Continuous Monitoring of Asthma Control

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Abstract

An asthma action plan (AAP) is a set of medication changes custom designed for asthma patients in case of an asthma exacerbation. However, many asthma patients fail to utilize the plan due to the subjective nature of when to implement and insensitivity to early symptoms of an asthma exacerbation. Continuous monitoring of important indicators of asthma exacerbation such as: shortness of breath from decreased respiratory volumes, cough and wheeze allows real time detection of an asthma exacerbation and helps patients utilize their AAP in a timelier manner. The previous team developed an asthma shirt: a portable, affordable, and non-invasive means of monitoring asthma. There were some modifications of the microphones and electronic connections of the current device that needed to be made to allow the patient to notice their symptoms of an asthma exacerbation sooner and allow them to contact their physician for treatment. The new design was evaluated using a virtual testing method in PSpice and produced an oscillating curve around an average output voltage with peaks ranging in size; the trials were consistent with no variance. This presentation outlines the human subjects testing protocol and modifications that will be made in the future development of this device to be used as a screening tool in the clinic setting.

Background: Anatomy & Physiology

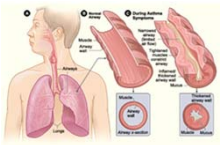

Figure 1. View of: (a) the respiratory tract showing airways and lungs, (b) the normal airway cross section and (c) the change in the cross section during asthma symptom[3]

Lungs:

- Extract oxygen from the environment, transfer it to the bloodstream
- Remove the carbon dioxide that has been accumulated in the bloodstream[1]
  - Air enters through the nasal cavity, splits equally into a right and left bronchus, into the multiple bronchi, bronchioles and respiratory bronchioles[2]
- Mucosal tissues line the airways to prevent small particles from entering the system

Asthma:

- Chronic lung disease which causes wheezing, coughing, breathlessness and chest tightening
  - 25 million people in the U.S alone[4]
- Lung's airways are constricted
  - During an asthma attack: airways swell making it (hyperresponsive smooth muscle contraction)[5]
  - Mucus in your lung increases
- Medicine is available, quick and short-term treatment[6]

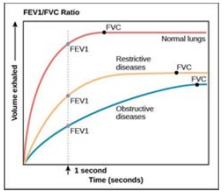

Figure 2. The volume exhaled increases as time moves forward. Notice that for obstructive diseases, the FEV_1 and FVC are much lower for obstructive diseases[7].

Background: Electrical Components

Electro-resistive Bands:

- Monitoring shortness of breath
- Change in resistance as the length changes
  - Stretches up to 160% original length
- Acts like a voltage divider
- Currently used to monitor ventilation[8]
  - Can be continously worn for up to 24 hours

Microphones: capture ambient audio; returns intensity in form of voltage

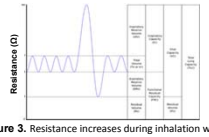

Figure 3. Resistance increases during inhalation when lung volume increases (proportional increase in length)[9].

Problem Statement

- Currently: 2 day detection rate
- Medication does not necessarily restore baseline
- There is a need for a device which will detect these symptoms sooner
  - Decreasing the likelihood of emergency medical procedures

Figure 4. Asthma symptoms vs. detection time[10]

Design Specifications

Non-restrictive wires	Machine Washable
Allow for continuous monitoring/transfer information quickly	Size Adjustable

Designs

Previous Design:

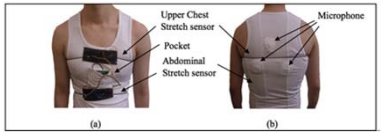

Figure 5. (a) Anterior view of the shirt with stretch sensors and pocket. (b) Posterior view of shirt showing three microphones located on the dorsal region[11].

Current Design:

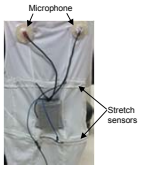

Figure 6. Posterior view of shirt showing two microphones, enclosure box, and stretch sensors around upper chest and abdomen

Testing Protocol

Methacholine Challenge - C. Harty (2009)[12]:

- Patient breathes in nebulized methacholine
  - Drug provokes bronchoconstriction
- Spirometry is used to quantify amount of airway constriction

Initial Testing:

- Individual will wear shirt for 10 minutes
  - Audio + Resistant band data
  - Determine any significant properties

Ethical Considerations:

- Methacholine challenge can cause muscle weakness
- Can cause violent coughing, or induce asthma attack

Results

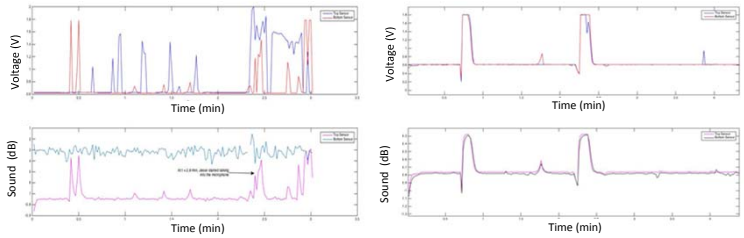

Figure 7. Top graphs show the resistant bands and bottom graphs show the microphone data. The graphs on the left show values for one trial, the graphs on the right show values for the testing for a second trial

Table 1. Subject characteristics of the two different graphs above

Trial 1	
Subject:	Male, age (20-30)
Breathing Rate:	12 breaths/min, average

Trial 2	
Subject	Male, age (30-40)
Breathing Rate:	Not enough data points

Conclusion

Reproducibility:

- Able to reproduce similar graphs for different subjects
  - Accurately captures breathing and coughing events for different individuals
  - Shirt is adjustable for different sizes
- ANOVA test show: p-value < 0.05; means are statistically different

Table 2. Single-factor ANOVA for Stretch Sensor Data (n=4)

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	12554216	7	1793459	224.3952	2E-225	2.015927
Within Groups	11509074	1440	7992.413			

Cost Summary

Cost of prototype: $150.00

Future Work

Short Term:

- Bluetooth implementation
- Patient Testing:
  - Patient will undergo Methacholine Challenge
    - Wearing shirt
    - Nurse in room to note observations
    - Determine any significant properties, compare to initial testing & gold standards

Long term:

- Make shirt more comfortable and aesthetically pleasing
  - Condense all components
  - Undershirt for daily use
- Smart phone application
  - Update user on how they are doing
- Longer battery life
  - Include a charger
- Continuous monitoring throughout the day
  - Weekly updates sent to clinic for research purposes

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