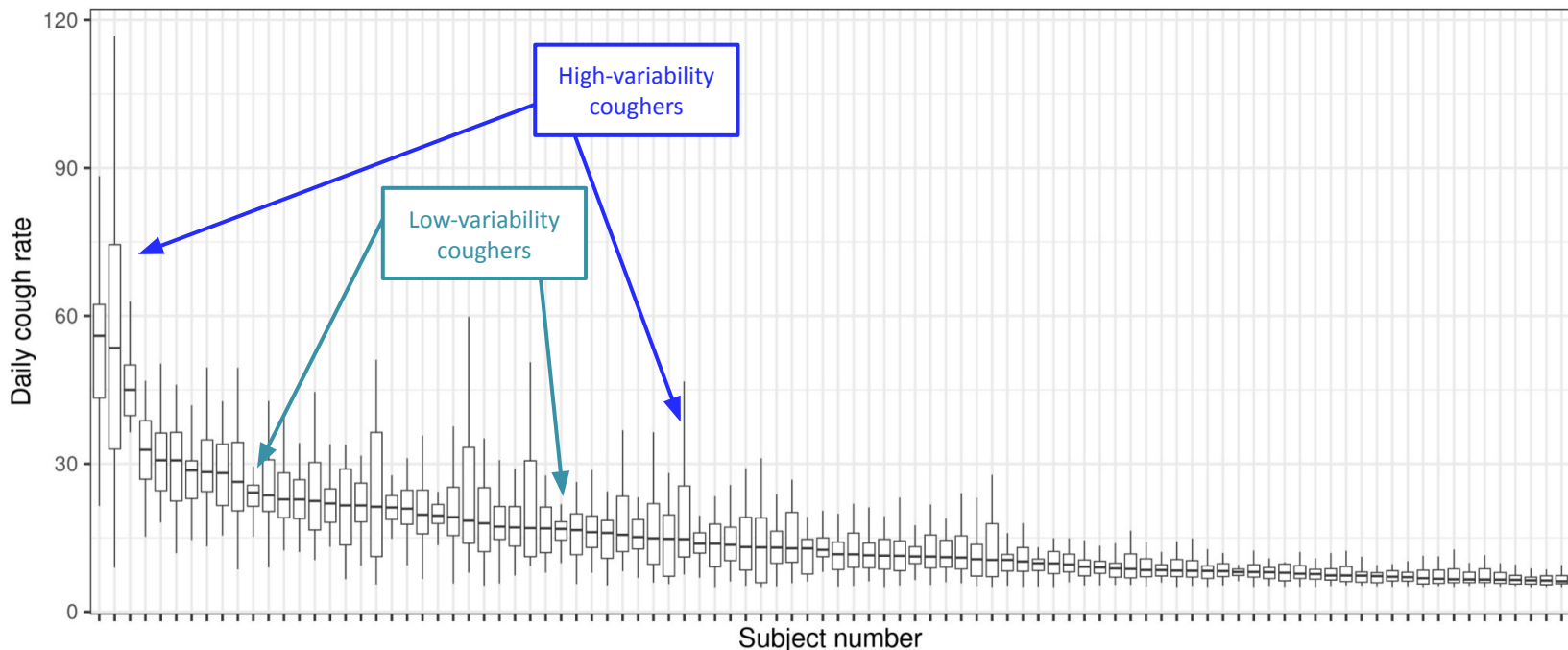
Chung KF, et al. Longitudinal cough frequency monitoring in persistent coughers: Daily Variability and Predictability. Lung. 2024

5. Cough predictability
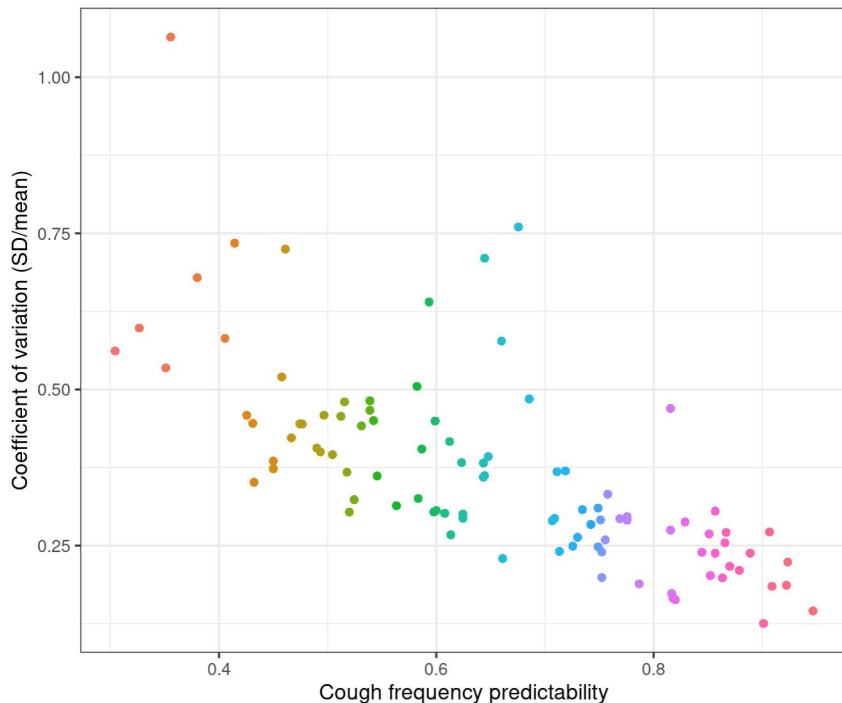
Monitoring for at least 2 weeks identifies *predictable coughers*

30 days of data from 97 problematic coughers, with 20+ hours of monitoring per day

Bottom right: predictable cough patterns, low variability

Upper left: unpredictable cough patterns, high variability

2 weeks of data yield good estimates of variability (CV), hence good estimates of predictability. Not possible with only one day of monitoring

Chung KF, et al. Longitudinal cough frequency monitoring in persistent coughers: Daily Variability and Predictability. Lung. 2024

6. Treatment response: Change point detection
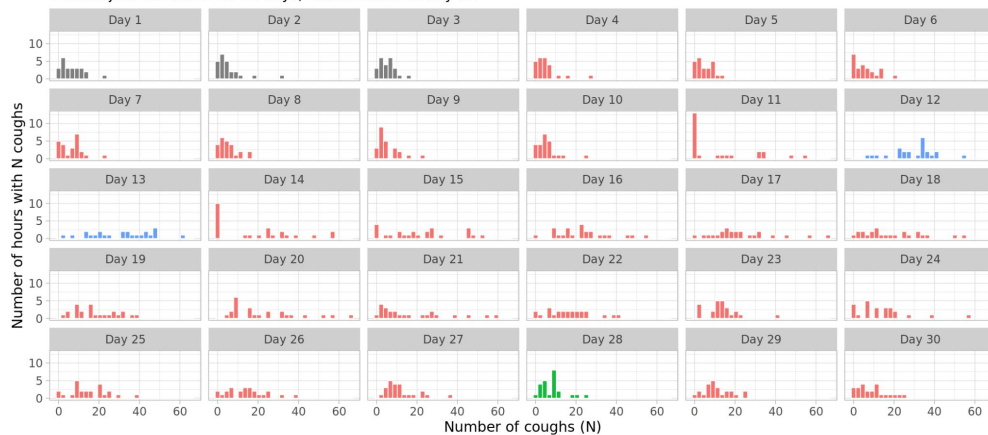
Continuous monitoring enables *retrospective* and *real-time* change detection.

Change in daily cough counts for an RCC patient (2 months of monitoring)
115 per day before Feb 14th ; 180 per day thereafter
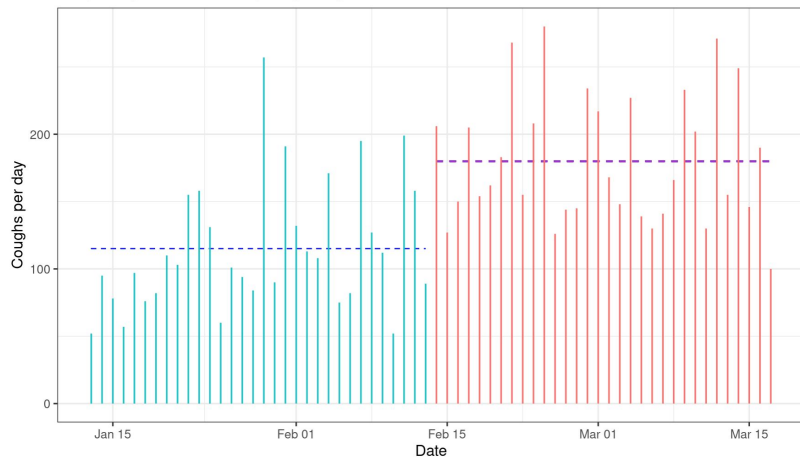
Hourly cough count distributions by day
One subject monitored for 30 days; exacerbation on day 12

Evidence of change versus previous 3 days ■ None ■ Strong ■ Very strong ■ NA

7. Diurnal patterns

Longitudinal measurements reveal higher/lower cough rates that are linked to times of the day or night.
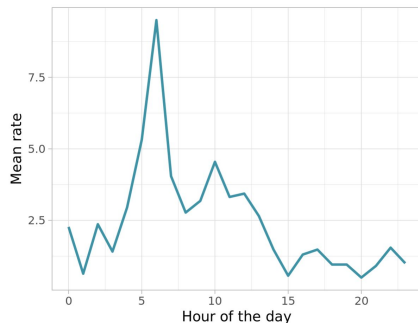
Significant increase in coughing after waking, followed by a steady decrease throughout the day
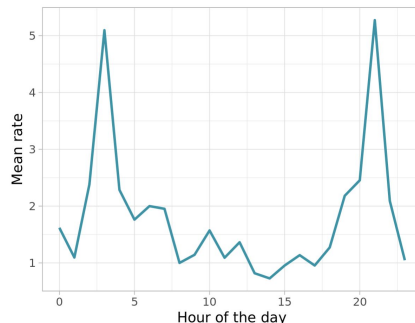
Increased coughing early and late in the day, with low cough rates in between
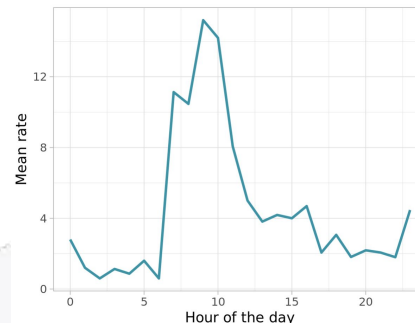
Significantly increased coughing mid-morning, followed by a steady decrease

Thanks to several weeks of reliable monitoring, we can see how these 3 subjects cough on average during each hour of the day

Powerful insight examples from continuous cough monitoring across therapeutic areas

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Cough Is Increasingly Understood In COPD

Dominant symptom

>70% of patients report cough and it is one of the three cardinal symptoms.

Chronic cough is **associated with severe** exacerbations.

Cough is an **early feature of COPD** which helps identify patients at risk of progressive disease.

The Burden of Cough and Phlegm in People With COPD: A COPD Patient-Powered Research Network Study

Radmila Choate [1,2], Cara B Pasquale [1], Nereida A Parada [3], Valentin Prieto-Centurion [4], Richard A Mularski [5], Barbara P Yawn [1]

Predicts exacerbations

Almost half of acute COPD exacerbations can be **predicted** > 3 days in advance by cough monitoring at home.

Pierre-Régis Burgel, MD, PhD [a] · Pascale Nesme-Meyer, MD [b] · Pascal Chanez, MD, PhD [c] · Denis Caillaud, MD [d] · Philippe Carré, MD [e] · Thierry Perez, MD [f] · Nicolas Roche, MD, PhD [g] · on behalf of the Initiatives Bronchopneumopathie Chronique Obstructive (BPCO) Scientific Committee [†] Show less

Domiciliary Cough Monitoring for the Prediction of COPD Exacerbations

Michael G. Crooks, [1,3] Albertus C. den Brinker, [2] Susannah Thackray-Nocera, [1] Ralph van Dinther, [2] Caroline E. Wright, [1] and Alyn H. Morice [1]

Cough Is Increasingly Understood In **Asthma**

Dominant symptom

Poor asthma control is associated with:
- Higher coughing
- Presence of nighttime cough
- Lower QoL

Cough is **common** in asthma, **independent** of pulmonary function tests (PFTs) and **poorly captured** by existing methods.

> Diagnosis and Management of Cough: ACCP Evidence-Based Clinical Practice Guidelines
>
> ## Chronic Cough Due to Asthma: ACCP Evidence-Based Clinical Practice Guidelines
>
> Peter V. Dicpinigaitis MD, FCCP
>
> Show more

> THE LANCET
> Respiratory Medicine
>
> PERSONAL VIEW · Volume 11, Issue 7, P650-662, July 2023   ⤓ Download Full Issue
>
> ## Cough and cough hypersensitivity as treatable traits of asthma
>
> Prof Kefang Lai, MD [a] · Imran Satia, MD [b,c] · Woo-Jung Song, MD [d] · Prof Gang Wang, MD [e] · Prof Akio Niimi, MD [f] · Philip Pattemore, MD [g] · Prof Anne B Chang, PhD [h,i,j] · Prof Peter G Gibson, MD [k] · Prof Kian Fan Chung, DSc MD [l,m] ✉ Show less

Predicts exacerbations

Cough monitoring might be used to **detect asthma exacerbations** 3-5 days in advance.

> ⟩ J Asthma Allergy. 2020 Dec 3:13:649-657. doi: 10.2147/JAA.S278119. eCollection 2020.
>
> ## Characteristics of Asthma-related Nocturnal Cough: A Potential New Digital Biomarker
>
> Frank Rassouli [#] [1], Peter Tinschert [#] [2], Filipe Barata [3], Claudia Steurer-Stey [4] [5], Elgar Fleisch [2] [3], Milo Alan Puhan [4], Florent Baty [1], Tobias Kowatsch [2] [3], Martin Hugo Brutsche [1]

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>
> 'The Very Breathless Caterpillar' — Paediatric diagnostics
>
> S87 Contactless and automated monitoring to study changes in nocturnal parameters before and after asthma attacks in children
>
> Article info
>
> P Nagakumar [1], W Do [2], O Carr [2], M Udani [2], L Fleming [3], S Saglani [4]

Cough's importance in other therapeutic areas

Bronchiectasis
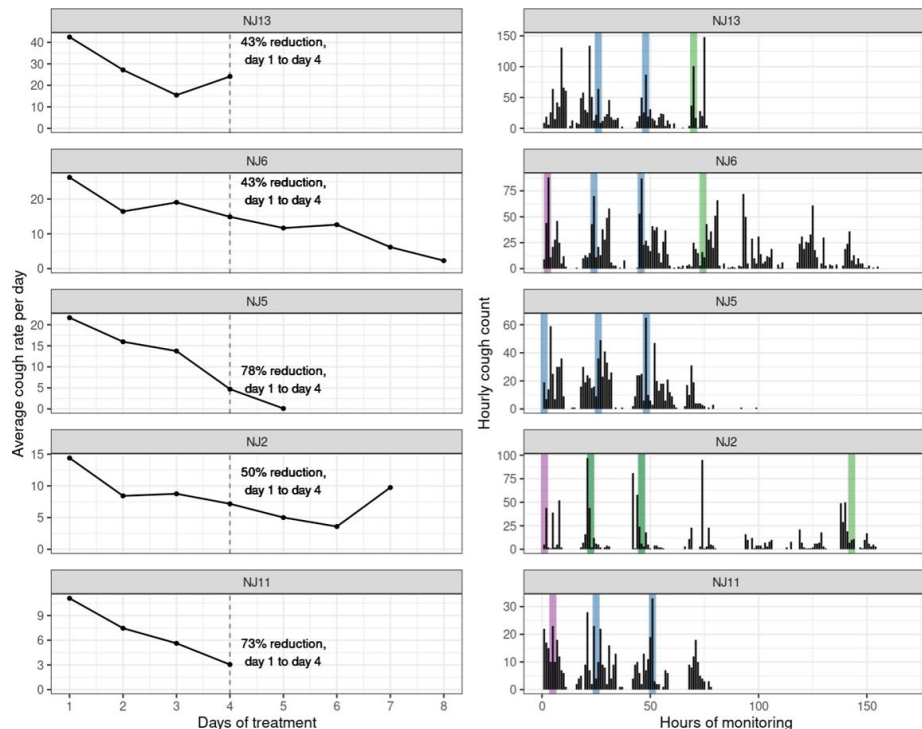
Cough as:

- A biomarker of treatment response
- An early detection of exacerbation
- A data-stream driving adherence to, e.g., airway clearance treatment protocols
- A data-stream for personalizing treatment

Left panel: daily average of hourly cough counts.

Right panel, the timing of cough inducing interventions including:
- **Hypertonic saline sputum induction,**
- **OPEP combined with hypertonic saline,**
- **High Frequency Chest Wall Oscillation trials.**

Griffith DE, et al. Using Continuous Cough Monitoring to Assess Bronchiectasis Therapy. Am J Respir Crit Care Med **2024**

Cough Is Increasingly Understood In Idiopathic Pulmonary Fibrosis (IPF)

Dominant symptom

In FDA's patient interviews - **coughing** was mentioned by over **3/4 of participants** as being **one of their most significant symptoms.**

Over 80% of patients with **IPF complain of cough.**

The Voice of the Patient

A series of reports from the U.S. Food and Drug Administration's (FDA's)
Patient-Focused Drug Development Initiative

> Curr Opin Pulm Med. 2024 Jun 25. doi: 10.1097/MCP.0000000000001087. Online ahead of print.

What causes cough in pulmonary fibrosis, and how should we treat it?

Katherine J Myall [1] [2], Peter S P Cho [1] [2], Surinder Birring [1] [2]

Predicts disease severity & mortality

Worse cough severity is associated with **worse** health-related **QoL**, disease **progression**, reduced transplant-free **survival** and **mortality**.

THE LANCET
Respiratory Medicine

Cough in idiopathic pulmonary fibrosis: more than just a nuisance

Christine L Vigeland • Maureen R Horton

Published: June 23, 2016 • DOI: https://doi.org/10.1016/S2213-2600(16)30150-3

American Journal of Respiratory and Critical Care Medicine

Home > American Journal of Respiratory and Critical Care Medicine > List of Issues > Just Accepted

Epidemiology and Prognostic Significance of Cough in Fibrotic Interstitial Lung Disease

Yet H Khor, Kerri A Johannson, Veronica Marcoux, Jolene H Fisher, Deborah Assayag, Helene Manganas, Nasreen Khalil, Martin Kolb, Christopher J Ryerson, and, the CARE-PF Investigators

Official Journal of the Asian Pacific Society of Respirology
Respirology

🔓 Free Access

Cough predicts prognosis in idiopathic pulmonary fibrosis

CHRISTOPHER J. RYERSON, MARTA ABBRITTI, BRETT LEY, BRETT M. ELICKER, KIRK D. JONES, HAROLD R. COLLARD

And cough may have a causal role in IPF disease progression

Cough Is Increasingly Understood In **Oncology**

Drug-Induced Lung Damage

Up to 55% of chemotherapy drugs result in **drug-induced interstitial lung disease** (DI-ILD)

DI-ILD has a 2 year average time to diagnosis reported in the literature, and **very high mortality** (severity of DI-ILD at diagnosis predicts the mortality).

Early detection of DI-ILD via cough monitoring in patients beginning chemotherapy could prompt early evaluation and result in better quality of life, and prognosis.

▸ J Clin Med. 2018 Oct 15;7(10):356. doi: 10.3390/jcm7100356 ☑

Drug-Induced Interstitial Lung Disease: A Systematic Review

Sarah Skeoch [1,2], Nicholas Weatherley [3], Andrew J Swift [3], Alexander Oldroyd [1], Christopher Johns [3], Conal Hayton [4], Alessandro Giollo [5,6], James M Wild [3], John C Waterton [7,8], Maya Buch [5], Kim Linton [9], Ian N Bruce [1,10], Colm Leonard [4], Stephen Bianchi [11], Nazia Chaudhuri [4,*]

Lung Cancer

Over 60% of **lung cancer patients cough**, and in the literature, cough is described as an **under-researched and under-treated symptom.**

Cough (and worsening of cough) is an **early indicator of pneumonitis**, an adverse effect of radiotherapy (standard of care for ~50% of lung cancer patients), but one that is often missed at early stages.

▸ Cancers (Basel). 2023 Jan 4;15(2):326. doi: 10.3390/cancers15020326 ☑

Early Identification of Pneumonitis in Patients Irradiated for Lung Cancer —Final Results of the PARALUC Trial

Dirk Rades [1,*], Elisa M Werner [1], Esther Glatzel [1], Sabine Bohnet [2], Steven E Schild [3], Søren S Tvilsted [4], Stefan Janssen [1,5]

▸ Chest. 2017 Jan 17;151(4):861–874. doi: 10.1016/j.chest.2016.12.028 ☑

Symptomatic Treatment of Cough Among Adult Patients With Lung Cancer
CHEST Guideline and Expert Panel Report

Alex Molassiotis [a,*], Jaclyn A Smith [b], Peter Mazzone [c], Fiona Blackhall [d], Richard S Irwin [e]; CHEST Expert Cough Panel, on behalf of the

Cough's importance in other therapeutic areas

Congestive Heart Failure (CHF)

Hourly cough rate vs a blood biomarker (NT-proBNP) in a patient with acute decompensation in heart failure.

Each 1 cough/hr decrease was associated with 95.03 pg/ml decrease in NT-proBNP.

Cough might be:

1. An early biomarker of decompensation in congestive heart failure

2. Treatment response biomarker

Hourly Cough Rate (blue) vs. NT-proBNP Level (red)
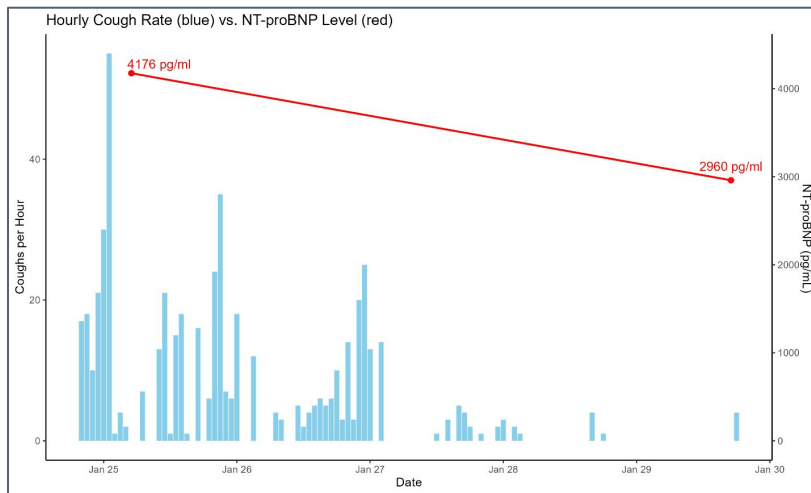
*Unpublished data: Matthew E. Lassman, George Perlman, Natalie Gendron, Nadia Giannetti (**2024**)*

Cough's importance in other therapeutic areas

Gastroesophageal reflux disease (GERD)

Coughing after eating is a well-established symptom of GERD.

Postprandial cough-monitoring and cough dynamics might be a simple, noninvasive differential diagnostic and treatment response biomarker.

Cystic Fibrosis (CF)

Cystic fibrosis patients cough significantly more than healthy subjects.

Cough in CF occurs mainly in the 1st and 2nd quarter of the night and correlates with parameters of disease severity (FEV1% and Immunoglobulin G).

Cough has been identified as a significant and early symptom of pulmonary exacerbations in cystic fibrosis.

Cough is both psychologically and physically a present symptom in CF patients and has influence on everyday life of the patients.

Cough's importance in other therapeutic areas

Tuberculosis (TB)

Non-Tuberculous Mycobacteria (NTM)

Cough is the cardinal symptom of TB and is of prime importance in transmission.

Cough-monitoring can predict clinical outcome for patients receiving empiric treatment and monitor for relapse.

Cough is common in NTM patients and provides objective evidence for making complicated therapeutic decisions.

Cough is a common adverse effect of inhaled therapies (e.g. Arikace) and its quantification can assist in treatment management.

Cough's importance in other therapeutic areas

Pulmonary sarcoidosis

Angiotensin-converting enzyme (ACE) inhibitors caused cough

Cough is an extremely common symptom of Sarcoidosis, and cough monitoring might improve diagnosis, management and outcomes of treatment.

Cough is the most common pulmonary symptom in exacerbations of pulmonary sarcoidosis.

Cough is a very common side-effect of ACEi.

The development of a dry cough can significantly decrease patient adherence to ACEi therapy.

Earlier medication plan review could be prompted via continuous cough monitoring.

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What's next?

View Hyfe's scientific publications <u>here.</u>

Email <u>peter@hyfe.com</u> (Chief Medical Officer) to discuss ideas and plan your study.
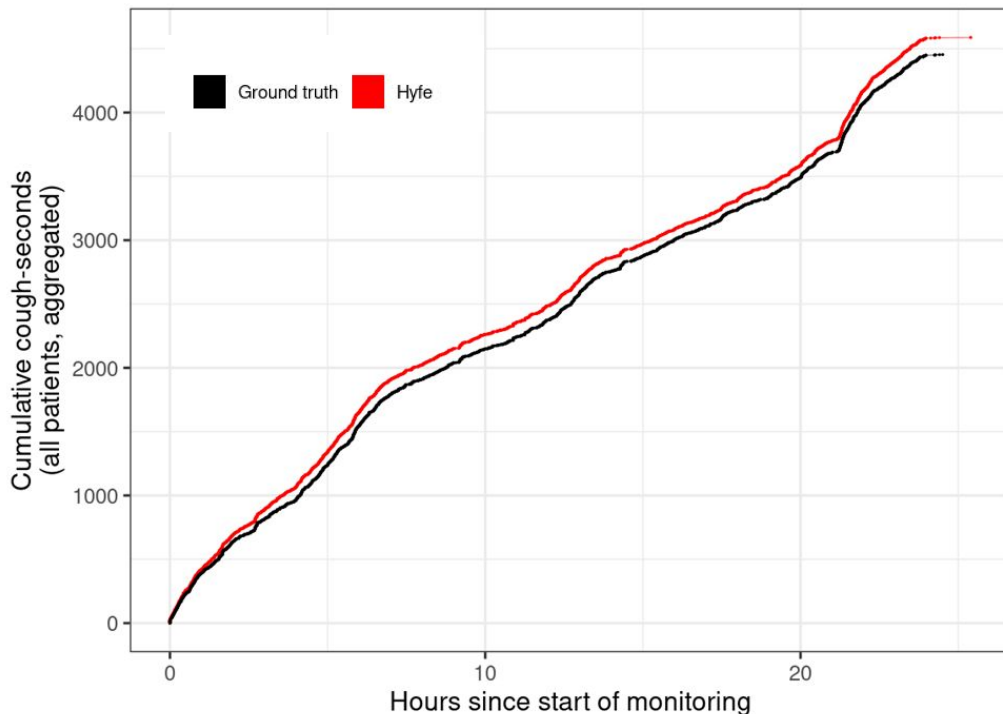
Hyfe

<u>**hyfe.com**</u>

Prior validation study (on deprecated device)

Cumulative chart for 23 problematic coughers with multiple etiologies, each monitored for 24h in real world environments with Hyfe + audio recorder.

- **Black line** = coughs detected by a trained physician listening to a continuous 24h audio recording

- **Red line** = Hyfe CoughMonitor

Results: Lin's Concordance Correlation Coefficient with ground truth (human annotations) was 0.985

Chaccour C, et al. Validation and accuracy of the Hyfe cough monitoring system: a multicenter clinical study. Nature Sci Rep. 2025

ClinOps experience gained in 50+ studies to date

Clear, simple Participant Guide translated & localised

Protocol-specific Site Manual and bite-size Mini Guides

Real-time data visibility & customisable adherence alerts

Online Training platform available 24/7, plus skilled in-person or remote trainers

Global logistics network with local depots and shipping/ customs expertise

Helpdesk via email and phone, across full US & EU timezones

#2

CoughPro: Hyfe's Consumer Wellness App for Smartphones (Android & iOS)

- Available globally
- Free

CoughPro : available on app stores

- Wellness App to help subjects live better with their chronic cough and have more informed conversations with their providers
- Not for diagnosing or managing disease
- 100k+ registered users globally
- Passive continuous privacy-preserving cough monitoring
- Cough triggers
- Personal Cough Report (available as PDF for sharing)

Globally available on every iOS and Android smartphone
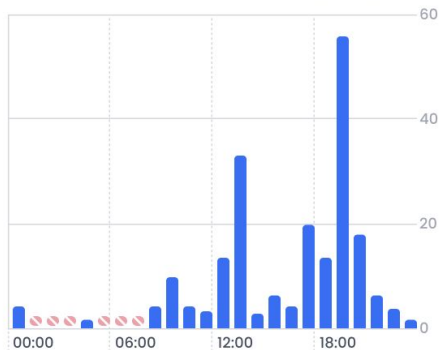
CoughPro insights - available on every smartphone

Cough counts

Hourly	**Daily**	Weekly	Monthly

COUGHS TODAY

201   Wednesday, 12 Apr 2023

00:00   06:00   12:00   18:00

Time tracked & cough rate

Daily	Weekly	Monthly

TIME TRACKED IN THE LAST 24HRS

18 hrs 54 min /24 hrs

COUGH RATE TODAY

8.9 /hr

DAILY COUGH RATE HISTORY

Yesterday	**9.1**/hr
10 Apr 2023	did not track
9 Apr 2023	**8.8**/hr
8 Apr 2023	**9.0**/hr

Cough trend

Daily	Weekly	Monthly

Last 24h compared to the last 4 days

COUGH TREND

↓ Lower

30/hr

20/hr

10/hr

0/hr

13 Apr   14 Apr   15 Apr   16 Apr   Today
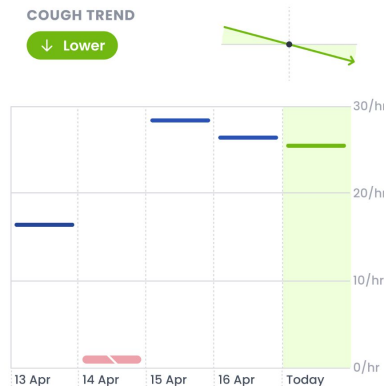
Cough bursts

Daily	Weekly	Monthly

Wed, 9 Apr 2023 ⌄

BURSTS TOTAL   **PEAK HOUR**
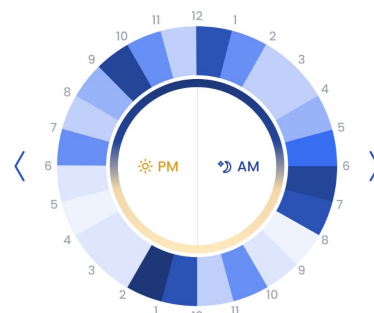
38   **1 – 2pm**

☀ PM   ☽ AM

BURST QUANTITY

1   9

CoughPro is Hyfe's smartphone-based wellness app, which runs passively and continuously in the background in a privacy preserving way.

CoughPro (https://coughpro.com/)