Development and Characterization of a Wireless Mouse-Based Spirometer

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***Abstract*— One of the biggest challenges, regarding the diagnosis and effective management of life-threatening respiratory diseases, is the inadequate access to diagnostic devices like spirometer. The available good-quality commercial spirometers are too expensive (typical spirometers cost $1000–$2500) to afford by the common people in most of the developing countries. This paper presents the development, metrological characteristics, performance evaluation of a cost-effective ($276), easy-to-operate, and electrical hazard-free spirometer using the wireless optical mouse as a novel displacement-sensing element. Computational algorithms generate graphical patterns and numerical values of various respiratory performance indices. The device obtained test results and statistical analysis using Bland–Altman technique show a reasonable match between the standard spirometer and established anthropometry and ethnicity-dependent predictor equations. The device can successfully discriminate the chronic obstructive and restrictive pulmonary diseases and confirms its prospect for clinical uses.**

***Index Terms*— COPD, CRPD, displacement sensor, predictor equations, respiratory indices, spirometer.**

I. Introduction

According to the latest WHO estimates, hundreds of millions of people suffer from various respiratory diseases worldwide. Out of which 235 millions are suffering from asthma, 64 millions have Chronic Obstructive Pulmonary Diseases (COPD) and rest from other critical respiratory diseases. In 2005, 2.5 million and 3.0 million people died of asthma and COPD respectively. The report predicts that by 2030, globally, COPD will be the third leading cause of death [1]. On the other hand, as per World Bank Development Indicators, 2008, at least 80% of humanity live on less than $10 a day [2]. Still, the nations do not necessarily need wealth to gain health. Knowledge on the cost-effective healthcare interventions can cut deaths due to various life threatening diseases [3]. Considering these aspects, this paper finds an immediate need to develop a reliable low-cost device, called as spirometer, to measure the flow and volume of the air moving into and out of the lungs, which offers important indices for the primary assessment of real-time respiratory disorders. Researchers have proposed various sensing technologies to measure vital spirometric values such as force expiratory volume in one second (FEV_1), peak expiratory flow (PEF), force vital capacity (FVC) etc. Carta *et al.* [4] have recommended the differential pressure sensor using the Venturi tube principle to measure the respiratory flow rate. The device needs a square root extractor, as the inferred flow rate is proportional to the square root of the measured pressure, a basic drawback of this mechanism. However, the system is handy and robust against temperature variation ranging from 0°C to 85°C. Lungsgaard *et al.* [5] have investigated an anemometer type respiratory flow sensor. Calibration of the sensor is complex because of its gas composition dependency in exhaled breath, bridge parameters etc. Moreover, a complex electronic circuit makes the system complicated. The turbine based flow transducer generates optical signal when the fan (fitted inside the mouthpiece rotation) rotates to track the respiratory flow[6]. However, the moving parts of the fan cut the sensor's reliability, increase frequency of maintenance leading to a high operating cost. Volume based sensor relies upon the displacement of bellows-shaped chamber coupled with mechanical linkages. A plastic tube couples the chamber and the subject's mouth. A potentiometer senses the bellows' displacement to generate an electrical signal [7]. However, such an arrangement relies on its dynamic parts. A sticking of the bellow-folds develops measurement inaccuracies. The folds of the bellows may adhere because of dirt, moisture. Leaks may also develop in the bellows material. The bellows' movement should be visually assessed during spirometry to ensure its smooth inflation. Movable mechanical linkages attached to the bellows deteriorate device's longevity [8]. Temperature sensor based spirometer exploits the variation of temperature due to respiratory cycles to infer the velocity of the respiratory air. A spirometer that relies on thermistor based flow sensor needs complex electronics to diminish self-heating error and compensate environmental changes [9]. Micro-machined thermal flow sensor used in spirometer provides satisfactory performance for home care use [10]. However, the main problems with the most of the methods are the malfunctioning of the sensor parts due to humidity, mucus and partly temperature variation. Moreover, the sensors depend on the gas properties like viscosity, density etc. Wei *et al.* [11] have presented a CMOS-process-compatible sensitive unidirectional respiratory flow sensor. The sensor is passive one and needs Wheatstone bridge circuit for usable electrical signal.The available commercial spirometers, such as MicroDirect (volume transducer) [12], Welch Allyn (flow sensor) [13], SDI Diagnostic (digital turbine) [14], Schiller spirovit (Pneumo-tacho sensor) [15], use these

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