



CHRISTMAS 2022: PHYSICAL (FAST FACTS)

Measuring human energy expenditure: public health application to counter inactivity

This article discusses the use of indirect calorimetry for the measurement of human energy expenditure. Quantification of energy expenditure during low efficiency walking (as depicted in the Monty Python sketch *The Ministry of Silly Walks*) is presented as an example of how physical activity recommendations could be met by exchanging ~11 minutes per day of normal walking with low efficiency walking—without requiring any further time commitment.

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Energy expenditure

Human energy expenditure involves the catabolism of macronutrients—mainly carbohydrates and fat—to carbon dioxide and water, which is coupled to the consumption of oxygen. Because this process produces heat, energy expenditure can be measured via direct calorimetry. This method requires a human calorimeter that is cost prohibitive and, more importantly, is limited in its capacity to measure energy expenditure from physical activity. Indirect calorimetry, which requires measurement of ventilation and gas exchange, has greater functionality with broader applications, and is the most widely used method of measuring human energy expenditure during physical activity.

Historically, ventilation and gas exchange were assessed by collecting expired air in impermeable canvas (Douglas) bags or large calibrated spirometers and then measuring the concentrations of oxygen and carbon dioxide either chemically or with calibrated electronic gas analysers.¹ Technology advances led to the development of automated systems that are now the standard for assessment of

energy expenditure. Automated indirect calorimetry systems consist of a flow meter to measure ventilation, gas analysers to measure concentrations of CO₂ and O₂ in both inspired and expired air, and computer software that calculates ventilation (VE), oxygen uptake (VO₂), and carbon dioxide production (VCO₂).¹ VE, VO₂, and VCO₂ are usually expressed with a dot above the V to denote the time derivative of measurement (typically per min; ie, L/min for VE, and either L/min or mL/kg/min for VO₂ and VCO₂),² and they are expressed this way in our main article.³ All require participants to wear a facemask or mouthpiece (with nose clip) to ensure that total ventilation is measured and samples of expired air can be directed to the gas analysers that are secured to a shoulder harness worn by the participant (fig 1). The ratio of VCO₂:VO₂ defines the respiratory quotient, which can be used to obtain the energy value per litre of O₂ consumed (kcal/L of O₂),⁴ and then allows for conversion of VO₂ to energy expenditure (kcal/min or kcal/kg/min). Automated systems have been validated against the optimal Douglas bag method, and have been shown to be accurate and reliable.¹

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Fig 1 | Participant during the Teabag style walking trial while wearing the portable metabolic measurement system

Applications—why quantification of energy expenditure is important

Indirect calorimetry systems basically come in two varieties—metabolic carts (limited mobility) and portable metabolic measurement systems (virtually unlimited mobility), and can be used to determine metabolic rate and fuel use at rest and during exercise, including for assessment of maximum cardiorespiratory capacity (VO₂max) (VO₂max is one of the strongest predictors of longevity, and a high age adjusted value of VO₂max is associated with lower risk of cardiovascular disease, type 2 diabetes, and cancer⁵). Indirect calorimetry can also detect changes in energy expenditure and fuel use (fats v carbohydrates) in response to changes in diet composition and energy intake, and is used to confirm the metabolic rate of various physical activities.⁶

The metabolic rate while resting is defined as 1 metabolic equivalent (MET; 1 MET = ~3.5 mL O₂/kg/min). The MET system allows for classification of physical activity by MET equivalents. Physical activities <3 METs are defined as light intensity, 3 to <6 METs as moderate intensity, and ≥6 METs as vigorous intensity.⁷ Knowledge of these intensity domains is important because a strong body of evidence supports the health benefits conferred by meeting the threshold of 150 minutes of moderate activity or 75 minutes of vigorous intensity exercise per week (or equivalent), including reduced risk of all cause mortality.⁸ Accordingly, quantifying the metabolic rate for various physical activities is crucial for determining whether individuals meet current physical activity guidelines for health promotion and disease prevention.

The metabolic rate for adults walking in their usual style is about 3 METs, which barely meets the moderate intensity threshold for health benefits. However, by decreasing the energy efficiency of walking—without increasing time spent walking—the MET level for that movement might be augmented from low-moderate to vigorous intensity physical activity, allowing adults to reap the greater health benefits associated with higher intensity physical activity.⁹

In our linked paper in *The BMJ* (doi:10.1136/bmj-2022-072833), we used a portable metabolic measurement system (Carefusion, San Diego, CA) to quantify the metabolic rate of walking in one's usual style compared with two styles of inefficient walking depicted in the Monty Python sketch *The Ministry of Silly Walks* (<https://www.youtube.com/watch?v=TNeeovY4qNU>).³

The walking trials

Our participants comprised 13 healthy adults (six women, seven men) aged 22–71 years with no known gait disorder. They were asked to perform three walking trials on an indoor track, each lasting five minutes, which is long enough to establish a steady state in VO₂, VCO₂, and respiratory quotient to ensure accurate assessment of energy expenditure for each walk. In one of the trials, participants walked at their usual, self-selected, pace. Two additional trials consisted of inefficient walking, whereby the participants were asked to recreate, to the best of their ability, the walks they had watched performed by actors John Cleese (Mr Teabag) and Michael Palin (Mr Putney) in *The Ministry of Silly Walks* sketch. As in the first trial, participants self-selected their walking pace.

Metabolic cost of low efficiency walking

Only the Teabag walk resulted in a significantly greater energy expenditure (kcal/kg/min)—about 2.5 times that of participants' usual walking style. For men and women combined, VO₂ while walking in their usual style was 11.3±1.9 mL/kg/min (or ~3.2 METs), which was similar to that of the Putney walk (12.3±1.8 mL/kg/min,

or ~3.5 METs). By contrast, the Teabag walk elicited a VO₂ of 27.9±4.8 mL/kg/min, or ~8.0 METs, which qualifies as vigorous intensity exercise. In terms of energy expenditure, exchanging just one minute of walking in one's usual style with one minute of Teabag walking was associated with an increase in energy expenditure of 8 kcal/min for men and 5 kcal/min for women.

Conclusions

Our study used indirect calorimetry to look at an important public health issue—how to remedy the high global prevalence of physical inactivity¹⁰—to show that adults could achieve 75 minutes of vigorous intensity physical activity per week by walking inefficiently for about 11 minutes per day. This strategy would require no additional time commitment because it replaces typical movement with less efficient, higher energy—and hopefully more joyful—physical activity.

Key points on measuring human energy expenditure

- Metabolic measurement systems can quantify energy expenditure during physical activity
- Adults could achieve 75 minutes of vigorous intensity physical activity per week by exchanging 11 min/day of normal waking with inefficient (Teabag style) walking
- The increase in vigorous intensity physical activity could have important public health benefits

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