Wearable Indirect Calorimeter [or respirometer] for Passive, Proportional, and Valveless Breath Sampling and Analysis
Technology #16315-19549-20345-20450

Applications

This invention has three distinct elements:

- First, a wearable respirometer that measures pulmonary ventilation and the carbon dioxide and oxygen levels of expired breath, and calculates whole body Respiratory Quotient (RQ) (i.e. the ratio of carbon dioxide produced to oxygen consumed in expired breath). This wearable respirometer can be used to: measure metabolic energy expenditure (metabolic rate) both at rest and during physical activity, estimate the metabolic fuel mixture (carbohydrate to fat ratio) being metabolized to meet the body’s energy demands, and assess an individual’s aerobic fitness (maximum rate of oxygen consumption).
- Second, an austere State Model of Fuel Metabolism that uses respirometer data (input) to generate (output) to provide individuals with useful [actionable] information regarding their metabolic state. Specifically, the State Model of Fuel Metabolism graphically illustrates how users’ diet (food amount, composition, and timing of consumption) and physical activity (exercise type, duration, intensity, and frequency) affect how carbohydrates and fat are burned and/or stored. The feedback regarding metabolic fuel use, which is characterized by an RQ measurement, enables individuals to tailor their diet and physical activities to achieve and maintain a desired pattern of fat- or carbohydrate-predominant fuel use, which will lead to desired changes in body composition (fat and muscle mass) and physical endurance/performance. The wearable respirometer and State Model of Fuel Metabolism can be employed by a broad demographic of individuals to improve metabolic health, minimize the likelihood of type 2 diabetes, and improve endurance exercise capacity.

Problem Addressed

The current state of the art for measuring weight loss is the bathroom scale. The majority of diet plans focus directly on caloric energy balance using a “calorie-in/calorie-out” (CICO) model that restricts calorie consumption and increases exercise. However, this method is prone to error since dieters must accurately count both their calories consumed and burned. More significantly, CICO fails to address the impact of dietary macronutrients (carbohydrate, fat, protein), exercise duration and intensity, or genetic differences on metabolic health. In contrast, the present invention uses RQ (explained below), rather than CICO, as an improved metric on which to focus. The associated device, a portable respirometer (also known as an indirect calorimeter), calculates a user’s RQ on demand by measuring the ratio of oxygen to carbon dioxide within exhaled breath. The RQ information from the wearable respirometer, organized and presented using the state model of fuel metabolism, enables users to quantitatively assess the impact of their macronutrient intake and their physical activity regardless of individual genetic variations and predispositions.
Technology

This invention includes a state model of fuel metabolism that calculates the RQ. This is the ratio of carbon dioxide produced to oxygen consumed, which is indicative of underlying metabolic activity including the burning glucose for energy, burning dietary fat for energy, storing glucose as glycogen, blocking the use of dietary fat as an energy source, and converting glucose into fat (de novo lipogenesis). The rates of these mechanisms within the model may be adjusted to account for age, gender, and genetic factors.

Without sacrificing accuracy, the inventive portable indirect calorimeter greatly improves on the size, cost, and overall ease of use over mixing chamber and breath-by-breath devices used to measure RQ. It consists of a bent, hand-held/jaw-held flow tube, as well as an attached, miniature, and valveless mixing chamber. The user breaths in and out of the flow tube naturally while it measures representative samples of breath. The internal geometry of the flow tube creates a pressure system that prevents ambient air from entering the mixing chamber with no need for moving parts. The breath sample extraction rate is directly proportional to the flow rate, allowing for a mixing chamber that is only a fraction of a liter in size while preserving the constituent gas mixtures in the full exhaled breath. Durable gas sensors in the mixing chamber compute RQ and energy expenditure based on measurements of the extracted breath based on oxygen and carbon dioxide levels, and volumetric flow rate. This system is capable of performing moving RQ averages over a plurality of exhalations, while the valveless design cycles the extracted breath back to the main flow stream presenting a low respiratory burden to the user.

In a distinct application, with minor modification (removal of fresh air inhalation valves), the flow tube from the wearable respirometer device can be reversed and used as an inhaler. Just as in the respirometer sampling system, the inhaler device is completely passive, requiring no external valves or power supplies. It is capable of measuring a patient’s respiratory flow rates and delivering a known amount of medicine from a mixing chamber. A dynamic stall passively shuts off flow to the mixing chamber on exhalation, avoiding dilution from ambient air and preventing excess medication from being delivered.

Advantages

- Provides quantified, on-demand information about a user’s metabolic state
- Replaces formulaic dieting technique of calorie restriction with on-demand measurement of individual’s metabolic fuel state reflecting their unique metabolism, diet and exercise activities
- Small, portable, and inexpensive
- Simple to use without a mask, nose clip, or moving parts
- Limited respiratory burden due to passive, valveless design
- Proportional sampling and delivery without dilution from ambient air
- Durable gas sensor lasting years without recalibration

Categories For This Invention:

Lincoln Laboratory
Medical Devices
Other (Medical Devices)
Life Sciences
Biotechnology
Food
Clinical Applications
Cardiovascular
Metabolism, Endocrinology, & Diabetes
Physical Medicine & Rehabilitation
Instrumentation
Other (Instrumentation)
Research Tools

Intellectual Property:

Systems, apparatus, and methods related to modeling, monitoring, and/or managing metabolism
US Patent Pending
2017-0055875
Systems, apparatus, and methods related to modeling, monitoring, and/or managing metabolism
US Patent Pending
2018-0125391
Methods and apparatus for passive, proportional, valveless gas sampling and delivery
Provisional
Carbon dioxide consumption for assessment of metabolic parameters
Provisional
Systems, apparatus, and methods related to modeling, monitoring, and/or managing metabolism
PCT
2017-019783

Inventors:

Gary Shaw
Andrew Siegel
Lawrence Candell
George Zogbi
Chris Ferraiolo
Kyle Thompson
Robert Standley
Reed Hoyt
Holly McClung

Publications:

Measuring Short-Term Substrate Utilization Response to High-Carbohydrates and High-Fat Meals in the Whole Room Indirect Calorime
Physiological Reports
June 2016, 4(12)

Image Gallery: