



## Nutritional Assessment Platform

Measuring Energy Expenditure using indirect calorimetry

Standard Operating Procedures

Version 1

8/29/2017

Auteurs: Annemieke Kok, Martine Sealy, Marijke Berkenpas

<b>Aim:</b>	Measuring energy expenditure using indirect calorimetry
<b>Population:</b>	Adults and children
<b>Time:</b>	Approximately 30 minutes



## Contents

---

1. Objective of the measurement .....	3
2. Abbreviations .....	3
2. Background information .....	3
3. Population .....	4
4. Veiligheid en Milieu .....	5
4.1. Safety issues .....	5
4.2. Environmental issues .....	5
5. Description of the measurement device .....	5
6. Cleaning and maintenance .....	5
6.1. Cleaning .....	5
6.2. Maintenance .....	5
7. Performing the test .....	6
7.1. Materials needed .....	6
7.2.1. Preparing for measurement .....	6
7.2.2. Performing the measurement .....	7
7.3. Documenting .....	7
8. Methodologic quality .....	8
8.1. Validiteit en betrouwbaarheid .....	8
References .....	9
Appendix 1: Flow chart of process of preparing, performing and documenting the test .....	10
Appendix 2: Influence of nutrition, cafein, nicotine, alcohol and medication on REE .....	11



## 1. Objective of the measurement

---

This SOP describes a method for measuring resting energy expenditure by indirect calorimetry using a canopy (ventilated hood), mask or mouthpiece. Indirect calorimetry measures O<sub>2</sub> consumption and CO<sub>2</sub> production, with this results resting energy expenditure can be calculated. Additionally, resting energy expenditure can be used to calculate total daily energy expenditure.

## 2. Abbreviations

---

REE; Resting Energy Expenditure

TEE; Total Energy Expenditure

RQ; Respiratory Quotient (VCO<sub>2</sub>/ VO<sub>2</sub>)

VCO<sub>2</sub>; Carbon dioxide production in l/ min

VO<sub>2</sub>; Oxygen consumption in l/min

## 2. Background information

---

Indirect calorimetry measures O<sub>2</sub> consumption and CO<sub>2</sub> production, for calculating REE and the RQ. This methods also allows estimation of the differential contribution of the macronutrient oxidation (ie, carbohydrate, fat and protein) to REE.

The calorimeter can be used with a canopy (ventilated hood), mask or mouthpiece or connected to mechanical ventilation. When using the first method; a constant airstream passes through the canopy which is positioned over the participant's head. When using the second method; the participant breaths through a mask or mouthpiece.

By measuring O<sub>2</sub> consumption and CO<sub>2</sub> production in inspired and expired air by the participant; RQ can be derived and subsequently the REE using the abbreviated Weir equation\* (1949):

$$\text{REE (kcal/ min)} = 3.9 * \text{VO}_2 \text{ (l / min)} + 1.1 * \text{VCO}_2 \text{ (l/ min)}$$

$$\text{REE (kcal/day)} = (3.9 * \text{VO}_2 \text{ (l/min)} + 1.1 * \text{VCO}_2 \text{ (l/min)}) * 1440$$

\*The abbreviated Weir equation can be extended with a measurement of energy losses by urinary nitrogen excretion (uN<sub>2</sub>). This non-abbreviated Weir equation is used less frequent in clinical practice because it is difficult to accurately measure urinary nitrogen excretion and it contributes only for at most 4% of daily energy expenditure in a clinical setting.



The respiratory quotient (RQ) is the ratio of CO<sub>2</sub> produced and O<sub>2</sub> consumed. It gives information about the amount of macronutrients metabolized, eg. fat, carbohydrate and protein. Each macronutrient has its own RQ, because a known quantity of O<sub>2</sub> is consumed and a known quantity of CO<sub>2</sub> is produced. For example, the RQ of carbohydrates is 1,0 because the number of O<sub>2</sub> consumed is equal to the number of CO<sub>2</sub> produced metabolizing 1 gram of carbohydrates.

RQ of the three macronutrients;

Carbohydrates; 1,00

Protein; 0,8

Fat; 0,70.

After an overnight fast in healthy participants the RQ varies between 0,68 and 0,9. Measurement error should be considered when obtaining a RQ below 0,67 or above 1,3 (air leakage, no steady state obtained). A repeated measurement should be considered. A RQ below 0,7 can be obtained in ketosis or hypoventilation (compensation after hyperventilation). A RQ above 1,0 can be obtained in acidosis, hyperventilation and in fed state.

### 3. Population

---

Adults and children

#### Indication:

- For accurately obtaining resting energy expenditure in patient care (eg. in unexplained weight loss or gain) or for research purposes.

#### Contra indications:

- Continuous oxygen therapy using a mask or nose goggle, which can not be stopped during a 30 minute test. (Measurement in oxygen dependent participants which can be stopped for 30 minutes should only be carried out with permission of their physician)
- Hyperventilation
- Having drains or tubes causing air leakage
- Sand bed;
- Not being able to lie flat and/or still during the measurement



## 4. Veiligheid en Milieu

---

### 4.1. Safety issues

Risk class: IIa, low risk. Risks related to performing the measurement are estimated low provided the experimenter is well trained.

A well trained experimenter is able to perform the measurement according to institutional standards and guidelines and is skilled in interpreting test results.

### 4.2. Environmental issues

N.a.

## 5. Description of the measurement device

---

Indirect calorimeter using a canopy (ventilated hood), mask or mouthpiece.

These SOP has not been written for any specific device or brand.

## 6. Cleaning and maintenance

---

### 6.1. Cleaning

When using a canopy; before every measurement an antibacterial filter should be used between the canopy and tube.

Clean the device after use according to the manufacturers' instructions and/or in accordance of the department of hospital hygiene and infection control.

### 6.2. Maintenance

Maintenance should be performed according to manufacturers instructions.



## 7. Performing the test

---

### 7.1. Materials needed

- Indirect calorimeter with canopy, mask or mouthpiece with nose goggle. Antibacterial filters, disinfection wipe and air pump for calibration (depending on the specific device/brand)
- Examination table or bed + pillow (if patient desires also a blanket)
- Scale and height measuring scale
- Quiet room with ambient temperature of 22-25°C (71,6-77°F)

### 7.2. Measurement procedure

See appendix 1 for flow chart of process of preparing, performing and documenting the test.

#### 7.2.1. Preparing for measurement

- Make sure the calorimeter has been warmed up before calibration.
- Perform the calibration of the calorimeter according to the manufacturers instructions
- When using the canopy, use a new antibacterial filter between the tube and canopy before every test.
- Inform the participant about the measurement and answer any questions.
- Check if the participant is in a fasted state (has not been eating or drinking (except water)), in the preceding five hours.  
Note; depending on the study population and the aim of the measurement the measurement can be performed in a fed state or the fasted state can be shortened.
- Check if the participant has not been smoking in the preceding two hours.
- Record whether the participant has used any medication
- Ask the participant to switch of his/her mobile phone.
- Measure participants weight on a calibrated scale.
- Measure participants height using the height measurement scale.
- Ask the participant to take place on the examination table/bed and lie in a comfortable supine position. The main end of the examination table/bed preferable in a 45° angle. If desired a blanket can be used to prevent cooling down of the participant during the test.
- The participant should rest in this position for at least 10 minutes before starting the measurement.



### 7.2.2. Performing the measurement

- Place the canopy over the head of the participant and make sure there is no air leakage or place the mask or mouthpiece.
- Start the measurement according to manufacturers instructions.
- Make sure the participant does not move, talk or fall asleep during the measurement. When the participant seems to be fallen asleep; wake him/her.
- Work quietly and do not talk and frequently observe the participant.
- End the measurement after a minimum of 20 minutes or when reaching a steady state of at least 10 minutes (variation  $VCO_2$  en  $VO_2 < 10\%$ ). Remove canopy, mask or mouthpiece.
- Remove the used filter from the canopy and throw it away.
- Clean the canopy and rubber cover according to the equipment manual / current hygiene guidelines in your institution.
- Change the paper on the examination table and / or change the (bed)sheets

### 7.3. Documenting

- Select a stable period of at least 15 minutes (variation  $VCO_2$  and  $VO_2 < 10\%$ ), discarding the first 5 minutes of the measurement (due to acclimatization of the participant, the REE will decrease and subsequently stabilize).
- Record the measured REE, the time period of the steady state, the RQ and the variation of the RQ,  $VCO_2$  and  $VO_2$  and other variables such as length, weight and medication in the electronic patient file or desired database.



## 8. Methodologic quality

---

### 8.1. Validiteit en betrouwbaarheid

Direct calorimetry is considered the gold standard for measuring resting energy expenditure. Direct calorimetry is the measurement of heat produced by metabolic processes in the body. The produced heat can be measured in an isolated measuring chamber. Although this method is accurate, the measurement is very expensive, not available everywhere and requires specific technical knowledge. For this reason, indirect calorimetry is most appropriate and most commonly used method in clinical practice.

Various factors such as nutrition, caffeine, nicotine, alcohol, medication, reading and listening music may have an effect on energy expenditure (see Appendix 2).

The validity and reliability of newer mobile devices varies by brand and (patient) population. In order to determine validity and reliability, this equipment is often compared to indirect calorimetry with ventilation hood. The disadvantage of using mobile equipment is that there is often no calibration of gas mixture possible, which makes the measurement slightly less accurate. The advantages are that they are more mobile, easier to operate and the measurement goes faster. In addition, this equipment is cheaper and for more people at their fingertips.



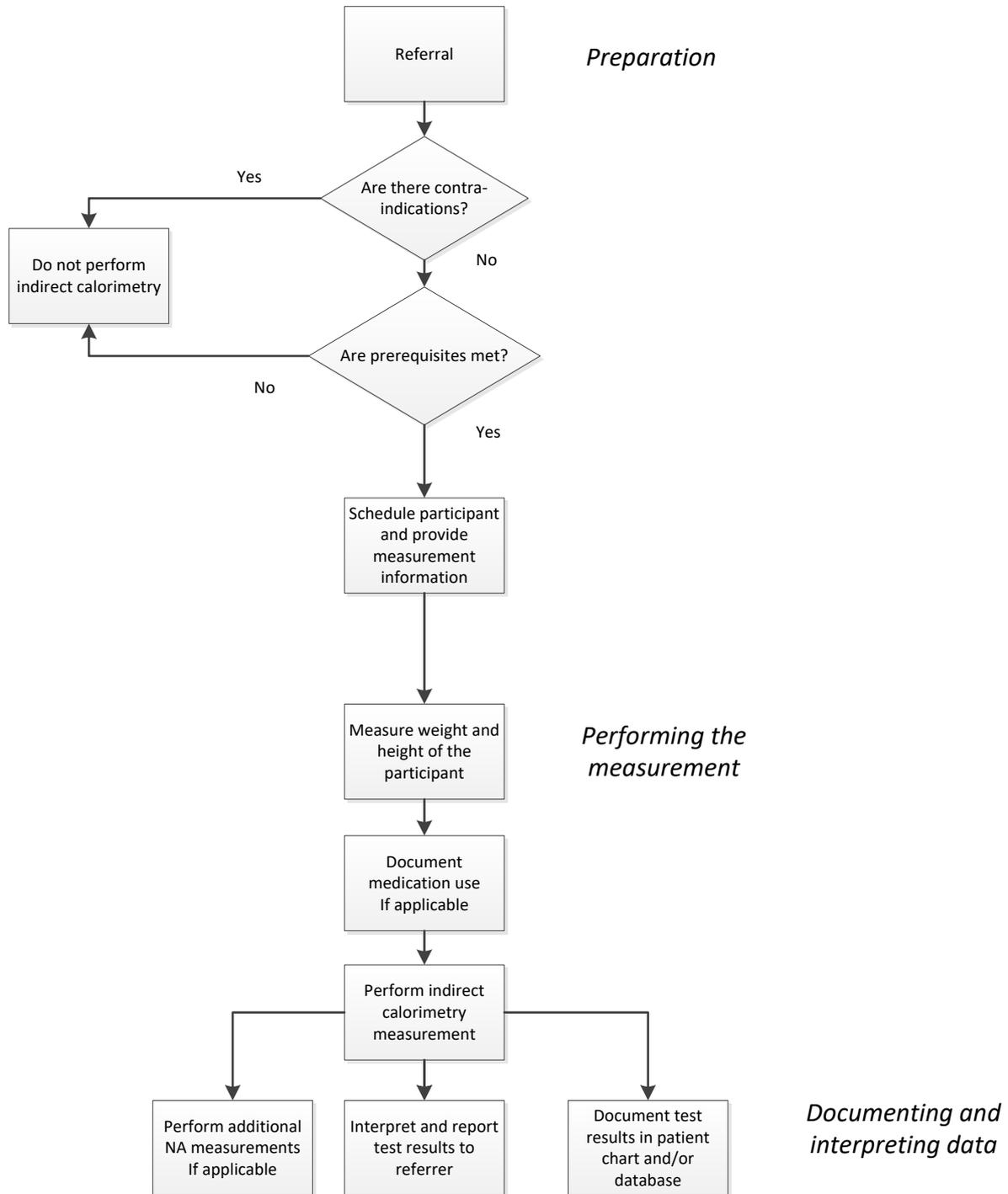
## References

---

- (1) Compher C, Frankenfield D, Keim N, Roth-Yousey L. Best practice methods to apply to measurement of resting metabolic rate in adults: a systematic review. *J Am Diet Assoc* 2006 Jun;106(6):881-903.
- (2) Fullmer S, Benson-Davies S, Earthman CP, Frankenfield DC, Gradwell E, Lee PS, et al. Evidence analysis library review of best practices for performing indirect calorimetry in healthy and non-critically ill individuals. *J Acad Nutr Diet* 2015 Sep;115(9):1417-46.
- (3) Haugen HA, Chan LN, Li F. Indirect calorimetry: a practical guide for clinicians. *Nutr Clin Pract* 2007 Aug;22(4):377-88.
- (4) Irving CJ, Eggett DL, Fullmer S. Comparing Steady State to Time Interval and Non-Steady State Measurements of Resting Metabolic Rate. *Nutr Clin Pract* 2017 Feb;32(1):77-83.
- (5) Reed GW, Hill JO. Measuring the thermic effect of food. *Am J Clin Nutr* 1996 Feb;63(2):164-9.
- (6) Snell B, Fullmer S, Eggett DL. Reading and listening to music increase resting energy expenditure during an indirect calorimetry test. *J Acad Nutr Diet* 2014 Dec;114(12):1939-42.
- (7) Weir JB. New methods for calculating metabolic rate with special reference to protein metabolism. *J Physiol* 1949 Aug;109(1-2):1-9.



Appendix 1: Flow chart of process of preparing, performing and documenting the test





## Appendix 2: Influence of nutrition, caffeine, nicotine, alcohol and medication on REE

The measured energy expenditure during an indirect calorimetry measurement can be influenced by several factors. It is important to mind the following effects while performing and/or interpreting a measurement.

	Effect on resting energy expenditure (REE)			Remark	Minimum time to measurement
	Direction	Effect size	Peak		
<b>Nutrition</b>	↑	7-9% of the amount of kcal taken	60-180 min.	The peak comes later in people with obesity and elderly	5 hours
<b>caffeine</b>	↑	7-11 %	30-150 min.	Upon intake of 4 cups	3 hours
<b>Nicotine</b>	↑	3-7 %	10-60 min.	When smoking 4-10 cigarettes; peak occurs fast	2 hours
<b>Alcohol</b>	↑	1-14 % in healthy adults	90 min.	Upon intake of 2 glasses	2 hours
		26 % in alcoholics after 8 hours of abstinence of alcohol		at 14 days abstinence REE is comparable to control patients	
<b>Tranquilizing medication</b> ①	↓				
<b>Stimulant medication</b> ②	↑				

↑ = increasing effect on REE    ↓ = lowering effect on REE

### ① Tranquilizing medication:

- **Opioids:** Strong painkillers such as morphine, fentanyl (including Durogesic®), codeine, methadone (including Symoron®), oxycodone (Oxynorm®, Oxycontin®), tramadol (Tramal®)
- **Beta blockers:** in high blood pressure and / or cardiac problems such as atenolol, metoprolol (Seloken®), propranolol, sotalol
- **Antipsychotics:** examples of chlorpromazine, haloperidol (Haldol®), clozapine (Leponex®), perphenazine, pimozide (Orap®), zuclopentixol, olanzapine? \*



- **Barbiturates:** tranquilizers / sleepers such as nitrazepam, temazepam (Normison®), zolpidem, diazepam and oxazepam (Seresta®)
- **②** Stimulating medication:
  - **Antidepressants:** such as amitriptyline (Sarotex®), fluoxetine (Prozac®), paroxetine (Seroxat®)
  - **Adrenaline, epinephrine and epinephrine antagonists:** (such as amphetamines): such as drugs (speed etc), Anapen®, Epipen®
  - **Methylphenidate (MPH):** such as Ritalin®
  - **Glucocorticoids:** such as dexamethasone, hydrocortisone, prednisolone
  - **Growth hormone:** such as somatropin (Genotropin®, Norditropin®, Omnitrope®)

#### General points of interest

- During hemodialysis, CO<sub>2</sub> is removed. This affects the CO<sub>2</sub> production during a REE measurement. Limited data has shown that it is recommended to perform a REE measurement at least 24 hours after hemodialysis.
- Physical activity prior to the REE measurement increases the REE. After moderate intensive physical activity (steady walking, cycling at 15 km / hour), it is recommended to wait 2 hours with performing a measurement. After intensive sports activities, it is advised to wait 14 hours with performing a measurement.
- It is recommended to let a patient rest on the research bank for a minimum of 10 minutes before starting the measurement.
- It is recommended to let a patient lie in a comfortable position during the measurement. An unnatural position has an increasing effect on the REE.
- A cold ambient temperature has an increasing effect on the REE. It is advised to perform the measurement at room temperature (22-25°C, 71,6-77°F). Possibly a blanket can be used.
- The REE varies over the day between 3 and 5% independently of the variables mentioned above.
- Reading a book or using an electronic device has an increasing effect on the REE (about 6.5%). Listening to self-chosen music increases the REE to a lesser extent (about 1.8%).

#### Literature:

- Compher C, Frankenfield D, Keim N et al. Best Practice Methods to Apply to Measurement of Resting Metabolic Rate in Adults: A Systematic Review. *J Am Diet Assoc.* 2006;106:881-93.
- Sharpe J, Byrne N, Stedman T et al. Resting energy expenditure is lower than predicted in people taking atypical antipsychotic medication. *J Am Diet Assoc.* 2005;105:612-615.
- Cuerda C, Velasco C, Merchán-Naranjo J et al. The effects of second-generation antipsychotics on food intake, resting energy expenditure and physical activity. *European Journal of Clinical Nutrition* (2014) 68, 146–152.
- Snell B, Fullmer S, Egger DL. Reading and Listening to Music Increase Resting Energy Expenditure during an Indirect Calorimetry Test. *Journal of the Academy of Nutrition and Dietetics* (2014); 114:12:1939–1942.