

Design and development of smartphone-based digital biomarkers to support recent changes in cystic fibrosis care.

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INTRODUCTION & OBJECTIVES

- Advancements in cystic fibrosis (CF) treatments have led to a decrease in disease severity for patients with CF (pwCF), necessitating the **development of new management strategies** to concurrently reduce their burden of care^{1,2,3}
- The rise of digital tools and connected devices presents an **opportunity to reorganize care by enabling the monitoring of patients from the comfort of their homes**.^{4,5,6}
- With the advent of Covid-19, home spirometry has become a significant strategy to improve telehealth for pwCF. However, portable spirometers have faced criticism due to **perceived inaccuracies, difficulties in usability, and low patient adherence**. As a result, current studies emphasize the potential of leveraging smartphones for their ease of use and potential to enhance patient compliance.^{7,8}
- Our aim was to develop a smartphone mobile application supporting a **home-based assessment of pwCF through the collection of sensor-derived digital biomarkers (dBMKs)**.

METHOD

The design of this software as a medical device (SaMD) followed a **four-step process**:

STEP 1

Identification of candidate dBMKs through a literature review;

STEP 2

Selection of appropriate biomarkers with CF experts (five physicians and one nurse) and identification of the measurement process;

STEP 3

Verification of the technical feasibility of collecting and analysing dBMKs from patients' homes;

STEP 4

Verification of the usability of the different parts of the mobile app with pwCF.

RESULTS

STEP 1 & 2 - IDENTIFICATION OF THREE SENSOR-DERIVED DIGITAL BIOMARKERS (dBMKs)

The review of literature identified **six candidate dBMKs** (maximum phonation time after exertion, speed, distance traveled, number of stops, frequency and duration of nocturnal cough) to target objectively measure **three major health concepts by using objective criteria in cystic fibrosis** (aerobic capacity, lung function and nocturnal cough). After interviews with experts and pwCF, we designed three smartphone-based patient self functional assessments to compute the selected dBMKs. To complement the functional assessments (lung function test, aerobic capacity test and nocturnal cough test) we added a **symptom questionnaire**. In the following figures the health measure, the dBMKs and the use of the smartphones tools are displayed.



Figure 1: MuCopilot™ content in terms of health concepts and related dBMKs along with a symptom questionnaire

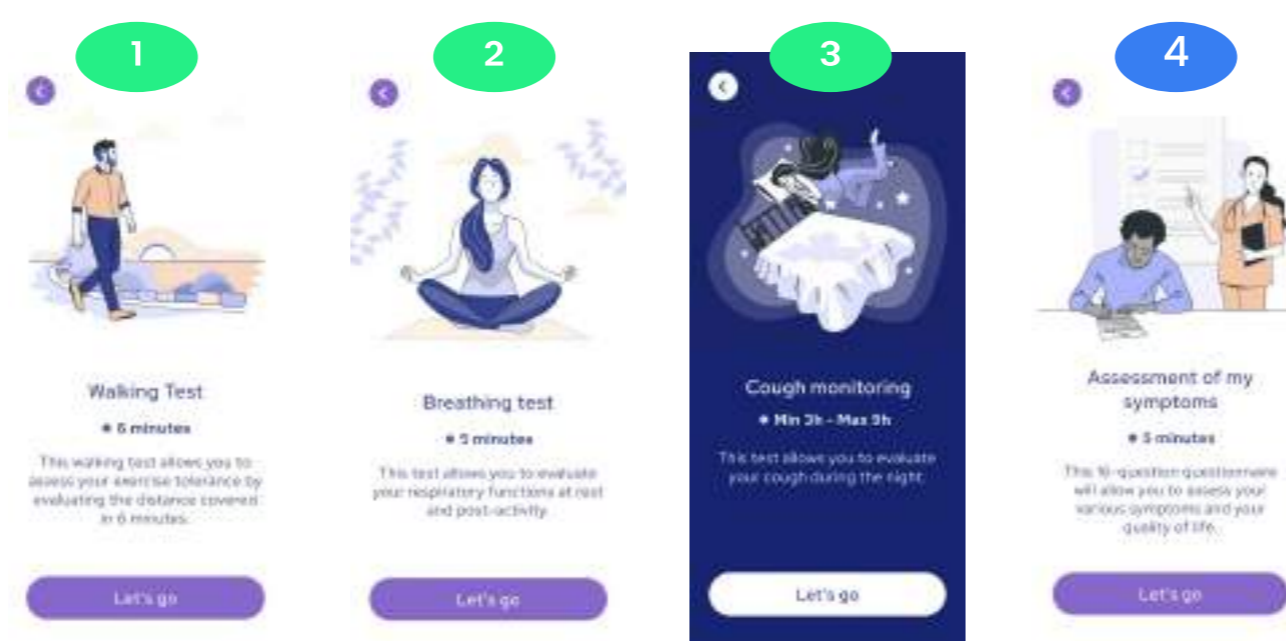


Figure 2: Mobile application screens of the MuCopilot™ features (smartphone based functional assessments and symptom questionnaire)

STEP 4 - USABILITY STUDY

Three **usability studies** were conducted involving **twenty-three pwCF** (demographics in fig. 5). The aim was to improve the mobile application by assessing perception of ease of use and usefulness.

Participants confirmed the **ease of use and usefulness** of the mobile application (fig. 6,7), after testing it on an online prototype (fig.2). They agreed on the usefulness of the application, both for preparing medical appointments and for regularly monitoring their symptoms.

These studies yielded **55 recommendations for improvement**, out of which **36 were prioritized and incorporated** into the development of the mobile application.

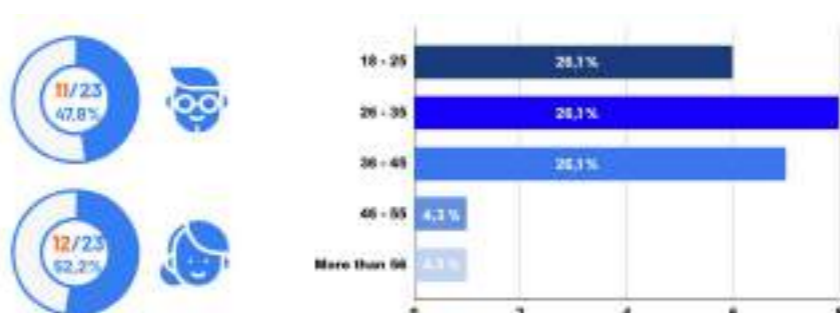


Figure 5: Usability studies patients' demographics (N=23)

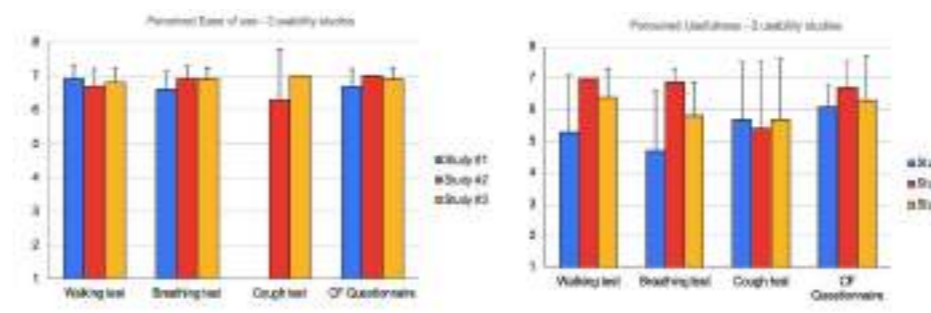


Figure 6: Patient-perceived ease of use (#1 n=7, #2 n=7 & #3 n=9)

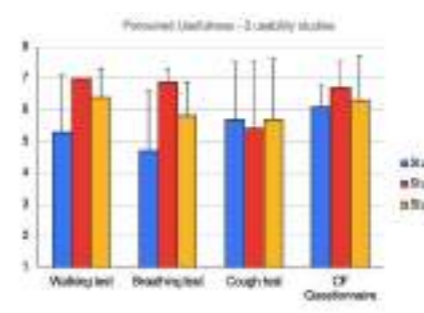


Figure 7: Patient-perceived usefulness (#1 n=7, #2 n=7 & #3 n=9)



Figure 8: Patient-interest in using MuCopilot (N=23)

STEP 3 - TECHNICAL FEASIBILITY

We have confirmed the **feasibility of data collection and analysis** for the three major health concepts. More specifically, the technical validation studies validated the use of the smartphone microphone for the following purposes (fig.3,4):

Lung function technical feasibility

We validated the feasibility of analyzing speech data based on the smartphone microphone through a Voice Activity Detection (VAD) Model.

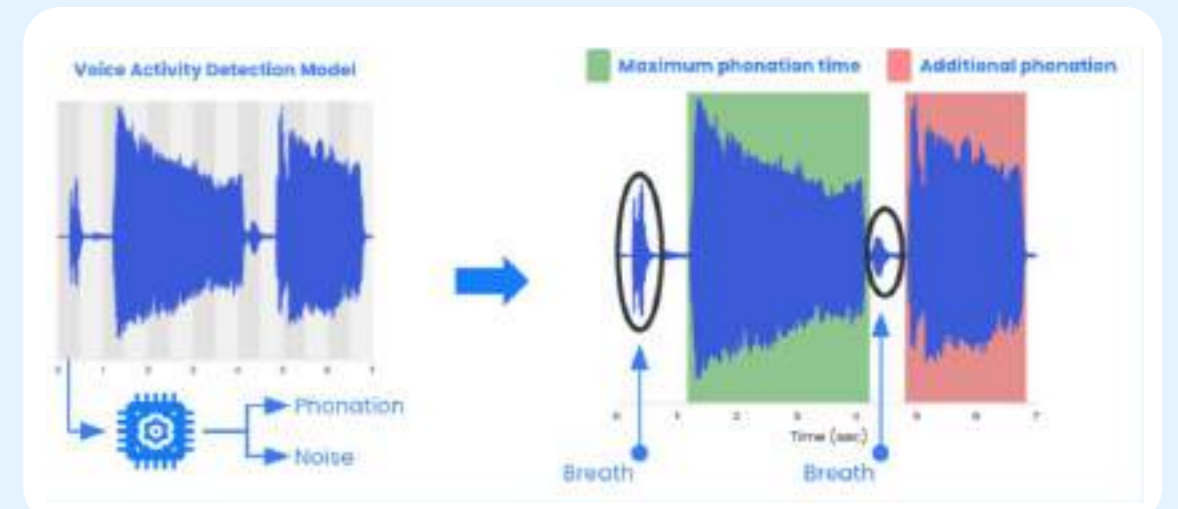


Figure 3: Maximum phonation time detection during Lung Function evaluation.

Cough monitoring technical feasibility

We validated the feasibility of analyzing cough data based on the smartphone microphone through a Machine Learning (ML) classification algorithm.

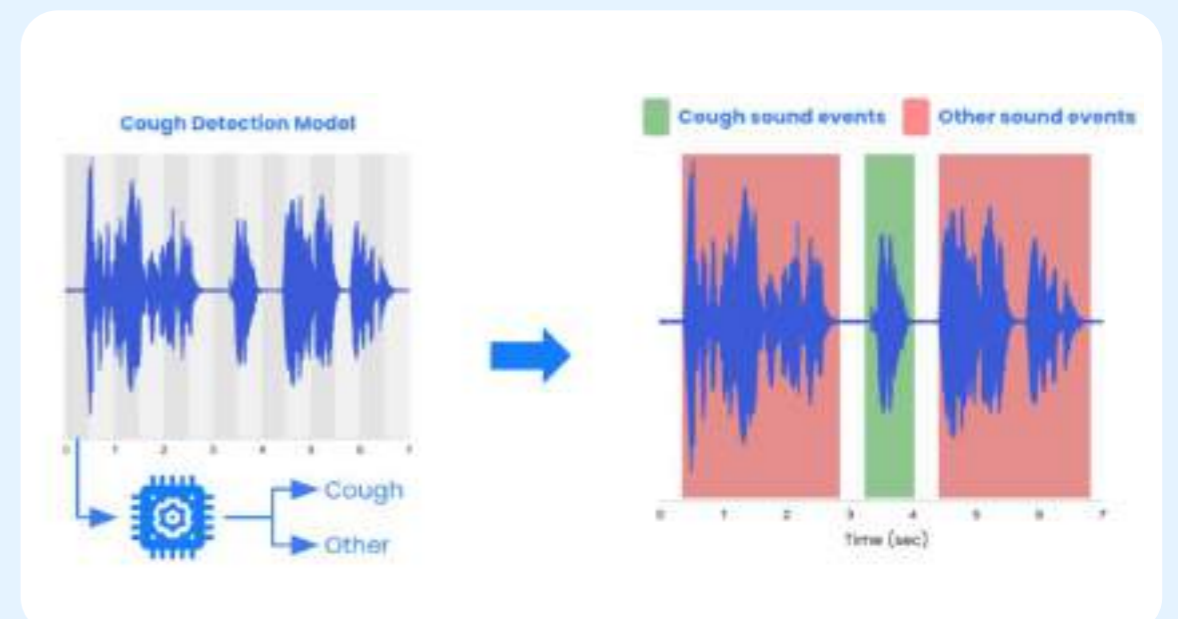


Figure 4: Cough sound event detection during Nocturnal Cough evaluation.

CONCLUSION

- The mobile application MuCopilot™ developed includes a questionnaire on symptoms and three tests to remotely assess the health status of pwCF.
- The next step is a clinical study that will include 70 people with CF during 2024 and follow them for three months. The aim of this clinical study is to prove that the software complies with Regulation 2017/745 related to Medical devices, so as a notified body can evaluate and certify it as a class IIa medical device. The study will also assess whether use of this mobile application and its six digital biomarkers in real-life conditions allows physicians to reliably evaluate the health status of pwCF from their homes. The primary objective is to demonstrate that the results of the MuCopilot digital tests at home are associated with the results of their standard counterparts carried out in-clinic.

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