Development of Simple Respiratory Checking Device for Spirometry

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Abstract: Chronic obstructive pulmonary disease (COPD) is a progressive disease that makes the patient hard to breathe. Since COPD is difficult to cure, daily treatment and lifestyle change can help the patient to feel better and slow down the progress of the disease. Therefore it is important to discover COPD in an early stage. In this study, a simple respiratory function checking device is developed and its potential is validated by the experimental results.

Key-Words: *Spirometry, COPD, Microphone, Smartphone, Respiratory Function Tester, FEV1.0%, FVC*

1. Introduction

Chronic obstructive pulmonary disease (COPD) is a progressive disease that makes the patient hard to breathe. COPD can cause coughing, wheezing, shortness of breath, chest tightness, and other symptoms. If the disease cannot be detected in early stage it will get worse over time. COPD is the third leading cause of death in the United State and the tenth in Japan [1]. Currently millions of people are diagnosed or estimated with COPD. However, most of them do not even know that they have suffer from COPD. COPD is caused due to smoking, long-term exposure to other lung irritants, such as air pollution or dust. It is usually diagnosed in hospital by a so-called "Spirometer" which is the main equipment used for basic Pulmonary Function Tests (PFTs).

COPD has few subjective symptoms and is easy to be diagnosed as a cold. This might be one reason why many clinics even do not have the PFTs equipment. However, daily treatment and lifestyle change can help patients feel better, work more active, and slow down the progress of the disease. It will be very important to discover COPD in an early stage. There are several PFTs devices in market or in developing, however, they have not yet widely used at home as the healthcare devices such as the blood-pressure meter. The purpose of this research is to develop a simple microphone-based function respiratory tester (MRFT) which is supposed to be an easy-operated device with high checking accurate.

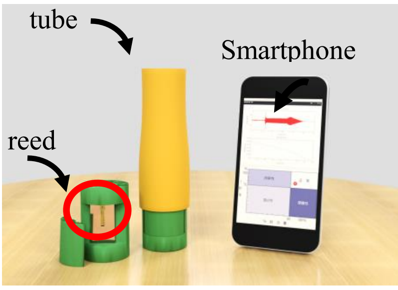

Figure 1 MRFT system model concept.

2. MRFT System

Figure 1 shows the idea concept of the Mic based Respiratory Function Tester (MRFT). Same as the spirometer, the patient takes a deep breath in and then blow as hard as possible to the tube. The air current will flow through the tube to the MRFT, in which a reed will be stimulated to generate a single frequency sound due to the reed vibration. The embedded Mic catches the sound and transmit to a smartphone through audio wire or by Bluetooth wireless. The PFTs parameters, FVC (Forced Vital Capacity), FEV1.0% (Ration of Forced Expiratory Volume in 1.0 second (FEV*1.0) and FVC in %), will be estimated and the results display on the smartphone.

The reed structure is referred from the general harmonica structure so it is easily tuning the sound by select the length of reed. Since there are many kind of noise in home environment, the single frequency sound by a reed can be easily extracted by

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a simple digital filter, which makes the data processing and parameter calculating algorithm much easier.

3. Signal Processing

Figure 2 shows the sound data obtained by MRFT and the data analysis process. Figure 2(a) is the original sound generated by the reed and captured by MIC and (b) shows the main component of the sound with a single frequency at 1040Hz. So it can be easily cut the other noise by a narrow bandpass filter with the central frequency at 1040Hz. The extracted signal is shown in (c). Figure 2(e) is the time viral volume curve of the forced expiratory flow obtained by the spirometer. From this graph the PFTs parameters (FVC and FEV1.0%) are calculated. The date shown in (d) is treated by integration of the envelop curve of data (c). The obtained curve (d) is similar to curve (e), which means the filtered data is acceptable to be used for estimation of FVC and FEV1.0%.

The parameter FEV1.0% is defined by Eq.(1)[2], where FEV1 is the Forced Expiratory Volume in 1.0 second.

$$\text{FEV1.0\%}=\left(\frac{\text{FEV}_1}{\text{FVC}}\right)\times 100 \qquad (1)$$

Vital Capacity (%VC) is calculated by Eq.(2).

$$\text{\%VC}=\left(\frac{\text{VC-measured(L)}}{\text{VC-predicted(L)}}\right)\times 100 \qquad (2)$$

The predicted value of VC is given by:

VC-predicted(male)(mL)=(27.63-0.112×age)×height(cm)

VC-predicted(female)(mL)=(21.78-0.101×age)×height(cm)

For normal persons the VC is almost same as FVC so that the %FVC is used hereinafter instead of %VC. Furthermore, since the value of FVC (FVC_{mic}) from our MRFT is calculated from the reed sound it is not the real FVC (FVC_{spiro}) as obtained from the spirometer. We have to convert the FVC_{mic} to FVC_{spiro}. The coefficient is calibrated by experimental tests in the same condition with the spirometer and our MRFT. The calibrating coefficient is obtained as

$$FVC_{spiro}/\ FVC_{mic}=814.5$$

4. Results and Discussions

Figure 3 shows the comparison PFT results of our MRFT with the spirometer. Subjects are young health men in their twenties. Both results are agreed well with each other and it indicates that our device (MRFT) has the enough potential to be a new home-use healthcare PFT device for screening COPD or other pulmonary disease in the future.

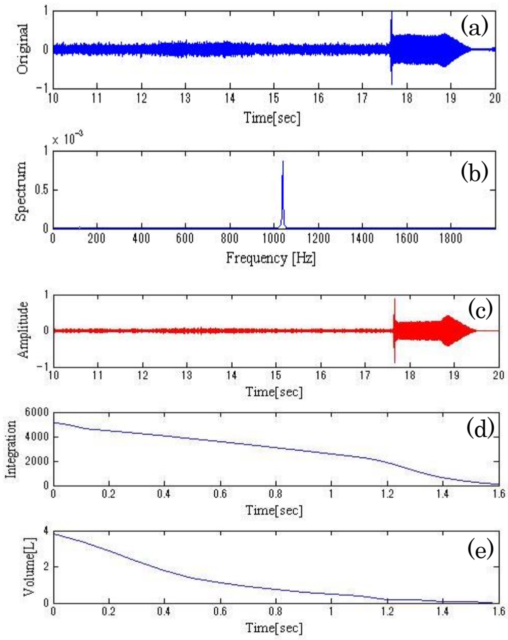

Figure 2 Data processing method. (a) Original sound data, (b) Spectrum, (c) Filtered data, (d) FVC curve calculated by MRFT, (e) FVC curve obtained from spirometer(HI-205).

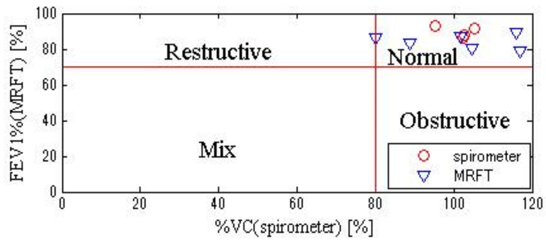

Figure 3 Comparison of PFTs results obtained by Spirometer and MRFT

References:

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