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Measurement of energy expenditure on a smartphone using a hand-held breath analyser

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Abstract

An indirect calorimeter is presented for measurement of Energy Expenditure (EE) in the free-living environment. A 1 minute breath sample is sufficient for EE calculation. A smartphone or laptop can display the EE data. The calorific energy required by the body is vital to healthcare (e.g. to ensure adequate feeding during physical exertion), and can provide dietary guidance for the general population. The availability of accurate calorimeters is limited, particularly for in- and out-patients. The novel analyser has been trialled against respiratory chambers. On average, resting EE was calculated to within 2.4 % for 9 subjects. The prototype uses an innovative NDIR sensor and an electrochemical sensor to calculate the volumes of CO_2 produced and O_2 consumed, with errors of 5.4 % and 3.4 % found respectively compared to the chambers. Further work includes investigating the energy cost of food digestion.

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Keywords: breath; energy expenditure; smartphone; metabolic rate; indirect calorimetry.

1. Introduction

Human energy expenditure, the amount of energy burned by the body at a given time, is dependent on activity, muscle mass and meal intake. Throughout a daily routine, the resting metabolic rate is modulated by content of meals and level of activity. The aim of this project is to develop a hand-held device capable of EE measurement for point of

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care applications. Our target is to develop a system capable of measuring a 1 % change in metabolic rate to identify and analyse the components that contribute total daily EE. The device contains sensors for oxygen (O_2), carbon dioxide (CO_2), flow rate, volatile organic compounds (VOCs), temperature and relative humidity. We present an affordable portable breath analyser capable of EE measurement from 1 minute of breath-by-breath data.

To verify the performance of the instrument, the device has been tested with 10 subjects (resting EE, where subjects fasted for 6 hours prior to measurement) inside respiratory rooms (the gold standard technique for indirect calorimetry [1]). The ability to take measurements using a smartphone was tested, with data shown over one working day. It is advantageous to make measurements of EE in a free-living environment to assess the energy burnt by subjects during their normal daily lifestyle, without being confined in a laboratory. It is proposed the energy cost of activities and food absorption (converting ingested macronutrients) during the daily routine of a subject can be calculated using measurements taken regular intervals during a one day period.

1.1. Background

The current generation of portable indirect calorimeters are expensive and require expertise to operate [1]. They are inaccessible to the general population and studies often focus on specific patient groups, such as an obese population. A device for routine use in the community would help increase awareness of the risks associated with becoming obese, and potentially prevent overweight individuals from increasing the trend towards obesity. Over the last two decades the proportion of the adult population in the UK categorised as obese has doubled for men and increased by 50 % for women [2]. A lack of knowledge about calorific intake requirements and a sedentary lifestyle are possible contributory factors. In the UK alone, obesity and related illnesses cause an economic burden of £51 billion annually [2]. The reduction in occupational manual labour has meant that previously common daily activity has decreased causing many individuals to become less active and more sedentary. In terms of lifestyle, standing rather than sitting can help increase metabolic rate, although this is less significant than participating in purposeful exercise. It has been reported a 45-minute bout of sprint interval training can increase metabolic rate by up to 14 hours post exercise (measured by indirect calorimetry, in a respiratory room) [3].

The doubly labelled water (DLW) method of EE determination allows for measurements in a free-living environment. In terms of lifestyle assessment, calculating EE through DLW measurements does not allow for specific activity variation in EE to be identified, instead only a total value is found over the complete measurement period (days or weeks) [4]. Activity monitors are becoming increasingly common place in smartphones, fitness bands and smartwatches. It has been reported that although these monitors provide an affordable means of activity tracking, they are black-box solutions [4], which prevents adaptation of internal equation sets to suit the end user. It was reported that activity monitors overestimated EE of patients with osteoarthritis of the hip, perhaps due to altered movement patterns [4]. A portable indirect calorimeter for use in the general population would overcome these drawbacks, and potentially offer a unique insight into the energy burned during familiar daily activities.

1.2. Methodology

To facilitate portable EE measurements, without the need for a bulky laptop computer or power supply, an Android smartphone application was developed for use with a small breath analyser. The novel analyser (Fig. 1 (a)) was developed using affordable sensors for O_2 (MOX-20, City Technology), flow (SFM2000, Sensirion) and temperature and relative humidity (ChipCap2, GE). Custom research sensors were developed for measurement of CO_2 (NDIR) and VOCs (MOX). The system is based on the principle of side-stream sampling. A continuous (150 ml/min) sample is taken from exhaled (and inhaled) air and pumped through a small sensor chamber (details are given in previous work [5]). The battery powered unit links to a smartphone via Bluetooth (block diagram Fig. 1 (b), data logging 200 Hz). The application, Fig. 1(c), instructs the user when to breathe, shows CO_2, O_2 and flow sensor data in real time and displays the EE calculated (cal/min) immediately after a 1 minute breath sample is given (first minute of data discarded, for familiarisation). An accompanying application was developed for computers (National Instruments LabVIEW 2015), which allowed multiple analysers to be connected simultaneously. Preliminary tests have been performed in a free-living environment. The measurements were taken hourly during a day for an office worker, between 10 am and 4 pm. EE was recorded using the smartphone itself without external data processing.