ABSTRACT

OUTCOME OBJECTIVES: Mobile computer assisted, beside incentive spirometry can be used to detect and calculate the frequency, amplitude, and duration of inspiration.

METHODS
A clinical patient-centered model in an academic research setting was used to demonstrate that computer assisted incentive spirometry could analyze the frequency, amplitude, duration, and calculated volume of inspiration. Sixty inspiratory cycles were recorded from a smartphone (n=30) and laptop computer (n=30) utilizing an external microphone and traditional incentive spirometer (Voldyne 5000, Hudson RCI, Temecula, CA). Multiple microphone-spirometer positions were investigated. Recordings were processed and analyzed utilizing Matlab (R2012a, The Mathworks, Inc., Natick, MA, USA).

RESULTS:
All inspiratory cycles were captured and recorded successfully. All smartphone recorded inspiratory cycles did not exceed 1.5KHz in broadband noise. Increasing amplitude of inspiratory sounds did not produce a significantly increased flow over microphone. No significant power difference was found between the smartphone and computer recordings when investigated 2-cm in front of lips and immediately behind the open-ended spirometry mouthpiece.

CONCLUSIONS:
Mobile, computer assisted recording and analysis of inspiratory cycles is a low-cost, and reproducible method for detecting detailed characteristics of inspiration. Future investigations of portable and automatically implemented signal processing may improve patient care and post-operative recovery.

INTRODUCTION
Incentive spirometry is a near universal component of medical and post-operative care. The goal of this technique is to encourage patients to take deep and slow breaths to assist in expansion of the lungs after surgery. This is crucial as many individuals are at risk of atelectasis secondary to pain and resultant shallow breathing.1

Conventional incentive spirometry is accomplished by the use of a large device that provides the patient with a visual feedback when they inhale for a minimum of 3 to 5 seconds for 5 to 10 consecutive cycles.1 The self-administered device however, suffers from low patient compliance. It is bulky, not user-intuitive, may induce pain, and does not monitor patient use or progression. Recently, advances in mobile and smartphone computing have penetrated everyday personal and clinical practice. With the increasing sophistication of software for these devices, mobile, point-of-care detection of patient focused goals are possible. Our study aims to assess the utility of a smartphone assisted incentive spirometry system.

RESULTS
Sixty inspiratory cycles were recorded using the system illustrated in Figure 1. Through an external microphone (3.5mm EarPod) thirty samples were recorded using a smartphone (iPhone 6s, Apple Inc., Cupertino, CA) and the remainder using a laptop computer (MacBook Pro 2013). For each computing device, ten samples were recorded at three locations from the user. Figure 1 (A) illustrates a microphone 2cm away from the user’s lips, (B) immediately behind the incentive spirometry, and (C) within the spirometer’s chamber.

The dataset of audio samples were analyzed utilizing Matlab (R2012a, The Mathworks, Inc., Natick, MA, USA). The frequency domain representation of the original signal was associated to a function of time by use of Fourier transformation. The data graphed represents noise amplitude, frequency, and duration.

METHODS
Utilizing a microphone and headphone jack all inspiratory cycles were successfully recorded and analyzed (Figures 2-4). The frequency, amplitude, and duration of inspiration were recorded. The maximum recorded amplitude of noise identified through Fourier transformation on iPhone (x=0.18 ± 0.02) was on average less and differed significantly from those recorded by computer (Figure 2, x=0.25 ± 0.02, p=0.027) when recorded in front of the lips and when placed inside the spirometer chamber (p<0.01). The range of frequencies captured by computer (range: 0-2kHz) at all microphone positions was wider than that recorded by iPhone (Figure 3, range: 0-1.5kHz), however all frequencies captured were less within the chamber than when outside of the spirometer or within the mouthpiece (Figure 4, p<0.01). Representative measurements of airflow at 500 Hz, 1000 Hz, and 1500 Hz demonstrated variable amplitude at each microphone position and method of recording.

DISCUSSION
Smartphone computing allows for the efficient storage of datasets readily available for computer-assisted analysis. Our study demonstrates a low-cost and easily reproducible system for recording inspiratory cycles. Future work is required prior to clinical application. Improvements include a frequency threshold and range restriction in order to exclude extraneous noise (ie. bedside alarms). Additionally, we expect that power and flow would correlate with noise amplitude, a made more significant in a reduced frequency range. With the appropriate user interface, the smartphone incentive spirometer has the ability to increase patient compliance, reduce hospital costs, increase accessibility, and improve patient care in the post operative setting.

REFERENCES