Evidence Analysis Library Review of Best Practices for Performing Indirect Calorimetry in Healthy and Non—Critically Ill Individuals

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ARTICLE INFORMATION

Article history:
Submitted 23 December 2014
Accepted 1 April 2015
Available online 30 May 2015

Keywords:
Indirect calorimetry
Resting energy expenditure
Resting metabolic rate
Evidence based
Non—critically ill

Supplementary materials:
Figure 2 is available online at www.andjrnl.org

http://dx.doi.org/10.1016/j.jand.2015.04.003

ABSTRACT

When measurement of resting metabolic rate (RMR) by indirect calorimetry is necessary, following evidence-based protocols will ensure the individual has achieved a resting state. The purpose of this project was to update the best practices for measuring RMR by indirect calorimetry in healthy and non—critically ill adults and children found the Evidence Analysis Library of the Academy of Nutrition and Dietetics. The Evidence Analysis process described by the Academy of Nutrition and Dietetics was followed. The Ovid database was searched for papers published between 2003 and 2012 using key words identified by the work group and research consultants, studies used in the previous project were also considered (1980 to 2003), and references were hand searched. The work group worked in pairs to assign papers to specific questions; however, the work group developed evidence summaries, conclusion statements, and recommendations as a group. Only 43 papers were included to answer 21 questions about the best practices to ensure an individual is at rest when measuring RMR in the non—critically ill population. In summary, subjects should be fasted for at least 7 hours and rest for 30 minutes in a thermoneutral, quiet, and dimly lit room in the supine position before the test, without doing any activities, including fidgeting, reading, or listening to music. RMR can be measured at any time of the day as long as resting conditions are met. The duration of the effects of nicotine and caffeine and other stimulants is unknown, but lasts longer than 140 minutes and 240 minutes, respectively. The duration of the effects of various types of exercise on RMR is unknown. Recommendations for achieving steady state, preferred gas-collection devices, and use of respiratory quotient to detect measurement errors are also given. Of the 21 conclusions statements developed in this systemic review, only 5 received a grade I or II. One limitation is the low number of studies available to address the questions and most of the included studies had small sample sizes and were conducted in healthy adults. More research on how to conduct an indirect calorimetry measurement in healthy adults and children and in sick, but not critically ill, individuals is needed.
J Acad Nutr Diet. 2015;115:1417-1446.

RESTING METABOLIC RATE (RMR) IS THE ENERGY expended to sustain normal body functions and homeostasis at rest and is generally the primary component of total energy expenditure.[1] It can be estimated or measured. Measurement of oxygen consumption (VO_2) and carbon dioxide (VCO_2) via indirect calorimetry (IC) is the more common method of measuring RMR.[1] An accurate measurement of RMR in healthy and non—critically ill individuals with IC is important for both clinicians and researchers.

In 2006, The Academy of Nutrition and Dietetics (Academy) Evidence Analysis Library published a systematic review of best practices to help practitioners identify the best procedures to accurately measure RMR with IC.[2] In 2010, a new Evidence Analysis Work Group was convened to update the Energy Expenditure section in the Evidence Analysis Library. The work group decided to re-examine only the measurement of RMR using IC for critically ill and non—critically ill individuals. Non—critically ill individuals are defined in the Evidence Analysis Library as: "those that do not have dysfunction of one or more organs/systems requiring dependence on advanced instruments of monitoring and therapy for survival." This systematic review is the analysis of literature in the non—critically ill population; recommendations for measurement of RMR in the critically ill population are published elsewhere. These recommendations/guidelines will help practitioners and researchers identify the conditions under which she or he can perform IC accurately and interpret the results properly. Aspects of IC that need further research are also identified.

METHODS

Evidence Analysis Team

The work group included six registered dietitian nutritionists with clinical and/or research experience. The Academy's Evidence Based Practice Committee oversaw the establishment of the Evidence Analysis Work Group. A thorough recruitment procedure was undertaken with requests for participation sent to members of the Academy dietetic practice groups, and known experts in this area. Once the applications were received, the committee reviewed and scored each candidate based on set of quantitative and qualitative criteria and potential for conflict of interest. When the work group convened in 2010, all members were orientated to the Academy's evidence analysis process. All work group members signed a conflict of interest disclosure form, as well as verbally declared any conflicts of interests before the start of each work group meeting, in accordance with Academy policy. Regular work group meetings were held via teleconference to complete question development, review the evidence, and develop conclusion statements reflecting consensus of the work group. A trained and experienced project manager facilitated these meetings with the assistance of the lead analyst.

Evidence Analysis Library Process

A complete description of the Evidence Analysis Process is available at the Evidence Analysis Library website.[3] Briefly, articles meeting the inclusion criteria were abstracted using Evidence Analysis Library worksheets, and reviewed for accuracy by Evidence Analysis Library analysts. Each article was assigned a quality rating (positive, neutral, or negative) based on a standardized rubric or quality criteria checklist developed and utilized by the Academy.[4] A summary evidence table was constructed for each question along with narrative summaries of the evidence.

Literature Search and Application of Inclusion/Exclusion Criteria

The search and identification of articles for inclusion was conducted in three phases (Figure 1). In the initial phase, the search for both critically ill and non−critically ill articles was completed together. The search strategy was developed by the work group, search consultant, and analysts and the search consultant conducted the search using the Ovid database (Figure 2, available online at www.andjrnl.org). Literature published between 2003 and 2012 was reviewed in order to update the original Energy Expenditure Project published in 2006, which covered literature from 1980 to 2003. The work group also evaluated all the included studies from the previous project and applied the current inclusion/exclusion criteria to these studies for the current project. References from pertinent review articles were also hand searched. The Ovid database search identified 11,071 articles and 195 articles were identified from the original project (Figure 3). After duplicate records were removed, 4,155 articles remained. Once the 4,155 articles were identified, 3,750 articles were excluded because they were conducted on critically ill subjects, or did not involve the measurement of RMR. Of the 405 articles remaining, work group members worked in pairs to screen each article based on the criteria listed in phase 2 of Figure 1, and assigned each article to the question(s) it addressed. Phase 3 criteria were applied after the evidence was evaluated for both the resting and fasting periods. These two criteria (resting and fasting conditions) were considered major factors in achieving a resting state. Subsequently, studies that did not meet these criteria or did not describe the resting and fasting periods were excluded. Some studies that had been considered for the 2006 Evidence Analysis Project were excluded for this analysis. After phase 3 was completed, these final inclusion/exclusion criteria were applied for all questions. Based on the inclusion/exclusion criteria for fasting and rest period, more than half of the articles from the original project were excluded.

Development of Conclusion Statements and Recommendations

Each question in the Evidence Analysis Library has a conclusion and recommendation. Conclusion statements were written and are supported by one of five grades, depending on factors such as quality, consistency, sample size, clinical impact, and generalizability of studies. Full conclusion statements are found on the Evidence Analysis Library.[4] Recommendations are rated as strong, fair, weak, consensus, or insufficient, and are considered "conditional" (the statement clearly defines a specific situation) or "imperative" (the statement is broadly applicable to a target population with restraints on their pertinence) based on standardized rubrics developed by the Academy.

When the phrase "more research is needed" appears in a recommendation, it implies that future research applying all the protocol standards identified in this guideline should be followed to more clearly answer the question. It should be noted that although some observed differences in RMR might be statistically significant, they might not be of practical importance, depending on the setting (ie, clinical practice vs research). Readers need to draw their own conclusions based on their particular setting.

RESULTS

A total of 43 primary research articles were included in the final analysis for all of the non−critically ill questions, some articles were used to answer more than one question. Of the 43 studies, all but 5 had been conducted on healthy adults. The exceptions included one study on healthy children (ages 7 to 12 years),[6] one study on patients with chronic obstructive pulmonary disease,[7] one study on stable hospitalized patients (mostly fractures),[8] one study conducted on individuals undergoing an elective thoracotomy,[9] and one study that included both stable individuals with cancer patients and healthy controls.[10] Therefore, unless otherwise indicated, all recommendations were developed based on studies of healthy people. Only 10 of the 43 studies were published in 2004 or later. The Table provides a summary of each study design and quality rating, participants, interventions, and outcomes of the 43 studies.

Rest Period for Adults

The rest period before the measurement of RMR is a critical step in conducting IC because many studies are not performed in an overnight metabolic unit. Therefore, when subjects come into a laboratory or office for measurement of RMR, it is important for the metabolic rate to return to a

Criteria	Inclusion	Exclusion
Phase 2		
Measurement devices	All indirect calorimeters, doubly labeled water, whole-room calorimeters	Accelerometers
Other	English language Human studies	Non-English language Animal studies
Subject dropout rate		>20%
Age	Children, adolescents, adults	Infants
Setting	Acute care, outpatient, community, healthy	Intensive care, critical care, burn unit
Health status	Healthy, chronically ill, non−critically ill	Critically ill, pregnant women, burns
Study design	Validation, methodology, time series, repeated measures, longitudinal, RCT,[b] clinical controlled studies, large nonrandomized observational studies, cohort, case control	Systematic reviews, narrative reviews, meta-analyses
Sample size	≥10 for each study group	<10 subjects per group
Measurements	At least two measurements in same subject	
Energy expenditure variable	Resting metabolic rate, basal metabolic rate, total energy expenditure	Sleeping metabolic rate, VO_2,[c] min ventilation
Phase 3 measurement protocols		
Rest period (adults)	Stated 20-min minimum rest period or a 15-min rest period if stated that first 5 min are discarded.	If resting period not described, or <20 min
Fasting period	Stated minimum 7-h fast, or overnight	If fasting period not described or <7 h or overnight

[a]See text for phase 1.

[b]RCT=randomized controlled trial.

[c]VO_2=oxygen consumption.

Figure 1. Phase 2 and 3[a] of search strategy and inclusion and exclusion criteria (resulted in elimination of 362 articles).

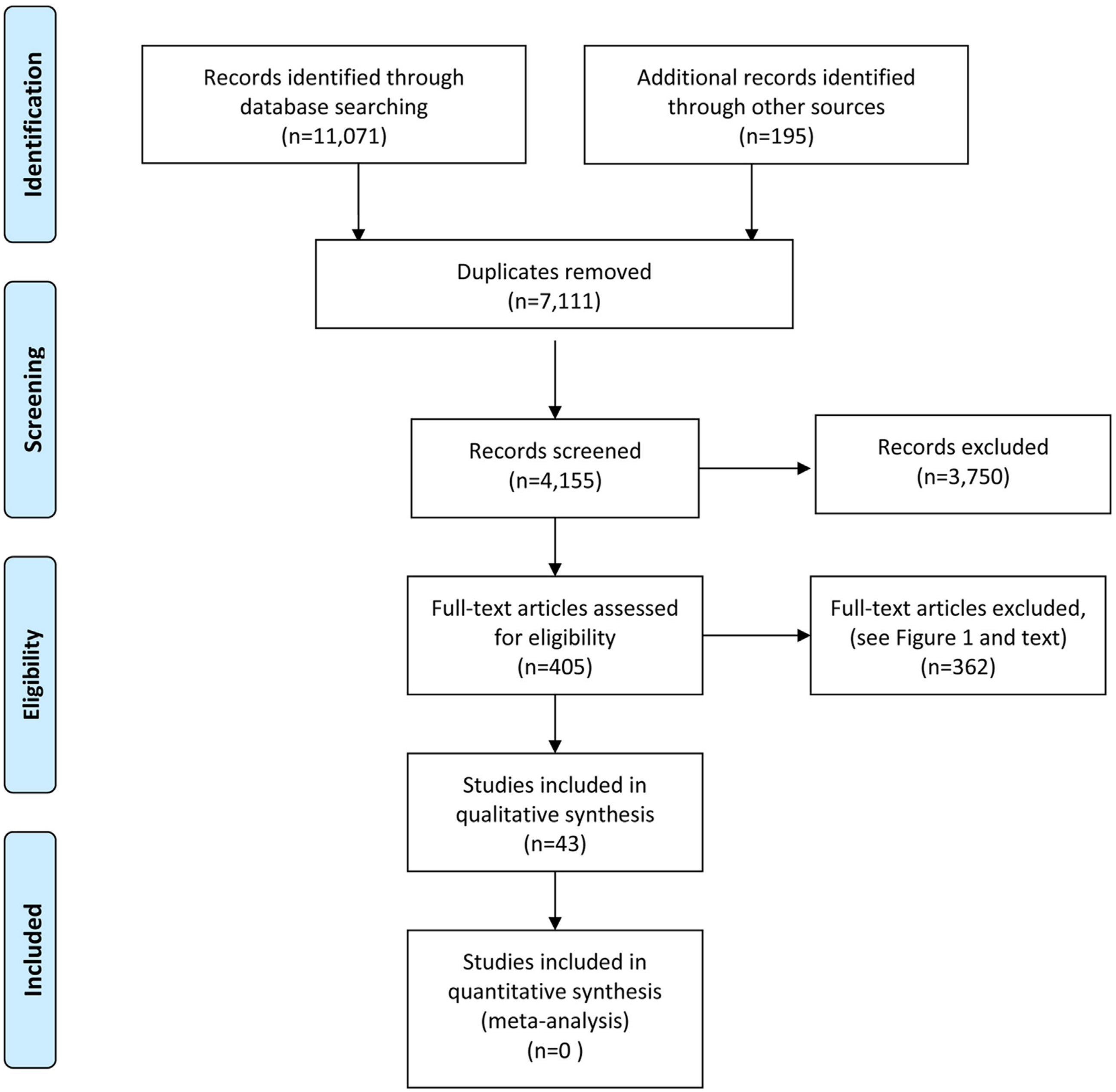

Figure 3. Search criteria (using Ovid Database). Flow diagram template from: Moher D, Liberati A, Tetzlaff J, Altman DG; The PRISMA Group. Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. *PLoS Med*. 2009;6(6):e1000097.[5] For more information, visit www.prisma-statement.org.

resting level before taking the measurement. Five studies were evaluated regarding the length of rest period needed before RMR measurement in adults. Fredrix and colleagues[8] reported no significant differences in RMR measures performed after 30 minutes of rest when sleeping in a facility the night before vs sleeping at home the night before and commuting to the facility (1,408 ± 202 kcal/day vs 1,437 ± 215 kcal/day, respectively). Similarly, Turley and colleagues[13] reported no significant differences in mean RMR measured after 30 minutes of rest when sleeping at home vs at the clinic the night before.

Studies evaluating shorter intervals suggest that although 15 minutes might not be a long enough rest period, a 20-minute rest period might suffice, as long as no movement is permitted. Frankenfield and Coleman[11] measured energy expenditure for 30 minutes after a 300-m walk and found that 95% of subjects reached a resting state by 20 minutes if the subjects remained still during the recovery period. However, energy expenditure continued to decline continuously through the entire 30-minute recovery period. Another study reported that, after a 10-minute walk, group mean RMRs measured after a 15-minute rest were significantly

Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non—critically ill individuals

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
How long of a rest period is needed before the measurement of RMR[a] in healthy and non—critically ill adults?				
Frankenfield and Coleman, 2009[11]	Randomized controlled trial; neutral	n=40 subjects (75% female, 25% male; age 41±13 y; 40% were obese)	RMR measured after a 30-min rest. Participants then walked 300 m, metabolic rate measured in 5-min intervals for 30 min. Recovery to rest was defined when metabolic rate <6% above RMR.	RMR achieved by min 10 of rest; 95% of all subjects met 6% threshold at 20 min.
Fredrix and colleagues, 1990[8]	Prospective cohort study; neutral	n=30 healthy adults; Netherlands	Compared RMR between an overnight stay in hospital vs coming into facility from home after overnight fast and limited physical activity.	Group mean RMRs not significantly different.
Kashiwazaki and colleagues, 1990[12]	Time study; neutral	n=23 males; age 20-29 y; Japan	RMR measured after sleeping in an ambient room temperature of 20°C (68°F) or 25°C (77°F) during summer and winter seasons. Subjects covered with a single duvet while sleeping.	RMR measures at 20°C (68°F) in winter were significantly greater (6% to 9%) compared 25°C (77°F). No significant difference in RMR measures at 25°C (77°F) in winter vs summer and 20°C (68°F) in summer. After a 10-min outdoor walk in both season temperatures, group mean RMR measured after a 15-min rest (in either 20°C [68°F] or 25°C [77°F]) were higher than second at 30 min of rest in both ambient room temperatures and differing seasons. Group mean RMR stabilized with a 30-min rest.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Schols and colleagues, 1992[7]	Cross-sectional study; negative	n=12 patients with chronic obstructive pulmonary disease; age 66±6 y; n=14 healthy controls; age 31±8 y; Netherlands	RMR measured for durations of 5, 10, 15, 20, 25, and 30 min.	No significant differences in RMR after awakening, transported to measurement laboratory in wheelchair and 7-min acclimatization period vs RMR after light physical activities and 20-min rest (1,406±238 kcal vs 1,431 l±259 kcal/day).
Turley and colleagues, 1993[13]	Randomized crossover trial; neutral	n=10 (4 male, 6 female); age 26.1 y; United States	Six randomized RMR measurements: 3 after sleeping at home, 3 after sleeping in the unit.	No significant differences in RMR after sleeping at home and traveling to clinic vs sleeping at clinic.
How long of a rest period is needed before the measurement of RMR in healthy and non−critically ill children?				
Mellecker and colleagues, 2009[6]	Nonrandomized crossover trial; neutral	n=23 (13 male, 10 female); age 7 to 12 y; multiethnic; China	Subjects completed two 35-min RMR measures in supine position; one with a face mask and one with mouthpiece/nose clip (the order was reversed in half of the subjects).	No significant difference in RMR measured at min 10, 15, 20, or 25 of rest compared to min 30 or either the face mask or mouthpiece/nose clip.
What kinds of activities can be done during the rest period in the healthy and non−critically ill?				
There were no studies identified to address the kinds of activities that can be done during the rest period of the non−critically ill.				
How long should the duration of the RMR measurement be to achieve a SS[b] in the healthy and non−critically ill adults?				
Horner and colleagues, 2001[14]	Time study; neutral	n=102 (female); age 50 to 79 y; United States	Compared RMR in 5-min segments 0 to 30 min.	After discarding first 5 min of data, a 5-min measure was sufficient to achieve SS.
Reeves and colleagues, 2004[10]	Diagnostic, validity, or reliability study; neutral	n=39 (22 cancer, 17 healthy), age 61±12 y; Australia	Compared RMR over 5-, 4-, and 3-min SS periods.	Minimum of 4-min SS needed for acceptable RMR.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Schols and colleagues, 1992[7]	Cross-sectional study; negative.	n=12 COPD[c]; age 66±6 y; n=14 healthy; age 31±8 y	RMR measured for durations of 5, 10, 15, 20, 25, and 30 min.	Group mean RMR did not differ between 5-, 10-, 15-, 20-, 25-, and 30-min measurement duration.
If SS cannot be achieved, how long should the duration of an indirect calorimetry measurement be in the healthy and non−critically ill?				
There were no studies identified to address the duration of an indirect calorimetry measurement, when steady state cannot be achieved to assure accuracy in the non−critically ill.				
How long should the duration of the RMR measurement be to achieve a SS in healthy and non−critically ill children?				
Mellecker and McManus, 2009[6]	Nonrandomized crossover trial; neutral	n=23 (13 male, 10 female); age 7 to 12 y; multiethnic; China	Two 35-min protocols (face mask, mouthpiece/nose clip).	RMR at min 10, 15, 20, or 25 not different from RMR at 30th min.
Is there a difference in RMR measurements related to the effects of different body positions in the healthy and non−critically ill individuals?				
Brandi and colleagues, 1996[9]	Before-after study; positive.	n=22; age 61±1.6 y	Measurements were made in the supine and 30-degree sitting position both preoperatively and postoperatively.	Preoperative RMR not significantly different in supine vs 30-degree sitting. Postoperatively, energy expenditure was significantly lower in sitting than supine ($P<0.001$).
Levine and colleagues, 2000[15]	Repeat measures, fixed order; neutral	n=24 (7 male, 17 female); white	Energy expenditure was measured for 20 min while the subject was sitting motionless, sitting and fidgeting (computer work, emulating answering a telephone, hand and foot tapping, arm and leg swinging, etc), standing motionless, and standing and fidgeting.	Mean sitting motionless RMR was 3.7±6.3% above the mean supine RMR measure (1,858 kcal/day). Mean standing motionless RMR was 6.1±1.7% above the mean supine RMR measure. Fidgeting further increased energy expenditure.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Sujatha and colleagues, 2000[16]	Descriptive; neutral	n=98 (female); age 29±5.58 y; India	RMR measured during daily activities such as sitting, standing, walking, sweeping, mopping the floor, washing clothes, etc.	Sitting RMR was 6% greater than lying down. RMR measured while standing was 14% greater than lying down.
Taguri and colleagues, 2010[17]	Reliability study; neutral	n=78 (41 male, 37 female); age 43±13 y; Japan	Lying and sitting RMR were collected.	No statistical analysis performed to compare sitting RMR and lying RMR, mean sitting RMR was 11%±7% greater than the mean lying RMR.
Is there a difference in RMR measurements related to different types of gas collection devices (such as face mask, mouthpieces/nose clips, or ventilated hood/canopy) in the healthy and non−critically ill individuals?				
Forse, 1993[18]	Diagnostic, validity or reliability study; neutral	n=10 female; age 27 y; n=20 male; age 28 y	Three 20-min RMR measures (canopy and face mask, canopy and mouthpiece, and canopy alone).	VO_2[d] higher for mouthpiece (8% above canopy) and mask (7% above canopy) than canopy alone.
McAnena and colleagues, 1986[19]	Diagnostic, validity or reliability study; neutral	n=18	RMR by hood and mask, randomized order.	RQ[e] lower with mask than hood (0.72±0.001 vs 0.87±0.02). RMR highly correlated between methods.
Mellecker and McManus, 2009[6]	Nonrandomized crossover trial; neutral	n=23 (13 male, 10 female); age 7 to 12 y; multiethnic; China	Two 35-min protocols (face mask and mouthpiece/nose clip O_2 data sectioned into 5-min blocks.	After 20 min, RMR by mask and mouthpiece/nose clip not different; however, CV[f] lower with mask (6%) than with mouthpiece/nose clip (12%) 65% reported mask to be comfortable; 31% reported mouthpiece/nose clip to be comfortable.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Segal, 1987[20]	Diagnostic, validity or reliability study; neutral	n=18 male; age 28±5 y; n=10 F; age 29±3 y United States	RMR by hood, mask, and mouthpiece/nose clip (random order).	RMR not different between devices.
What is the effect of diurnal (time of day) variation on resting metabolic rate (RMR) in the health and non−critically ill individuals?				
Leff and colleagues, 1987[21]	Time study; neutral	n=14 (12 female), age 26.8±1.7 y; United States.	RMR measured hourly for 3 to 5 min from 8 AM to 4 PM, 2 separate days.	No differences among daytime measurements (morning, late morning, early afternoon)
Weststrate and colleagues, 1989[22]	Randomized crossover trial; neutral	n=10 male; age 22±0.5 y	Post-absorptive RMR measured for 1 h in the morning or afternoon.	Mean RMR not different between morning and afternoon.
What are the room conditions (in terms of temperature) required for RMR measurement in the healthy and non−critically ill individuals?				
Claessens-van Ooijen and colleagues, 2006[23]	Nonrandomized crossover trial; neutral	n=20 male subjects (10 lean, 10 overweight); age 25±6 y; Netherlands	A thermoneutral condition was established in a cold ambient environment (15°C/59°F) by covering the subjects with a duvet. Cold exposure was achieved by removing the duvet after 60 min of baseline measurement; after 60 min of cold exposure, the duvet was replaced for 60 min of rewarming. RMR was measured continuously.	Heat production increased significantly during cooling by 11.8% in all subjects, with a larger increase in the lean group compared with the overweight group (17.2% vs 6.4%, *P*=0.04). EE[g] of overweight subjects returned to baseline during rewarming. EE in lean subjects remained elevated, resulting in a significant increase in heat production between rewarming and baseline in the lean group compared with the overweight group (*P*=0.01).

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Kashiwazaki and colleagues, 1990[12]	Time study; neutral	n=23 males; age 20 to 29 y; Japan	RMR measurements made after sleeping in an ambient room temperature of 20°C/68°F or 25°C/77°F during summer and winter seasons. Subjects were covered with a single blanket while sleeping.	RMRs at 20°C (68°F) in winter were significantly greater (by 6% to 9%) compared to RMRs measured at 25°C/77°F during the winter. No significant difference was found among the RMRs measured at 25°C/77°F in winter, 25°C/77°F in summer and 20°C/68°F in summer. Both room temperature and outdoor temperature affect RMR measures.
van Ooijen and colleagues, 2004[24]	Time study; neutral	n=20 subjects (10 male, 10 female); age 19 to 36 y; Netherlands	Subjects stayed overnight in an ambient temperature respiratory chamber (22°C/71.6°F) covered with a duvet. In the morning, subjects were moved to a stretcher and RMR was measured at ambient room temperature (22°C/71.6°F for 1 h. Subjects were then exposed to cold (15°C/59°F for 3 h. RMR measured every 60 min.	Group mean RMR increased 3 h after moderate cold exposure (15°C/59°F) were 11.5%±9.1% and 7.0±0.5% in winter and in summer seasons, respectively, compared to group mean RMRs taken at comfortable ambient temperatures (22°C/71.6°F). The increase in area under the curve was slightly but not significantly higher in winter compared to summer.

What are the room conditions (in terms of humidity, lighting and noise) required for RMR measurement in the healthy and non−critically ill individuals?

There were no studies identified to address room conditions (such as humidity, lighting and noise) required for RMR measurement in the non−critically ill.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
How long should a healthy and non−critically ill individual fast before an RMR measurement to avoid the Thermic Effect of Food (TEF)?				
Belko and Barbieri, 1987[25]	Nonrandomized crossover trial; neutral	n=12 male; age 25±1.5 y United States	TEF measured after two 1,500-kcal meals, 5 h apart, and after four 750-kcal meals, 2.5 h apart. TEF determined by measuring metabolic rate for 6 min every 30 min for 150 min after each small meal and for 300 min after each large meal.	Large and small meals yielded same 7% TEF over 10 h; metabolic rate not back to baseline by 10 h.
Bielinski and colleagues, 1985[26]	Nonrandomized crossover trial; neutral	n=10 male; age 21.8±0.3 y; Switzerland	TEF measured after mixed meal (1,300 kcal, 55% carbohydrate [CHO], 18% protein and 27% fat) consumed on two occasions: After 4-h rest, and on next day, 30 min post 3 h exercise.	RMR increased 32.8±2.6% and remained increased over 5-h post-prandial period
Bissoli and colleagues, 1999[27]	Nonrandomized controlled trial; neutral	n=16 (10 female) vegetarian, age 34±9 y; n=16 (10 female), nonvegetarian, age 30±5 y; Italy	TEF measured after test meal (515 kcal, 80% CHO, 10% protein, and 8% fat).	TEF >180 min not different between vegetarians (12±7.2%) and nonvegetarians (10±6.8%)
Blond and colleagues, 2011[28]	Diagnostic, validity or reliability study; neutral	n=10 normal weight (5 male, 5 female; age 26.8 y, 37.4 y), n=10 overweight (5 male, 5 female; age 29.2 y, 30.4 y, n=10 obese (5 male, 5 female; mean age 39.4 y, 35 y; France	TEF measured 15-180 min after evening meal (687 kcal, 39.5% CHO, 25.6% protein, and 34.9% fat) on 2 consecutive days.	Mean TEF was 4.9% and remained elevated at end of 3-h period.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Kinabo and Durnin, 1990[29]	Nonrandomized crossover trial; positive	n=16 female, age 22±1.5 y; Scotland	TEF measured over 5 h after four test meals that differed by meal composition (high fat, low CHO or low fat, high CHO) and caloric content (600 kcal or 1,200 kcal).	TEF post-consumption of 1,200 kcal was higher (85 kcal, 81 kcal; low CHO, high CHO, respectively) than after 600 kcal (54 kcal for low and high CHO). RMR remained elevated at end of 5 h.
Levine and colleagues, 2000[30]	Before-after study; neutral	n=36 (16 female) with alcoholism, age 42±2 y; n=36 (16 female) healthy, age 43±2 y	TEF measured for 150 min after standard 20-min meal (7.14 kcal/kg, mean 478 kcal, 55% CHO, 12% protein, 33% fat).	TEF same in individuals with and without alcoholism (25.1±2.8 kcal and 25.8±4.8 kcal); RMR remained elevated by end of 3-h period.
Poehlman and colleagues, 1988[31]	Nonrandomized crossover trial; neutral	n=12 male vegetarian, age 27±2 y; n=11 male nonvegetarian, age 22.5±0.9 y; United States	TEF measured for 180 min after liquid meal (10 kcal per kg fat-free mass, 55% CHO, 24% protein, 21% fat, 621.7±19.9 kcal for vegetarians and 677.2±19.2 kcal for nonvegetarians)	Mean TEF was lower in vegetarians (0.31±0.02 kcal/min) than nonvegetarians (0.42±0.02 kcal/min). RMR remained elevated at 180 min.
Raben and colleagues, 2003[32]	Randomized crossover trial; neutral	n=19 (9 female), age 23.3±0.5 y; Denmark	TEF measured for 5 h after four morning meals (approximately 600 kcal): high protein (37.2% CHO, 32% protein and 31.1% fat), high CHO (65.4% CHO, 12.2% protein, 23.7% fat), fat (23.9% CHO, 11.6% protein, 64.4% fat) or alcohol (42.9% CHO, 12.1% protein, 24.3% fat, 23.0% alcohol).	TEF highest after alcohol (9%) followed by protein (8.3%) and fat and CHO (7.1%); peak TEF occurred between 60 and 120 min and remained elevated at 300 min.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non–critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Segal and colleagues, 1992[33]	Randomized crossover trial; neutral	n=13 lean male (11.2±1.4% body fat), age 29±2 y; n=10 average male (22.4±1.6% body fat), age 29±2 y; n=12 obese male (33.4±1.6% body fat), age 31±1 y (United States)	TEF measured for 3 h after liquid meal (Sustacal: 720 kcal, 55% CHO, 24% protein, 21% fat) on 2 days.	Day-to-day, intra-individual CV in TEF was approximately 5.7%. For both days, mean TEF was greater for lean and average males than for obese males. TEF peaked at 60 to 90 min postprandial. RMR remained elevated at 3 h.
Segal and Gutin, 1983[34]	Randomized crossover trial; positive	n=10 lean female; age 28.9±3.6 y; n=10 obese female, age 29.2±5.1 y; United States	TEF measured for 4 h after test meal (910 kcal, 46% CHO, 14% protein, 40% fat).	TEF peaked at 114±14 min and 138±12 min for lean and obese, respectively, but was not different between groups (5.5% vs 5.2%, respectively). RMR remained elevated at 4 h.
Weststrate and colleagues, 1989[22]	Randomized crossover trial; neutral	n=10 male, age 22±0.5 y; Netherlands	TEF measured for 4 h after meal (456 kcal) during morning or afternoon.	TEF over 4 h was 0.15 kcal/min above RMR. Although greatly reduced (0.03 to 0.05 kcal/min above baseline), RMR remained elevated at 4 h.
Weststrate and Hautvast, 1990[35]	Randomized Crossover trial; neutral	n=10 (5 female), age 23±0.08 y, 8.8% to 25.1% body fat; Netherlands	TEF measured for 210 min after yogurt-based test meal (312 kcal) with and without exercise.	TEF peaked between 30 and 120 min. TEF had dissipated by 210 min in all but the exercise and CHO group.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Weststrate and colleagues, 1990[36]	Randomized crossover trial; neutral	n=22 male, Mean age 26.5 y; Netherlands	Study 1: TEF measured for 90 min after three concentrations of alcohol (20 g alcohol in 75, 180, 300 mL water). Study 2: TEF measured for 4 h on four afternoons after receiving duplicate treatments of: 20 g alcohol/ 180 mL water with liquid yogurt meal (468 kcal, 60% CHO, 13% protein, 27% fat); and placebo aperitif (0 kcal) with isocaloric liquid yogurt meal (609 kcal, 60% CHO, 13% protein, 27% fat).	Study 1: TEF ↑ in dose-dependent fashion, from 4.4% with 75 mL alcohol to 6.2% with 300 mL alcohol. Study 2: TEF peaked at 2 h postprandial, and was not different between treatments. Although nearly dissipated, RMR remained slightly elevated at 4 h.
How long should a healthy and non−critically ill individual refrain from consuming caffeine or other stimulants before an RMR measurement?				
Arciero and colleagues, 2000[37]	Randomized crossover trial; neutral	n=10 female; age 18 to 22 y n=10 female; age 50 to 67 y; United States	Placebo vs caffeine (5 mg/kg fat-mass) with RMR measured at baseline, plus 15-min intervals over 90 min.	RMR ↑ 15.4%±7.0% in younger women vs ↑ 7.8%±6.0% in older females at 90-min post caffeine intake.
Belza and colleagues, 2007[38]	Randomized controlled trial; neutral	n=80 (62 female); age 47.6 to 11.0 y; Demark	Placebo or a bioactive supplement (1,500 mg green tea extract, 1,218 mg L-tyrosine, 302 mg caffeine, 450 mg cayenne 3,890 mg calcium carbonate) for 8 wk. RMR measured at pre/post intervention over 4 h.	Bioactive supplement ↑ RMR compared to placebo by 87.3 kJ/h (95% CI 50.9 to 123.7; P=0.005); RMR still significantly elevated at 240 min.

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Belza and colleagues, 2009[39]	Randomized crossover trial; neutral	n=12 male; age 23.7±2.6 y; Demark	500 mg green tea extract; 400 mg tyrosine; 50 mg caffeine or placebo; RMR was measured pre/post treatment during a 4-h period.	RMR ↑ 6% after caffeine ingestion (72±25 kJ/4 h; P=0.01) compared to placebo; RMR still elevated at 240 min.
Greenway and colleagues, 2004[40]	Randomized crossover trial; neutral	n=12 age 18 to 65 y; United States	Placebo vs caffeine (dosage?) + ephedra supplement (dosage?); RMR was measured pre/post treatment over 2 h.	RMR ↑ 8±0.1% with caffeine + ephedra (P<0.01).
Komatsu and colleagues, 2003[41]	Randomized crossover trial; neutral	n=11 female; age 20±1 y; Japan	Water, oolong tea, or green tea ingestion; RMR was measured at baseline, and over 120 min.	At 90 min, RMR ↑ with oolong tea (237.3±10.1 kJ/h; P<0.05) and green tea (223.2±3.9 kJ/h) compared to water. RMR still elevated at 120 min.
Yoshida and colleagues, 1994[42]	Nonrandomized controlled trial; neutral	n=10 female; age 25.5±1.2 y; Japan	4 mg caffeine/kg; RMR was measured at baseline, plus over 60 min; Protocol was repeated with a caffeine load of 8 mg/kg.	RMR ↑ at 60 min with both caffeine loads of 4 mg (4.06±0.47 kJ/min) and 8 mg (4.45±0.48 kJ/min) post ingestion
How long should a healthy and non−critically ill individual refrain from smoking and nicotine intake before an RMR measurement?				

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Collins and colleagues, 1996[43]	Nonrandomized crossover trial; neutral	n=16 male; age 41±11 y; United States	Nonsmoking; smoking 6 low-nicotine (0.8 mg nicotine) cigarettes or smoking 6 high-nicotine (1.74 mg nicotine) cigarettes.	Smoking 2 low-nicotine or 2 high-nicotine cigarettes ↑RMR 6.8% ($P<0.05$) in 20 min. After smoking five high-nicotine cigarettes, RMR ↑9.3% ($P<0.05$) at 140 min compared ↑5.9% after 5 low-nicotine cigarettes; Cumulatively, at 2 h, high-nicotine cigarette smoking ↑RMR 6.9% compared to ↑5.2% after smoking low-nicotine cigarettes.
How long should a healthy and non−critically ill individual refrain from resistance exercise before an RMR measurement?				
Williamson and Kirwan, 1997[44]	Nonrandomized control; neutral	n=12 male; age 66.5 y, range=59 to 77 y; United States	Baseline basal metabolic rate (BMR) (control) compared to a single bout of exercise; BMR measured pre/post-exercise at 48 h.	BMR ↑ 48 h after exercise compared to control group; over 24 h, 1,627±193 kcal were expended post-exercise compared to the control at 1,570±193 kcal ($P<0.006$).
How long should a healthy and non−critically ill individual refrain from very light intensity physical activity before an RMR measurement?				
Frankenfield and Coleman, 2009[11]	Prospective cohort; neutral	n=40 (30 female); age 41±13 y; United States	Subjects walked 300 m on a measured course; RMR was measured in 5-min intervals over 30 min.	After a 300-m walk, RMR was achieved by the 10th min of recovery; At 20 min, 95% of the subjects met the 6% RMR threshold.
How long should a healthy and non−critically ill individual refrain from light intensity physical activity before an RMR measurement?				
There were no studies identified to address how long non−critically ill or healthy individuals should refrain from light intensity physical activity before an RMR measurement.				

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non–critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
How long should a healthy and non–critically ill individual refrain from moderate or vigorous intensity physical activity before an RMR measurement?				
There were no studies identified to address how long non–critically ill or healthy individuals should refrain from moderate or vigorous intensity physical activity before an RMR measurement.				
Can RQ be used to detect error in a measurement of RMR in the healthy and non–critically ill adults?				
Bissoli and colleagues, 1999[27]	Nonrandomized controlled trial; neutral	n=16 (6 male, 10 female); vegetarians; age 34±9 y; n=16 nonvegetarians (6 male, 10 female); age 30±5 y; Italy	Compared RMR and thermogenic effect of food after eating a test meal containing 515 kcal (with 80% CHO, 10% protein, and 8% fat).	The 3-h mean RQ was 0.84±0.09 in vegetarians and 0.88±0.13 in nonvegetarians.
Clark and Hoffer, 1991[45]	Cross-sectional study; neutral	n=29 healthy males; age 24.4±3.3 y; Canada	Explored the disagreement between use of the Harris-Benedict and Owen formulas with regard to prediction of RMR.	On day 1, mean RQ ranged from 0.72 to 0.90 (mean 0.81±0.05) and on day 2 mean RQ ranged from 0.68 to 0.90 (mean 0.83±0.00).
Johnston and colleagues, 2002[46]	Randomized crossover trial; neutral	n=10 female; age 19.0±0.4 y; United States	Compared postprandial thermogenesis between a high-protein, low-fat diet vs a high-CHO, low-fat diet for 1 day.	Group mean postprandial RQ was approximately 0.04, 0.03 and 0.05 points greater than fasting (fasting RQ before high-CHO diet was 0.81±0.01 and 0.79±0.02 before high-protein diet) after a high-CHO breakfast (455 kcal), lunch (643 kcal) and dinner (668 kcal); changes in the RQ post meals did not differ by diet.

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RESEARCH

Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non−critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Leff and colleagues, 1987[21]	Time study; neutral	n=14 (12 female, 2 male); age 26.8±1.7 y; United States	On 2 separate days, RMR was measured hourly for 3 to 5 min from 8 AM to 4 PM.	There was a trend for RQ to decrease throughout the day on both day 1 and day 2; on day 1, RQ declined from 0.73 at 8 AM to 0.81 at 2 PM, and on day 2, RQ declined from 0.81 at 9 AM to 0.73 at 1 PM.
Liu and colleagues, 1995[47]	Cross-sectional study; neutral	n=223 (102 males, 121 females); age 43.8±14.3 y; China	Evaluated factors that may influence BMR.	While the range of individual RQ measurements was not reported, group mean RQ was 0.88±0.06.
Romijn and colleagues, 1990[48]	Time study; neutral	n=12 healthy men; age 30±1 y; Netherlands	Evaluated the influence of short-term starvation (16 and 22 h) on glucose metabolism.	RQ values ranged from 0.72 to 0.80 and 0.65 to 0.79 after 16 h and 22 h of fasting, respectively; mean RQ decreased from 0.77±0.01 to 0.72±0.01 ($P<0.005$).
Weststrate and Hautvast, 1990[35]	Randomized crossover trial; neutral	n=10 (5 male, 5 female); age 23± 0.08 y; Netherlands	Assessed the effects of short-term carbohydrate overfeeding (yogurt-based test meal containing 312 kcals) and prior exercise on RMR and diet-induced thermogenesis.	During the weight maintenance phase, the individual range for fasting RQ was 0.80 to 0.86 (mean 0.83±0.01), but 4.5 h after the meal, RQ values ranged from 0.81 to 0.99 in individuals

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Table. Description of studies included in the evidence analysis to perform indirect calorimetry in healthy or non–critically ill individuals (*continued*)

Author(s), year	Study design; quality rating	Population	Intervention	Outcomes
Zauner and colleagues, 2000[49]	Repeated measures (time series); neutral	n=11 (4 male, 7 female); age 28±4 y	Investigated RMR during short-term starvation, after fasting for 36, 60 and 84 h.	Group mean RQ declined from 0.83±0.05 initially to 36 h of fasting (0.74±0.04) to 60 h of fasting (0.72±0.03) to 84 h of fasting (0.71±0.04).

[a]RMR=resting metabolic rate.
[b]SS=steady state.
[c]COPD=chronic obstructive pulmonary disease.
[d]VO_2=oxygen consumption.
[e]RQ=respiratory quotient.
[f]CV=coefficient of variation.
[g]EE=energy expenditure.

higher than at 30 minutes of rest.[12] However, Schols and colleagues[7] reported that 20 minutes was sufficient to achieve rest; there were no significant group mean RMR differences between measurements performed after awakening, being wheeled down to the measurement laboratory, and allowing a 7-minute acclimatization period vs measurements taken after light physical activities and allowing a 20-minute rest (1,406 ± 238 kcal/day vs 1,431 ± 259 kcal/day). In summary, all studies evaluated showed that a resting condition is achieved by minute 30 of reclined rest, but studies that measured shorter rest periods indicate that a resting condition can occur in as little as 20 minutes in many adults, if they remain still. Individuals who move during the rest period do not achieve a resting state by 20 minutes and may not be at complete rest at 30 minutes.

Rest Period in Children

Measuring RMR in children, especially very young children, presents a challenge because many small children cannot rest quietly for 20 to 30 minutes and then undergo an additional 20 to 30 minute measurement. Mellecker and McManus[6] measured RMR in children aged 7 to 12 years, when a rest period was not given. They found that there were no significant differences in RMR measured at minutes 10, 15, 20, or 25 of measurement compared with minute 30. This suggests that in children, when a rest period before an IC test is not possible, data recorded after minute 10 of the measurement are not significantly different from data recorded at minute 30. However, RMR values recorded at minute 20 of the measurement were the least variable and most indicative of rest in children.

Activities during the Rest Period

No studies were identified that addressed what kind of physical activities, if any, could be done during the rest period in healthy or non–critically ill populations. However, research shows that certain activities, such as laughing, reading, or listening to music, during an IC test increase RMR.[50,51] Therefore, it is reasonable to recommend subjects rest quietly during both the rest period and during the measurement.

Steady State in Adults

Steady state (SS) is defined in the Evidence Analysis Library glossary as "a pre-determined criterion that defines a minimum variation in gas exchange variables from one minute to the next." SS and RMR are not necessarily synonymous. SS is often determined by achieving ≤10% coefficient of variation (CV) for a specified amount of time in one or more of the following parameters: VO_2, VCO_2, RQ (≤5% CV), or minute ventilation. Data obtained before SS are often discarded. The purpose of the discard period and SS requirement is to minimize artifact (nonmetabolic variation in gas exchange) in the measurement. SS definitions vary by measurement length (4 to 25 minutes), CV (<5% to 10%), and combination of gas-exchange variables (VO_2, VCO_2, RQ, minute ventilation). Schols and colleagues[7] found that after discarding the first 7 minutes, RMR did not vary when followed at 5-minute intervals from 5 minutes to 30 minutes.

Horner and colleagues[14] demonstrated that >80% of individuals can achieve SS for 5 consecutive minutes at 15 minutes, but only 32% to 35% could sustain SS for 10 minutes after 15 minutes. Reeves and colleagues[10] reported no statistically significant difference in the means between RMR measured at 5 minutes, 4 minutes, and 3 minutes. However, using Bland-Altman plots, when comparing 5-minute SS to 4-minute SS, the spread of the data points was within the predefined level of agreement of ±2%; but when comparing 5-minute SS to 3-minute SS, the level of agreement exceeded 2%. Therefore, 3 minutes was determined to be unacceptable.[10] Based on the evidence reviewed in healthy adults after discarding the first 5 minutes of data to exclude artifact, achieving at least 4 minutes of RMR measurement (with ≤10% CV in VO_2 and VCO_2) is the minimum measurement time acceptable.

There were no studies identified that addressed the duration of an IC measurement required to achieve an accurate RMR measure when SS cannot be achieved in healthy or non−critically ill individuals.

SS in Children

One original research study evaluated the duration of RMR measurement required in healthy children to achieve SS using two different protocols, one with a face mask and the other with a mouthpiece/nose clip (with the order being reversed in half of the subjects).[6] In addition, both protocols allowed the rest period to occur during rather than before the RMR measurement. At minute 20 of RMR measurement, mean RMR values for the mask or mouthpiece/nose clip devices were not statistically different (1,408 ± 264 kcal/day and 1,440 ± 352 kcal/day, respectively; P=0.697); however, the CV for the minute 20 RMR measurement was lower with the mask than with the mouthpiece/nose clip (CV 6% vs 12%, respectively). Based on this single piece of evidence reviewed, in healthy children, the rest period may be included in the RMR measurement period. When using this approach, RMR measurements recorded before minute 10 should be discarded as nonresting, and measurements taken starting at minute 10 might be optimal.

Body Position during Measurement

Four original research studies were evaluated regarding the effects of different body positions on measurement of RMR in non−critically ill adults. One study of older patients undergoing an elective thoracotomy reported that energy expenditure before surgery was not significantly different in the 30-degree head-of-bed elevation position than in the supine position; however, after surgery, the supine position resulted in greater RMR than the 30-degree head-of-bed elevation.[9] One study in healthy individuals found that the mean RMR when sitting motionless was 3.7%±6.3% and while standing motionless was 13%±8% above the mean supine RMR.[15] Other studies have reported that sitting RMR is 11%±7% greater than the lying RMR, and that the mean energy cost of sitting and standing are 6% and 14% greater than lying down.[16,17] Fidgeting in any of these positions further increases RMR.[9,15] Based on the evidence reviewed, healthy subjects should maintain a supine position and avoid fidgeting during the RMR measure.

Gas-Collection Devices

Four studies[6,18-20] evaluated whether different types of gas-collection devices (ventilated hood/canopy, mouthpiece/nose clip, or face mask) have an impact on RMR measurements. Forse[18] was the only study of three in adults that reported a statistically significant difference, with a higher RMR measurement using a mouthpiece/nose clip or face mask, compared with the ventilated hood. Based on the research reviewed in adults, there is conflicting evidence regarding RMR measurements made comparing a ventilated hood with either mouthpiece/nose clip or face mask; this may be due to differences in subject comfort. One study in children[6] reported no significant differences between RMR measurements comparing mouthpiece/nose clip vs face mask, but ventilated hoods were not tested. Additional research comparing gas-collection devices is needed.

Time of Day of Measurement

Two original research studies[21,22] were evaluated regarding the effect of the time of day (diurnal variation) on RMR. Both studies reported no significant effect of diurnal variation between morning and afternoon RMR measures. However, in both studies, subjects remained at rest in the facility the entire day. Based on the limited evidence reviewed, diurnal variation has minimal effect on RMR in the non−critically ill population. This recommendation is helpful in inpatient settings, but studies comparing coming from home for a morning measurement vs coming from home for an afternoon measurement are needed. Research on larger, more heterogeneous populations is also needed.

Room Temperature

Three original research studies were evaluated regarding proper room temperature for RMR measurement. All three studies reported differences in energy expenditure as a function of room temperature. As room temperature decreased, energy expenditure increased. Room temperature (≤20°C [68°F]) increased RMR relative to a room temperature of approximately 22°C to 25°C (72°F to 77°F). The use of a blanket to warm subjects minimized the increase.[12,23] Two studies reported an effect of season on RMR, with cold indoor room temperature resulting in greater increases in energy expenditure during the winter compared to the summer.[12,24] No studies were found that evaluated the effect of increased room temperature (>25°C or 77°F) on RMR. The relevance of this recommendation to healthy children and non−critically ill adults or children is unknown.

Room Conditions (Humidity, Light, and Noise)

There were no studies identified to address room conditions (such as humidity, lighting, and noise) required for RMR measurement in healthy and non−critically ill populations.

Fasting Period

The thermic effect of food (TEF) on RMR is complex. Among other factors, TEF is determined by the macronutrient composition in a meal and the number of calories consumed. The studies that meet the inclusion/exclusion criteria in this project were based on caloric content, not macronutrient distribution. An energy load of approximately 478 to 750 kcal increased metabolism for at least 3 hours, and RMR remained elevated throughout 3 hours with no trend back toward baseline noted.[25,30] Other studies have shown that consumption of 450 to 900 kcal results in an elevated metabolic rate for at least 4 hours,[22,34] with a residual elevation of approximately 40 to 100 kcal/day remaining at the end of the 4-hour measurement period. In contrast, Weststrate and Hautvast[35] found that, after consumption of 312 kcal, the TEF effect was negligible at 210 minutes. Studies of postprandial periods of 5 hours show that consuming 600 to 1,200 kcal or 1,500 kcal increases RMR, and RMR remains elevated throughout the measurement period without any decrease toward baseline levels.[25,29] One study[26] reported that the TEF of consuming 1,300 kcal was negligible at 7 hours post consumption. Therefore, based on the evidence reviewed, individuals who consume approximately 1,300 kcal should not be measured until 7 hours post consumption. If subjects are not able to fast as recommended, research suggests a small meal ($\leq$300 kcal) can be ingested and RMR can be measured 2 hours later. However, the majority of studies did not include a measurement period long enough to observe when RMR returns to baseline levels. Additional research is needed in this area.

Caffeine and Other Stimulants

Caffeine and other stimulants are known to raise metabolic rate; however, the magnitude of increase and duration of the effect are not clear, and the effects are likely dose- and product-dependent. Six studies were evaluated to answer this question. Studies differed in the dose of caffeine (absolute [mg]) or relative dose of caffeine [per body weight or fat free mass]), making comparisons and conclusions difficult. Research showed that doses of caffeine as small as 50 mg significantly increased RMR, and RMR was still elevated by 6% at 4 hours.[37,39,42] Doses of 5 mg/kg fat-free mass administered to women increased RMR 7% to 15%, depending on age.[37] Results of the effects of tea on RMR are mixed. Two studies found green tea had no effect on RMR, and one study showed oolong tea increased RMR for $>$2 hours.[39,41] Products with multiple stimulants increased RMR for at least 4 hours.[38,40,41] Based on the evidence reviewed, RMR remains elevated for at least 4 hours; however, the length of time RMR remains elevated after ingestion of caffeine or other stimulants beyond this time remains unknown.

Smoking and Nicotine

Many devices are used to deliver nicotine (cigarettes, pipes, electronic cigarettes, chewing, patches, gum, or nasal spray), many have not been evaluated to determine their effect on RMR measurement. Only one study was evaluated for this question. One nonrandomized crossover trial compared baseline RMR to RMR measured under low smoking (0.8 mg nicotine) and high smoking (1.74 mg nicotine) conditions; nicotine was delivered to subjects via cigarette smoking.[43] At 140 minutes, the low nicotine condition increased RMR 5.2% and the high nicotine condition increased RMR by 9.3%. The time required for RMR to return to baseline was not measured. Based on this study, it is unknown how long RMR is increased in response to smoking, but there is a significant acute increase in RMR for at least 140 minutes after smoking cigarettes. No studies evaluating the use of other nicotine-containing products were identified. Additional research is needed regarding various nicotine-containing products and the duration of effect on RMR.

Effects of Exercise on RMR

The majority of studies on the effects of exercise on RMR measured the increase energy expended as excess post exercise oxygen consumption (EPOC) not RMR. EPOC refers to the VO_2 consumed after cessation of exercise. Two phases of EPOC have been identified. The first phase is rapid or short-term EPOC, which is an increase in VO_2 immediately after exercise and generally lasts 10 to 90 minutes.[52] The second phase is called slow or long-term EPOC, which is a modest elevation in VO_2 that can last up to 48 hours.[53] Both phases of EPOC must be measured to accurately determine the thermogenic effect of an exercise on RMR. However, RMR as measured by the Weir equation (used by most indirect calorimeters), includes both VO_2 and VCO_2. Based on the evidence that VCO_2 is 10% of RMR, studies that measured only VO_2 without any measures of RMR were excluded from analysis.

Resistance Exercise. Only one original research study was evaluated regarding the length of time a healthy individual should refrain from resistance exercise before an RMR measurement. This study was conducted on untrained older men performing a single 90-minute bout of concentric-only resistance exercise.[44] During the next 24 hours, mean energy expenditure was 1,570$\pm$193 kcal in the control group compared to 1,627$\pm$193 kcals in the exercise group. At 48 hours, VO_2 was still significantly elevated by 3% and 57 kcal/day ($P<0.0002$) compared to the control group. Therefore, at least 48 hours may be required after 90 minutes of concentric resistance exercise in novice resistance exercisers if 57 kcal/kg/day is considered clinically significant. More research evaluating the effects of resistance exercise on RMR in trained vs untrained subjects, and exercise intensity of resistance exercise is needed.

Very-Light-Intensity Physical Activity. One study was evaluated on the effect of very-light-intensity physical activity on RMR. Frankenfield and Coleman[11] had subjects walk 300 m, after which RMR was measured in 5-minute intervals for 30 minutes. Results showed that if subjects lay still, recovery to rest occurred by 20 minutes in 95% of subjects. However, RMR continued to decrease throughout the entire 30-minute rest period. Based on only this study, it was concluded that 30 minutes of rest is required for RMR to return to baseline after very light intensity physical activity. However, more research evaluating longer durations of very light activity is needed.

Light-Intensity Physical Activity. Light-intensity physical activity is defined as physical activity that performed at 2.0 to 2.9 times the intensity of rest.[54] No studies were found that evaluated light-intensity physical activity.

Moderate- or Vigorous-Intensity Physical Activity. Exercise done between 3.0 and 8.7 times the intensity of rest defines a range of moderate to vigorous physical activity.[54] No studies evaluating the duration of increased RMR after these types of activities were identified. Because this represents a large range of various physical activity, it is

Evidence analysis conclusions and recommendations	Conclusion grade and recommendation rating
How long of a rest period is needed before the measurement of RMR[a] in healthy and non—critically ill adults?	
Conclusion: Based on the evidence reviewed, all studies evaluated showed that resting condition is achieved by min 30 of reclined rest, but studies that measured shorter rest periods indicate that resting condition can occur in as little as 20 min in many adults. Individuals who move during the rest period do not achieve a resting state by 20 min and may not be at complete rest at 30 min. Rest periods have primarily been tested in healthy adults; one study tested both healthy adults as well as stable COPD patients and found that 20 min was required to achieve rest in both groups. *Recommendation:* The practitioner should aim for a 30-min rest period before starting a measurement of RMR in a healthy adult or those with stable chronic obstructive pulmonary disease. If this is not possible, a 20-min rest period may be sufficient.	Grade I Strong; imperative
How long of a rest period is needed before the measurement of RMR in healthy and non—critically ill children?	
Conclusion: Based on the evidence reviewed, when a rest period is not given before the test, data recorded after min 10 of the measurement are not significantly different from data recorded at min 30. RMR values recorded at min 20 of the measurement are most indicative of rest in healthy children. *Recommendation:* The practitioner should aim for a 30-min rest period before starting a measurement of RMR in a healthy child. However, if the child cannot cooperate with both a premeasurement rest and rest during measurement, the practitioner may choose to forgo the premeasurement rest period, initiate the RMR measurement immediately, then discard first 10 min of data.	Grade III Weak; Conditional
What kinds of activities can be done during the rest period in healthy and non—critically ill individuals?	
Conclusion: No studies were identified to address the kinds of activities that can be done during the rest period in healthy and non—critically ill individuals. *Recommendation:* The practitioner should ensure healthy adults rest quietly and not engage in any activity during the 30-min rest period.	Grade V Consensus; Imperative
How long should the duration of the RMR measurement be to achieve a steady state in healthy and non—critically ill adults?	
Conclusion: Based on the evidence reviewed, in adults, after discarding the first 5 min of data to exclude artifact, achieving at least 4 min of steady state (10% or less coefficient of variation in VO_2[b] and VCO_2[c]) is acceptable. Research indicates that measurements as short as 4 min in steady state are comparable to longer steady state measurements. Measurement periods have primarily been tested in healthy adults; one study tested both healthy adults as well as stable COPD patients and found no significant differences between various RMR measurement lengths. *Recommendation:* When measuring RMR in a healthy or non—critically ill adult, the practitioner should discard the data for the first 5 min, and then use a validated steady state definition to determine the duration of the remainder of the measurement.	Grade III Weak; Conditional

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Figure 4. 2014 Evidence analysis conclusion statements and recommendations for performing indirect calorimetry in healthy and non—critically individuals.

Evidence analysis conclusions and recommendations	Conclusion grade and recommendation rating
If steady state cannot be achieved, how long should the duration of an indirect calorimetry measurement be in the healthy and non−critically ill?	
Conclusion: There were no studies identified to address the duration of an indirect calorimetry measurement when steady state cannot be achieved to ensure accuracy in healthy and non−critically ill individuals *Recommendation:* None	Grade V None
How long should the duration of the RMR measurement be to achieve a steady state in healthy and non−critically ill children?	
Conclusion: Based on the evidence reviewed, in healthy children, the rest period may be included in the RMR measurement period. When using this approach, RMR measurements recorded after the 10th min are not significantly different from RMR measured after 30 min of rest, but RMR measurements taken around the 20th min may have the least variability. *Recommendation:* When measuring RMR in a healthy child who is unable to rest, the practitioner should include the rest period in the measurement, discard the first 10 min of data then continue the measurement until a steady state is achieved.	Grade III Weak; conditional
Is there a difference in RMR measurements related to the effects of different body positions in healthy and non−critically ill individuals?	
Conclusion: Based on the evidence reviewed, some postures affect measurement of RMR in healthy and non−critically ill adults. One study of RMR older patients measured RMR before undergoing an elective thoracotomy reported that energy expenditure was not significantly different in the 30-degree head-of-bed elevation than in the supine position. In healthy individuals, three studies reported that sitting RMR was greater than supine or lying RMR, and standing energy expenditure was greater than sitting or lying RMR. One study demonstrated that fidgeting in any of these positions further increased the RMR. *Recommendation:* The practitioner should conduct RMR measurements in a healthy and non−critically ill adult in the supine position when possible.	Grade II Fair; imperative
Is there a difference in RMR measurements related to different types of gas-collections devices (such as face mask, mouthpieces/nose clips, or ventilated hood/canopy) in healthy and non−critically ill individuals?	
Conclusion: Based on the research reviewed, there is conflicting evidence regarding RMR measurements made comparing a ventilated hood with either mouthpiece/nose clip or face mask in healthy adults; this may be due to differences in patient comfort. One study in healthy children reported no significant differences between RMR measurements comparing mouthpiece/nose clip vs face mask. Additional research comparing gas collection devices is needed. *Recommendation:* The practitioner may select any gas collection device (ventilated hood/canopy, mouthpiece and nose clip, or face mask) for an RMR measurement in a healthy individual or child.	Grade III Weak; Imperative

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Figure 4. *(continued)* 2014 Evidence analysis conclusion statements and recommendations for performing indirect calorimetry in healthy and non−critically individuals.

Evidence analysis conclusions and recommendations	Conclusion grade and recommendation rating
What is the effect of diurnal (time of day) variation on RMR in healthy and non−critically ill individuals?	
Conclusion: Based on the limited evidence reviewed, diurnal variation has minimal effect on RMR in healthy adults. Additional research on larger, more heterogeneous samples is needed. *Recommendation:* The practitioner may conduct a measurement of RMR at any time of day in a healthy adult, as long as resting conditions can be achieved.	Grade III Weak: Imperative
What are the room conditions (in terms of temperature) required for RMR measurement in healthy and non−critically ill individuals?	
Conclusion: Decreased room temperature (<20°C or 68°F) has been shown to increase RMR in healthy adults, relative to a room temperature of approximately 22°C to 25°C (72°F to 77°F). The use of a blanket minimized this increase. Seasonality has also been shown to have an effect on RMR, with cold indoor room temperature resulting in greater increases in energy expenditure during the winter compared to the summer. No studies were found that evaluated the effect of increased room temperature (>25°C [77°F]) on RMR. Further research is needed to better define the thermoneutral room temperature range and to examine the effect of increased room temperature on RMR in the healthy and non−critically ill. *Recommendation:* The practitioner should minimize the effect of ambient temperature on RMR in a healthy adult by keeping the room temperature between 22° to 25°C (72°F to 77°F) or providing a blanket during the measurement.	Grade II Fair: Imperative
What are the room conditions (in terms of humidity, lighting and noise) required for RMR measurement in healthy and non−critically ill individuals?	
Conclusion: There were no studies identified to address room conditions (such as humidity, lighting and noise) required for RMR measurement in healthy and non−critically ill individuals. *Recommendation:* The practitioner should measure RMR in a healthy or non−critically ill adult or child in a quiet room.	Grade V Consensus: Imperative
How long should a healthy and non−critically ill individual fast before an RMR measurement to avoid the thermic effect of food (TEF)?	
Conclusion: Based on the evidence reviewed, consuming meals containing approximately 450 kcal to 1,500 kcal increases metabolic rate in healthy adults for at least 3 to 5 h; however, the majority of studies did not include a measurement period long enough to observe a return to baseline levels. The thermic effect of food dissipates depending on the amount of calories consumed. One study reported that the thermic effect of consuming approximately 300 kcal was negligible after 3.5 h post consumption and another study reported that the thermic effect of consuming 1,300 kcal was negligible after 7 h post consumption. Additional research is needed in this area. *Recommendation:* Before measurement of RMR, the practitioner should ensure the healthy adult has fasted at least 7 h to	Grade II

(continued on next page)

Figure 4. *(continued)* 2014 Evidence analysis conclusion statements and recommendations for performing indirect calorimetry in healthy and non−critically individuals.

Evidence analysis conclusions and recommendations	Conclusion grade and recommendation rating
minimize the TEF. If a 7-h fast is not clinically feasible before measurement of RMR in a healthy adult, the practitioner should instruct the individual that a small meal (≤300 kcal) may be consumed 4 h before the measurement.	Fair; Imperative
How long should a healthy and non−critically ill individual refrain from consuming caffeine or other stimulants before an RMR measurement?	
Conclusion: Based on the evidence reviewed, caffeine and other selected stimulants increase RMR for at least 4 h in healthy adults. The duration of an increased RMR after ingestion of caffeine or other stimulants is unknown. Research identifying the duration of elevated RMR after ingestion of caffeine and other stimulants is needed.	Grade III
Recommendation: The practitioner should ensure that a healthy adult refrains from ingesting caffeine or other stimulants for at least 4 h before an RMR measurement.	Fair; Imperative
How long should a healthy and non−critically ill individual refrain from smoking and nicotine intake before an RMR measurement?	
Conclusion: Based on the limited evidence reviewed, there is a significant acute increase in RMR after smoking cigarettes in healthy adults. While evidence suggests that RMR is elevated for at least 140 min after smoking, the length of time required for RMR to return to baseline is unknown. Additional research is needed regarding nicotine-containing products.	Grade III
Recommendation: If a healthy adult uses nicotine products, the practitioner should ask the individual to abstain from such products for longer than 140 min before an RMR measurement.	Weak; Conditional
How long should a healthy and non−critically ill individual refrain from resistance exercise before an RMR measurement?	
Conclusion: Based on one study in healthy, untrained older men performing a single bout of resistance exercise, BMR was reported to be elevated by 3% (57 kcal) at 48 h post exercise. Therefore, at least 48 h may be required after 90 min of resistance exercise.	Grade III
Recommendation: None	None
How long should a healthy and non−critically ill individual refrain from very light intensity physical activity before an RMR measurement?	
Conclusion: Based on the limited evidence reviewed, 30 min of rest is required for RMR to return to baseline after very light intensity physical activity (ie, <5 min of activity) in healthy adults.	Grade III
Recommendation: If a healthy adult engages in very light intensity physical activity (eg, getting dressed, driving, walking <5 min, etc) before an RMR measurement, the practitioner should ensure a 30-min rest period before the RMR measurement.	Weak; conditional

(continued on next page)

Figure 4. *(continued)* 2014 Evidence analysis conclusion statements and recommendations for performing indirect calorimetry in healthy and non−critically individuals.

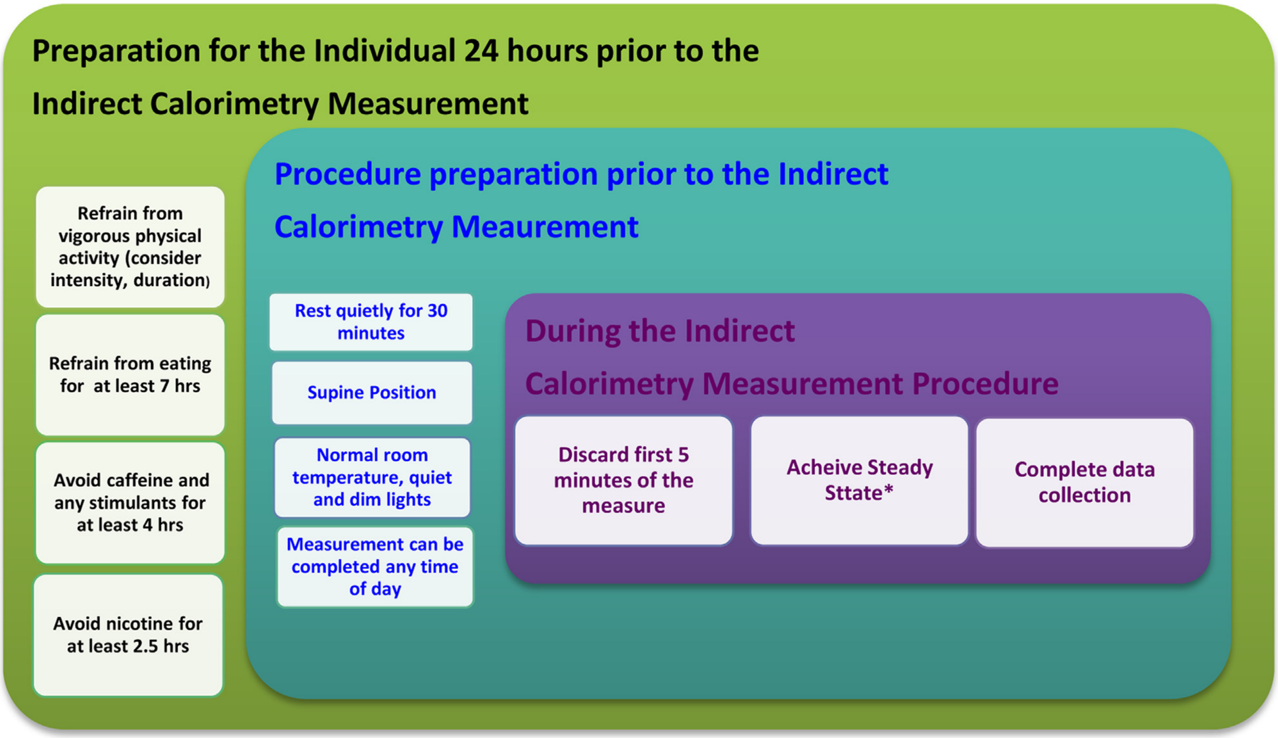
Evidence analysis conclusions and recommendations	Conclusion grade and recommendation rating
How long should a healthy and non−critically ill individual refrain from light to vigorous intensity physical activity before an RMR measurement?	
Conclusion: There were no studies identified to address how long a healthy or non−critically ill individual should refrain from light to vigorous intensity physical activity before an RMR measurement. *Recommendation:* If a healthy adult engages in light to vigorous intensity physical activity, the practitioner should instruct the individual to refrain from physical activity before the RMR measurement for a period of time (eg, 12-48 h for moderate to vigorous physical activity).	Grade V Consensus; conditional
Can respiratory quotient (RQ) be used to detect error in a measurement of RMR in healthy and non−critically ill adults?	
Conclusion: Based on the evidence reviewed, in healthy adults who had fasted overnight (7 to 14 h) per protocol before the RMR measurement, RQ ranged from 0.68 to 0.90. In addition, limited research regarding prolonged fasting (beyond 14 h, violating protocol) reported that RQ declined with longer fasts to values as low as 0.65 after 22 h of fasting. However, limited research reported that RQ remained $<$1.0 even though subjects had eaten within the past 3.0 to 4.5 h, violating protocol. In individuals who consumed a meal 2.5 h before measurement, fasting RQ (range=0.79 to 0.81) increased by only 0.03 to 0.05. Research demonstrates that RQ has poor accuracy to evaluate feeding protocol violations. *Recommendation:* If the RQ falls outside the physiologic range ($<$0.67 or $>$1.3) in a healthy adult, the practitioner should suspect an error and repeat the RMR measurement.	Grade II Consensus; conditional
Conclusion: None *Recommendation:* If the RQ falls between 0.67 and 0.90 in a healthy adult, the practitioner should accept the measurement because RQ values within this range cannot reliably be used to detect feeding protocol violations.	None Consensus; conditional
Conclusion: None *Recommendation:* If the RQ is between 0.91 and 1.3 in a healthy adult who has fasted, the practitioner should suspect a problem and consider repeating the measurement.	None Consensus; Conditional

[a]RMR=resting metabolic rate.

[b]VO_2=oxygen consumption.

[c]VCO_2=carbon dioxide production.

Figure 4. *(continued)* 2014 Evidence analysis conclusion statements and recommendations for performing indirect calorimetry in healthy and non−critically individuals.



*Steady state is achieved at 10% or less coefficient of variation in VO_2, VCO_2 or minute ventilation

Figure 5. Illustration of timeline and sequence of events before the indirect calorimetry procedure.

recommended research be conducted across a variety of moderate to vigorous exercise intensities and durations to determine how long an individual should refrain from these activities before RMR measurement.

Appropriate Use of RQ

RQ is the volume of CO_2 exhaled divided by the volume of O_2 consumed (VCO_2/VO_2). Eight original research studies were evaluated to determine whether RQ can be used to detect measurement error in non–critically ill or healthy individuals. Three studies reported that in subjects who had fasted overnight (7 to 14 hours) before the RMR measurement, RQ ranged from 0.68 to 0.90.[21,45,47] Two studies evaluated prolonged fasting (beyond 14 hours). One reported that mean baseline RQ (0.83) declined to 0.74, 0.72, and 0.71 after 36, 60, and 84 hours of fasting, respectively.[49] The other study reported individual RQ values as low as 0.65 after 22 hours of fasting.[48]

On the other hand, two studies reported that RQ remained <1.0, even though subjects had eaten within the past 3.0 to 4.5 hours.[27,35] One study reported that the fasting RQ (range=0.79 to 0.81) increased by only 0.03 to 0.05 in individuals who consumed a meal 2.5 hours before measurement.[46] These three studies suggest that, in response to a meal, RQ does not increase in a manner that reflects expected physiological substrate utilization values.

Based on the evidence reviewed, RQ has poor accuracy to evaluate feeding protocol violations (ie, not fasting). The physiologic range of RQ reflecting cellular metabolism across the fed and fasted state is 0.67 to 1.3; therefore, if the RQ falls outside the physiologic range (<0.67 or >1.3) the clinician should suspect an error and repeat the measurement. If the RQ falls between 0.68 and 0.90, the clinician should accept the measurement, because reasonable fasting RQs have been recorded within this range. However, if the RQ is between 0.91 and 1.3 in a non–critically ill or healthy individual who has fasted, it is recommended that the clinician suspect a problem and consider repeating the measurement. An RQ between 0.91 and 1.3 could be observed in an individual who has not fasted, however, it could also be due to an error in calibration, a leak in the calorimeter, a ventilation problem (ie, hypo- or hyperventilation), or some other artifact or protocol violation.

Conclusion statements and recommendations for each question are found in Figure 4, and Figure 5 summarizes the recommended procedure for conducting IC in healthy or non–critically ill populations.

DISCUSSION

Of the 21 conclusion statements in this project, only 5 received a grade I or II. The rest of the conclusion statements received a lower grade, or no grade, indicating that further research in this area is warranted. Only 10 new original research papers were found since the original Evidence Analysis Library review in 2006. Many studies did not report the methods completely enough to meet the inclusions/exclusions criteria for the current project. Most studies received a neutral or negative rating. In almost all cases, study sample sizes were small, and the subject populations were not adequately diverse to make generalizable recommendations (ie, only men or only women, only healthy subjects, and older populations not represented). The work group recommends the following research is valuable to clarify appropriate protocols to accurately measure RMR:

1. Determine the length of time a child should rest before RMR measurement, how long an RMR measurement should be, and where in the data SS is achieved. Mellecker and McManus[6] provided some helpful findings, but their work should be confirmed. Determining rest periods and SS in children younger than age 7 years is also necessary.
2. The duration of RMR measurement needed to achieve SS in healthy and non–critically ill adults may be shorter than many clinicians traditionally follow. Research for this project suggested that once SS is achieved, only 4 minutes of measurement need to be averaged. This finding should be confirmed, as it would be a significant change in IC testing procedures for many practitioners.
3. If SS is not achieved during a study, research is needed to clarify the duration of time that data should continue to be collected and averaged to obtain an accurate RMR, or whether the subject should be asked to repeat the measurement at another time.
4. Research on the accuracy of measuring RMR with different gas-collection devices is conflicting, and further research is needed.
5. Based on two studies reviewed, the time of day the measurement occurs was not important if all other resting criteria are met. The conclusion was given a grade III with a weak recommendation, suggesting the practitioner should be cautious in implementing this recommendation. Research not included in this current analysis suggests afternoon measurements can be significantly higher than morning measurements.[55] More research with larger and more heterogeneous samples is needed.
6. Some room conditions are not controllable (ie, humidity) during the measurement of RMR, and light, noise, and temperature are often modifiable. Research on atypical room temperatures ($<$68°F or $>$77°F) is known, but the effects of room temperatures closer to typical room temperature (72°F) are not known and could be explored. With respect to light and noise, it is reasonable to assume they would adversely affect RMR, but currently there is no evidence to confirm this.
7. More research on the TEF of caloric loads and macronutrient distribution is needed. It is common to advise a subject to refrain from eating overnight, but, depending on the caloric load and macronutrient distribution, duration of the TEF will vary, and overnight fasting might be longer or shorter than necessary. It would also be helpful to confirm how many calories can be consumed if a 7-hour fast is not feasible or medically prudent.
8. The effects of caffeine and nicotine or other stimulants on RMR need further investigation. Much research in this area was designed to determine how these substances might increase metabolism in relation to weight loss. Research on how long these substances interfere with the measurement of RMR is needed.
9. Investigation of the effects of various physical activities on RMR is needed. It is common practice to instruct a subject to refrain from exercise 12 to 24 hours before an RMR measurement. However, there are many types of intensities and durations within the term *physical activity* or *exercise* and the effects of each are highly variable. Some research suggests the effects of a long hard workout might last longer than 24 hours. And factors such as novice vs trained resistance exercisers might influence the effect of exercise on metabolic rate. The work group recommends RMR be the variable measured to better understand the effect of exercise on RMR.

Strengths and Limitations

One of the strengths of this evidence analysis is the high bar set for inclusion of studies in the analysis. Studies that did not define their methods well or whose methods were not adequately rigorous by evidence-based recommendation were excluded. However, this is also a limitation because, for many questions, there were very few studies that could be included in the analysis. A second limitation is the lack of an effect size calculation for each study. At the time of this project, calculation of effect size was not part of the Evidence Analysis Library process; therefore, all studies were weighted equally in our analyses and conclusions. Another limitation is the limited sample population for many of the studies. The vast majority of studies reviewed were conducted in small samples (75% of the articles had sample sizes between 10 and 23 subjects) of healthy adults; therefore, these protocol recommendations might not be generalizable in disease states, both acute and chronic, including patients who are hospitalized but not critically ill. Children and the elderly were under-represented in this review. Until more research is available in these populations, however, it is reasonable to suggest these recommendations be followed. Although it was not the intent of the work group to focus on healthy populations only, the vast majority of studies that were identified for the project had been conducted on healthy subjects. Research on RMR measurement in the acute and chronically ill populations, children, and people of diverse ages, races, and body weights is needed.

CONCLUSIONS

Evidence-based guidelines are a helpful starting point for researchers and clinicians seeking to obtain an accurate RMR measurement. This review article outlines the best practices for accurately measuring RMR in healthy individuals and some non–critically ill populations; however, many aspects of IC measurement protocol remain to be clarified. Additional research is needed in more heterogenous populations, especially acutely, but not critically, ill adults and children.

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STATEMENT OF POTENTIAL CONFLICT OF INTEREST

No potential conflict of interest was reported by the authors.

FUNDING/SUPPORT

This project was funded by the Academy of Nutrition and Dietetics Evidence Analysis Library.

ACKNOWLEDGEMENTS

The authors would like to thank Hannah Brinton, Catherine Carmella, and Laree LaPierre for their assistance in preparing the tables.

Search Terms: Search Vocabulary
See specific search terms in the search strategy under "Other Electronic Database Search."

Electronic Databases

PubMed database not searched.

CENTRAL database not searched.

Database: Ovid MEDLINE(R) <1946 to April Week 3 2012>

Search Strategy:

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1. exp Calorimetry/ or exp Calorimetry, Indirect/ (22520)
2. exp Energy Metabolism/ or exp Basal Metabolism/ (255144)
3. Calorimetry.mp. (28588)
4. ("resting energy expenditure" or "REE").tw. (2472)
5. ("basal metabolic rate" or "BMR").tw. (2014)
6. ("basal metabolism" or "energy metabolism").tw. (17676)
7. or/1-6 (287053)
8. limit 7 to (English language and humans) (82975)
9. limit 8 to (case reports or comment or duplicate publication or editorial or in vitro or interview or lectures or letter or news or "review") (22751)
10. 8 not 9 (60224)
11. exp "Reproducibility of Results"/ (228971)
12. exp Methods/is, mt, st [Instrumentation, Methods, Standards] (8780)
13. exp Reference Standards/ (29980)
14. (validity or reproduciblity or reliability or accuracy).mp. (296429)
15. (validit$ or reproduciblit$ or reliabilit$ or accurac$ or variabilit$).tw. (424390)
16. exp Validation Studies/ (54950)
17. exp Clinical Protocols/ (110181)
18. or/11-17 (730043)
19. (resting adj5 period).mp. (958)
20. exp Time Factors/ (920295)
21. exp Rest/ (11087)
22. or/19-21 (930688)
23. 10 and 18 and 22 (311)
24. exp Monitoring, Physiologic/is [Instrumentation] (16930)
25. exp Quality Control/ (36933)
26. exp Nutrition Assessment/ (20326)
27. or/24-26 (73997)
28. 10 and 18 and 27 (248)
29. 23 or 28 (538)
30. limit 29 to yr="2003 -Current" (303)

Database: Ovid MEDLINE(R) without Revisions <1996 to April Week 3 2012>

Search Strategy:

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1. exp Calorimetry/ or exp Calorimetry, Indirect/ (14698)
2. exp Energy Metabolism/ or exp Basal Metabolism/ (142686)
3. Calorimetry.mp. (19427)
4. ("resting energy expenditure" or "REE").tw. (1760)
5. ("basal metabolic rate" or "BMR").tw. (1217)
6. ("basal metabolism" or "energy metabolism").tw. (1025421111xz)

(continued on next page)

Figure 2. Search string for identification of papers related to measuring resting metabolic rate in healthy and non−critically ill individuals.

7	or/1-6 (164743)
8	limit 7 to (english language and humans) (54471)
9	limit 8 to (case reports or comment or duplicate publication or editorial or in vitro or interview or lectures or letter or news or "review") (15267)
10	8 not 9 (39204)
11	exp "Reproducibility of Results"/ (204530)
12	exp Methods/is, mt, st [Instrumentation, Methods, Standards] (6345)
13	exp Reference Standards/ (21057)
14	(validity or reproduciblity or reliability or accuracy).mp. (214527)
15	(validit$ or reproduciblit$ or reliabilit$ or accurac$ or variabilit$).tw. (306809)
16	exp Validation Studies/ (54140)
17	exp Clinical Protocols/ (74552)
18	or/11-17 (551728)
19	(resting adj5 period).mp. (556)
20	exp Time Factors/ (459705)
21	exp Rest/ (4560)
22	or/19-21 (464115)
23	10 and 18 and 22 (236)
24	exp Monitoring, Physiologic/is [Instrumentation] (10228)
25	exp Quality Control/ (24332)
26	exp Nutrition Assessment/ (13752)
27	or/24-26 (48188)
28	10 and 18 and 27 (206)
29	limit 23 to yr="2012 -Current" (2)
30	28 not (23 not 29) (190)
31	limit 30 to yr="2009 -Current" (63)

Total articles identified to review from electronic databases:

Figure 2. *(continued)* Search string for identification of papers related to measuring resting metabolic rate in healthy and non−critically ill individuals.