

Resting Energy Expenditure Measured by Indirect Calorimetry in Infants and Young Children with Chronic Lung Disease

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Objective: To determine resting energy expenditure (REE) by indirect calorimetry and to compare measured resting energy expenditure (mREE) by indirect calorimetry with prediction equations (pREE).

Material and Method: Infants and young children with chronic lung diseases from King Chulalongkorn Memorial Hospital were enrolled and assessed for nutritional status and severity of chronic lung diseases. For mREE, indirect calorimetry was performed by custom-made airtight canopy with O₂ and CO₂ sensors, with the patients were in a resting state. Prediction equations were Food and Agriculture/World Health Organization/United Nations University (FAO/WHO/UNU), Schofield-Weight, Schofield-Weight/Height, Harris Benedict, and Harris Benedict-Infant equations. Agreement between mREE and pREE was assessed by Bland-Altman method.

Results: Eighteen patients (median age 6 months, range 1 to 26 months) were recruited. Sixteen children had weight for age Z-score below -2 SD. Median weight for age Z-score, length for age Z-score and weight for length Z-score were -3.0, -3.1, and -1.9, respectively. Median mREE was 53.8 kcal/kg/day (interquartile range 47.5 to 72.6 kcal/kg/day). The Schofield-Weight/Height equation showed the lowest mean of difference at 0.94 kcal/kg/day with 95% confidence interval for the bias -44.4 to 46.3 kcal/kg/day.

Conclusion: To ensure optimal nutritional support, REE should be measured by indirect calorimetry in pediatric patients with chronic lung diseases. Based on our finding, the Schofield-Weight/Height equation was the most accurate equation for predicting REE in this group of patients.

Keywords: Resting energy expenditure, Indirect calorimetry, Chronic lung disease, Prediction equations

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Chronic lung diseases normally refer to a group of pulmonary diseases that damage peripheral airways and/or lung parenchyma. Common causes are bronchopulmonary dysplasia (BPD), meconium aspiration syndrome, chronic interstitial lung disease, pulmonary fibrosis, and recurrent respiratory tract infection^(1,2). Infants with chronic lung diseases are at risk for developing complications in various systems, such as pulmonary, cardiovascular, gastrointestinal, and nutritional complications. These infantile patients usually fail to thrive due to higher energy expenditure, restricted fluid intake, poor nutritional intake, impaired intestinal absorption, and diminished appetite⁽³⁻⁵⁾. Optimal nutritional support plays a pivotal role, not only regarding growth and development, but also to

compensate for the high energy demands of the disease. In humans, new lung tissues can regenerate until mid-childhood⁽⁶⁾. The first few years of life are therefore critical, as it is during this period that patients may outgrow the disease if provided adequate pulmonary and nutritional support. There have been very few studies that have measured resting energy expenditure (mREE) by indirect calorimetry in infants and young children with chronic lung diseases who were not intubated in the intensive care unit. Only one study in this population has been carried out beyond the intensive care setting⁽⁷⁾. The researchers in that study reported that mean resting energy expenditure (REE) was 55.8±7.0 kcal/kg/day in nine infants with cystic fibrosis, an energy expenditure rate higher than that of normal infants.

Total energy expenditure (TEE) is determined by the summation of REE, dietary-induced thermogenesis, and energy expended during physical activity. In infants, REE is responsible for approximately half

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of TEE. This proportion increases considerably to approximately 65 to 70% after one year due to declining energy demand for growth^(8,9). As such, 65 to 70% is the generally applied standard for the estimation of energy requirement in pediatric patients. Energy expenditure can be measured in vivo by either the costly stable isotope technique or by indirect calorimetry⁽¹⁰⁾. The latter method quantifies the concentrations of oxygen and carbon dioxide in both inspired and expired air and then calculates REE using the Weir equation⁽¹¹⁾. There are two practical ways of collecting gas exchange among non-intubated subjects, to include: 1) using a nose clip and a respiratory valve with a rubber mouthpiece, 2) using the ventilated hood system, which is more suitable for infants. These measurements are difficult to apply in a standard clinical setting. As a result, prediction equations for REE are frequently used in clinical practice. The following prediction equations are frequently used in children: Food and Agriculture/World Health Organization/United Nations University (FAO/WHO/UNU), Schofield-Weight, Schofield-Weight/Height, Harris Benedict, and Harris Benedict-Infant. It should be noted that, these prediction equations have been extrapolated from either older age groups or healthy populations. Moreover, agreement between REE predicted by these equations and REE measured by indirect calorimetry in infants and young children with chronic lung diseases has rarely been assessed in previous studies.

The aim of the present study was to measure REE in infants and young children with chronic lung diseases by indirect calorimetry and to compare the mREE with predicted REE (pREE) from frequently used prediction equations.

Material and Method

Study design

This was a cross-sectional study, determining REE by indirect calorimetry. The study was approved by the Institutional Review Board of the Faculty of Medicine, Chulalongkorn University. The researchers described the study to the parents of the patient subjects before obtaining signed informed consents.

Subjects

Infants and young children with chronic lung diseases aged below 2 years or weighed less than 12 kilograms were recruited from the Nutrition and Pulmonology Clinic at King Chulalongkorn Memorial Hospital between March 1, 2013 and July 30, 2014.

Criteria for diagnosing chronic lung diseases included the presence of underlying conditions relating to chronic lung diseases (e.g., BPD, chronic aspiration, and recurrent respiratory infection) and at least one of the following: chronic respiratory symptoms and signs such as cough, dyspnea, tachypnea, adventitious lung sounds, or abnormal chest X-ray that was compatible with chronic lung diseases.

Infants who presented with unstable clinical symptoms, such as current respiratory infection, chronic disease that may affect VCO₂ (carbon dioxide production) and VO₂ (oxygen consumption) measurements (such as cyanotic heart disease) were excluded from the present study.

Study protocol

Body weight and length of infants were measured by a standard precision hospital scale, without clothing. Body mass index (BMI) was calculated as weight divided by length squared (kg/m²). The Z-scores of weight for age, length for age, weight for length, and BMI were calculated using the WHO AnthroPlus software program.

Indirect calorimetry

The mREE was measured by indirect calorimetry. Infants were placed in a custom-made airtight canopy for a period of 15 to 30 minutes, 2 hours after their last meal. This indirect calorimetry model was developed by the Department of Physiology, Faculty of Medicine, Chulalongkorn University. The machine consists of three major component parts, as follows:

1) The airtight canopy was designed to encapsulate patients being studied. The canopy is composed of a transparent box sized 100 cm (L) x 50 cm (H) x 50 cm (W) that is positioned on a flat surface. The O₂ and CO₂ sensors connected to the gas analyzer were attached to the canopy. Before use, the canopy is tested for air leakage by pumping air into the canopy at a pressure above 300 mmHg.

2) The gas analyzer (Model ML 866, Serial 430-0394) is developed by ADInstruments (Colorado, USA). Precision and accuracy are tested by known standard gas (25% O₂, 5% CO₂), with a result of ±0.1% for oxygen and ±0.3% for carbon dioxide.

3) The computer is programmed with Chart Pro™ version 5 (ADInstruments, Colorado, USA). The computer is attached to the gas analyzer to analyze percentage of carbon dioxide emitted and percentage of oxygen available to the patient. Measurement of

VCO₂ and VO₂ are performed while the patients are quiet and the values remained stable.

The patients were rested in the supine position for approximately 30 minutes before being tested. The infants were quiet and awake during the rest stabilization period. Testing was conducted in a temperature controlled environment within the canopy system. The VO₂ and VCO₂ measurement readings were taken and recorded after a steady state, any episodes of crying, agitation, or coughing were edited out. Two measurements of REE were recorded and averaged.

The mREE was calculated using oxygen consumption (VO₂) and production of carbon dioxide (VCO₂), according to Weir's formula⁽¹¹⁾:

$$\text{mREE (kcal/day)} = 3.941\text{VO}_2 \text{ (ml/minute)} + 1.106\text{VCO}_2 \text{ (ml/minute)} \times 1,440$$

Prediction equations

The pediatric equations for pREE that were used in the present study were detailed in Table 1^(2,12-17).

The pREE was calculated for all patients and compared with mREE.

Statistical analysis

Sample size was calculated according to a previous study that compare REE in children aged 4 to 10 years with BPD to prediction equations⁽¹⁸⁾. The lowest correlation coefficient (r) between the mREE and Schofield-Weight equation was 0.7. Sample size was calculated using the following equation:

$n = [(Z\alpha + Z\beta \sqrt{(1 - r^2)})/r]^2 + 2$. With a power of 90% and a significance level of 0.05, a minimum of 16 participants was required.

Statistical analysis was performed with SPSS software version 20 (IBM, Armonk, NY, USA)

and MedCalc version 8 (Medcalc, Ostend, Belgium). All quantitative data were expressed as median and interquartile range. Using the Bland-Altman method, a plot of mREE-pREE difference (Y-axis) for each equation against the average of mREE and pREE (X-axis) was made to assess agreement between mREE and pREE from different equations. Level of agreement was assessed by calculating the bias (mean of difference) and the 95% confidence intervals for the bias.

Results

Demographic data

Eighteen participants were enrolled, 12 boys and six girls. Median age of participants was six months old (range 1 to 26 months). Median weight was 4.9 kilograms (interquartile range 3.6 to 6.3 kilograms) and median height was 58 centimeters (interquartile range 47 to 76 centimeters). Eleven out of 18 patients (61%) were diagnosed with BPD, four patients (22%) with recurrent aspiration pneumonia and three patients (17%) with diaphragmatic hernia. Seven patients (38%) required oxygen therapy, 6 patients (33%) required inhaled bronchodilator or inhaled corticosteroid, and four patients (22%) required diuretics.

Nutritional status

Sixteen out of 18 participants (88.9%) were undernutrition, with stunting more prevalent than wasting (Table 2). The median weight for age Z-score, length for age Z-score, and weight for length Z-score were -3.0, -3.1, and -1.9, respectively. In general, this group of patients had improved nutritional status, as shown by median weight for length and BMI Z-score higher than length for age Z-score.

Table 1. Description of prediction equations^(2,12-17)

Source	Data collection period	No. of subjects	Population	Equations
FAO/WHO/UNU	1910 to 1980	>7,500	Children and adolescents (age 3 to 18 years)	Male: REE = 60.9 x Wt - 54 Female: REE = 61 x Wt - 51
Schofield-Weight	1935 to 1985 FAO/WHO/UNU data included	>7,500		Male: BMR = 59.48 x Wt - 30.33 Female: BMR = 58.29 x Wt - 31.05
Schofield-Weight/Height	1935 to 1985 FAO/WHO/UNU data included	>7,500		Male: BMR = 0.167 x Wt + 1517.4 x Lt - 617.6 Female: BMR = 16.25 x Wt + 1023.2 x Lt - 413.5
Harris-Benedict (adult)	1909 to 1917	239	136 men, 103 women (age 15 to 74 years)	Male: REE = 66.47 + 13.75 x Wt + 5.0 x Lt - 6.76 x age Female: REE = 655.10 + 9.56 x Wt + 1.85 x Lt - 4.68 x age
Harris-Benedict (infant)	1909 to 1917	94	51 boys, 43 girls (aged 2 hours to 7 days)	Infant: REE = 22.10 + 31.05 x Wt + 11.5 x Lt

FAO/WHO/UNU = Food and Agriculture/World Health Organization/United Nations University; REE = resting energy expenditure (kcal/day); BMR = basal metabolic rate (kcal/day); Wt = body weight (kilogram); Lt = length (meter)

Comparison of REE by indirect calorimetry (mREE) and prediction equations (pREE)

Demographic data, mREE by indirect calorimetry, and pREE by prediction equations (FAO/WHO/UNU, Schofield-Weight, Schofield-Weight/Height, Harris Benedict and Harris Benedict-Infant)

Table 2. Anthropometric data of participant subjects

Z-score ¹	Weight for age	Length for age	Weight for length ²	BMI
Normal	2 (11.1%) ³	4 (22.2%)	9 (53.0%)	7 (38.9%)
Less than -2 SD	7 (38.9%)	5 (27.8%)	3 (17.6%)	2 (11.1%)
Less than -3 SD	9 (50.0%)	9 (50.0%)	5 (29.4%)	9 (50.0%)
Median	-3.0	-3.1	-1.9	-2.4
Interquartile range	-5.7 to -2.5	-3.5 to -1.8	-3.5 to -0.7	-3.6 to -1.2

BMI = body mass index

¹ Z-scores were calculated using WHO Anthro Plus (version 3.2.2, January 2011, available from www.who.int/childgrowth/software)

² n was 17 due to no reference data for one premature infant (subject No. 9)

³ Data were presented as n (%)

were shown in Table 3. The median mREE was 53.8 kcal/kg/day (interquartile range 47.5 to 72.6 kcal/kg/day). Comparative data describing the difference between mREE and pREE was presented in Table 4. The Harris Benedict-Infant equation demonstrated the highest mean of difference at 19.8 kcal/kg/day, with 95% confidence interval for the bias -10.2 to 49.8 kcal/kg/day. The Schofield-Weight/Height equation demonstrated the lowest mean of difference at 0.9 kcal/kg/day, with 95% confidence interval for the bias -44.4 to 46.3 kcal/kg/day and demonstrated the best agreement on the Bland-Altman plot (Fig. 1).

From the Bland-Altman plot (Fig. 2a, b), pREE from the FAO/WHO/UNU, and Schofield-Weight equations tended to underestimate the higher REE. Furthermore, the pREE from the Harris Benedict equation seemed to underestimate the REE in boys, but overestimated the REE in girls (Fig. 2c). The Bland-Altman plot of mREE and Harris Benedict-Infant equation (Fig. 2d) demonstrated that this equation underestimated REE, as compared to indirect calorimetry.

Table 3. Demographic data and resting energy expenditure

No.	Gender	Age (month)	Weight (kg)	Length (cm)	Severity of chronic lung diseases	Resting energy expenditure (kcal/kg/day)					
						Indirect calorimetry	FAO/WHO/UNU	Schofield-W	Schofield-WH	HB	HB(i)
1	M	18	5.1	65	O ₂ dependent ¹	49.1	50.3	53.5	72.6	25.5	36.9
2	M	7	6.2	69	O ₂ dependent	47.5	52.2	54.6	69.6	24.4	35.9
3	M	1	2.2	46	Room air	85.5	36.4	45.7	36.7	44.8	43.5
4	M	6	3.7	47	O ₂ dependent	50.0	46.2	51.2	26.3	31.6	38.6
5	M	14	7.0	69	Room air	36.8	53.1	55.1	59.8	22.7	35.5
6	M	13	9.2	76	Room air	30.4	55.0	56.2	58.4	20.6	34.4
7	M	9	6.3	70	Room air	34.9	52.3	54.7	70.7	24.1	35.9
8	F	7	3.6	56	O ₂ dependent	86.8	46.8	49.7	60.6	191.1	39.0
9	F	26	5.3	64	O ₂ dependent	51.5	51.2	52.3	62.6	133.6	36.7
10	F	12	6.4	64	Room air	51.1	53.0	53.4	54.0	111.4	35.7
11	F	5	4.7	57	Room air	60.3	50.2	51.7	52.1	147.9	37.1
12	M	2	4.0	52	Room air	62.2	47.4	51.9	42.9	30.7	38.1
13	F	4	5.1	58	Room air	56.1	51.0	52.2	51.5	137.9	36.7
14	M	5	7.0	67	Room air	40.4	53.2	55.6	57.2	23.3	35.3
15	M	3	4.1	57	Room air	62.4	47.7	52.1	60.5	30.3	38.1
16	M	5	3.4	56	O ₂ dependent	72.6	44.8	50.5	69.3	33.5	39.6
17	M	1	3.6	53	Room air	72.6	45.9	51.1	52.0	32.8	38.9
18	F	12	3.6	55	O ₂ dependent	81.2	46.8	49.7	57.7	190.5	39.0
Median						53.8	50.3	52.1	58.1	32.2	37.0
interquartile range						47.7 to 72.6	46.7 to 52.3	51.0 to 54.6	52.0 to 62.6	24.4 to 133.6	35.8 to 38.9

M = male; F = female; FAO/WHO/UNU = Food and Agriculture/World Health Organization/United Nation University; Schofield-W = Schofield-Weight; Schofield-WH = Schofield-Weight/Height; HB = Harris Benedict; HB(i) = Harris Benedict-Infant

¹ All of the patients in these studies were full-time oxygen dependent

Table 4. Data relating to the Bland-Altman plot of the differences between mREE and prediction equations

	n	r	Mean of differences (kcal/kg/day)	95% CI of mean differences		95% CI for the bias	
				Lower	Upper	Lower	Upper
mREE, FAO/WHO/UNU	18	-0.8	8.2	-2.2	18.6	-32.7	49.1
mREE, Schofield-Weight	18	-0.9	5.0	-4.6	14.7	-33.1	43.2
mREE, Schofield-Weight/Height	18	-0.2	0.9	-10.6	12.5	-44.4	46.3
mREE, Harris Benedict	18	0.5	-12.5	-40.4	15.5	-122.7	97.7
mREE, Harris Benedict-Infant	18	0.9	19.8	12.2	27.4	-10.2	49.8

mREE = measured resting energy expenditure by indirect calorimetry; FAO/WHO/UNU = Food and Agriculture/World Health Organization/United Nation University

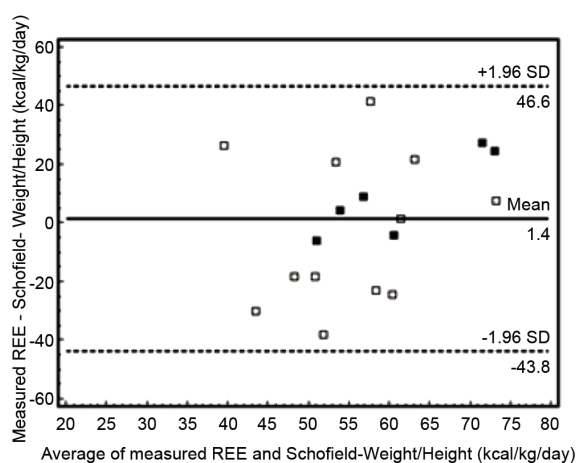


Fig. 1 Bland-Altman plot of the difference between measured REE by indirect calorimetry and prediction equation by Schofield-Weight/Height equation (opaque square: female, transparent square: male).

Discussion

Our study demonstrated that REE in infants and young children with chronic lung diseases, as measured by indirect calorimetry, was approximately 54 kcal/kg/day (interquartile range 48 to 73 kcal/kg/day). This result was similar to that of a previous study⁽⁷⁾ in nine cystic fibrosis infants that reported a mean REE 55.8±6.9 kcal/kg/day, as measured by open-circuit indirect calorimetry. The figures were approximately 10% higher than the healthy control group. Denne⁽⁵⁾ reviewed nine studies done between 1981 and 1997 and concluded that energy expenditure in infants with chronic lung diseases was between 50 and 75 kcal/kg/day. However, most of those studies had small sample size (below 10 subjects) and subject age varied from days to six months. Most other studies⁽¹⁹⁻²¹⁾ were carried out while the subjects were on mechanical ventilators and being parenterally-fed.

Yunis et al⁽²¹⁾ reported REE by indirect calorimetry of 53.8±5.75 kcal/kg/day. In the present study, the infants were parenterally fed with intravenous glucose with amino acids. Chessex et al⁽²⁰⁾ showed that mean REE by indirect calorimetry was 62±5 kcal/kg/day in infants who were on mechanical ventilator and being parenterally fed with a glucose-rich-regimen. Other studies reported the total rather than REE. Yeh et al⁽²²⁾ demonstrated that TEE by opened-circuit indirect calorimetry was 76.0±11.7 kcal/kg/day in BPD infants who still required O₂ therapy (FiO₂ range 0.35 to 0.60), which was higher than the control group (58.5±7.2 kcal/kg/day). Total daily energy expenditure was extrapolated from 6 hour VO₂ and VCO₂ values. de Gamarra et al⁽²³⁾ revealed that the mean of TEE in premature newborns with BPD measured by indirect calorimetry, was 76 kcal/kg/day. de Meer et al⁽²⁴⁾ demonstrated similar TEE of 73 kcal/kg/day in premature newborns with BPD, as compared to 63 kcal/kg/day in the control group by double labeled water technique.

There are few reports in the literatures that suggest an increase in energy expenditure (either resting or total) of around 10 to 25% in infants with chronic lung diseases compared with healthy infants, due to an increased resting oxygen consumption^(5,24,25). These results varied according to measurement techniques and conditions of the patients. In general, the measurement of REE should be performed in a thermoneutral environment with the subject in a resting and postprandial state, at least 12 hours after eating. However, it is impractical for infants and young children to fast for 12 hours, similar to the scenario in our study. Indeed, the primary effect of diet-induced thermogenesis occurs within two hours after feeding in infants; therefore, measurement after two hours of feeding is acceptable, being considered nearer to REE than to TEE⁽¹⁰⁾. Another strength of our study was indirect calorimetry by custom-made airtight canopy

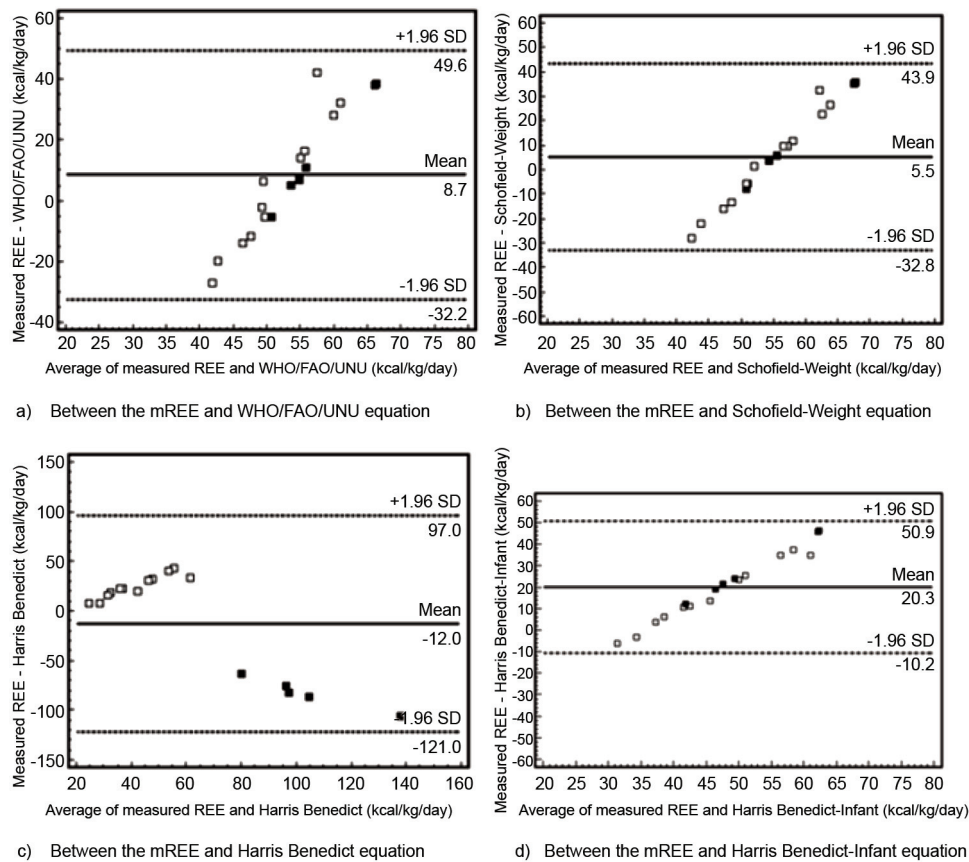


Fig. 2 Bland-Altman plot of the difference between the measured resting energy expenditure (mREE) by indirect calorimetry and prediction equations in kcal/kg/day (opaque square: female, transparent square: male).

that was suitable for infants and young children who were not on mechanical ventilator. The conventional device was designed for adults or infants who were supported with endotracheal tube or able to breathe into the mouthpiece only. More clinically stable chronic lung diseases infants, such as those in our study, have often been neglected in terms of collection of energy expenditure data. This may be partially due to difficulties associated with this traditional measurement technique. Most previous studies were conducted on patients in severe respiratory distress and who were ventilator-dependent. Patients in the present study were in more stable condition, either cared for at home or ready to be discharged from the hospital. Thus, the REE data from our study may be slightly lower than the previously published figures from other studies.

The secondary aim was to assess agreement between the mREE and the pREE. Based on our finding, we propose that Schofield-Weight/Height may be the most reliable prediction equation in infants and

young children with chronic lung diseases. Bott et al⁽¹⁸⁾ suggested that the Harris Benedict equation showed the best agreement by Bland-Altman method between mREE and pREE in BPD children aged 4 to 10 years. This discrepancy may be due to the difference in age range. The Harris Benedict equation was developed from 239 adults (range age 15 to 74 years old) and then extrapolated for use in children; thus, it may not be adequately suitable for infants and young children like those in our study⁽¹⁵⁾. However, Thomson et al⁽⁷⁾ showed that FAO/WHO/UNU, Schofield-Weight, and Schofield-Weight/Height equations underestimated and Harris Benedict overestimated REE in infants with cystic fibrosis by analysis of variance. Kaplan et al⁽²⁶⁾ found that Schofield-Weight/Height was the best equation for patients from birth to 3 years demonstrating a failure to thrive. Similarly, Sentongo et al⁽²⁷⁾ reported the Schofield-Weight/Height equation as being least likely to underestimate REE in children with failure to thrive. It should be noted that the Kaplan et al⁽²⁶⁾ and

Sentongo et al⁽²⁷⁾ studies were conducted on infants and children with gastrointestinal disorders and the comparison was made by paired t-test. It is now generally accepted that the Bland-Altman method is the most appropriate method for assessing agreement between two methods of clinical measurement^(28,29). The factors that can affect REE include age, gender, body size (weight and height), body composition (fat mass (FM) and fat-free mass (FFM)), and the presence of morbidity. The FFM is more metabolically active than FM; therefore, FFM has more influence on REE than does weight. In small children, height is the main predictor of FFM. Sentongo et al⁽²⁷⁾ reported that FFM was a significant factor among the well-known factors (age, weight for age Z-score, and height for age Z-score) in predicting REE. This may explain why the Schofield-Weight/Height equation, using weight and height as primary variables, performed better in predicting REE in infants and young children, despite being derived from the same database as the FAO/WHO/UNU and Schofield-Weight equations. In spite of this, Harris Benedict and Harris Benedict-Infant, having both weight and height in the equations, failed to demonstrate good agreement because the former was derived from an adult population and the latter was developed from 94 infants (aged 2 hours to 7 days), which were aged much older and younger than those in our study⁽¹⁴⁾.

Despite showing the lowest mean of difference by Bland-Altman method (0.94 kcal/kg/day), the 95% confidence interval for the bias of the Schofield-Weight/Height equation was significant (-44.4 to 46.3 kcal/kg/day). As a result, we propose that the best method for assessing energy expenditure in infants with chronic lung diseases is a clinical measurement, such as indirect calorimetry or stable isotopes technique, which may be suitable for REE and TEE in normal living conditions, accordingly. Alternatively, further research is needed to develop a disease and age-specific prediction equation for use in these younger patients.

Conclusion

To ensure optimal nutritional support, REE should be measured by indirect calorimetry in pediatric patients with chronic lung diseases. Based on our finding, the Schofield-Weight/Height equation was the most accurate equation for pREE in this group of patients.

What is already known on this topic?

From the previous study, REE in infants with chronic lung diseases was between 50 and 75 kcal/kg/

day and our finding, REE was also in this range. However, REE should be measured by indirect calorimetry in this group.

What this study adds?

Based on our finding, the Schofield-Weight/Height equation was the most accurate equation for pREE in infants and young children with chronic lung disease who were beyond intensive care setting.

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Potential conflicts of interest

None.

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การศึกษาการใช้พลังงานขณะพักของเด็กโรคปอดเรื้อรัง โดยวิธีการวัดพลังงานทางอ้อม *indirect calorimetry*

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วัตถุประสงค์: เพื่อศึกษาการใช้พลังงานขณะพักของเด็กโรคปอดเรื้อรัง โดยวิธีการวัดพลังงานทางอ้อม *indirect calorimetry* และเพื่อเปรียบเทียบค่าพลังงานขณะพักโดยวิธี *indirect calorimetry* และวิธีคำนวณจากสูตรพลังงาน

วัสดุและวิธีการ: ผู้มีพันธะตรวจประเมินภาวะทางโภชนาการและความรุนแรงของโรคปอดเรื้อรังในผู้ป่วยเด็กอายุน้อยกว่า 2 ปี ที่เป็นโรคปอดเรื้อรัง และวัดการใช้พลังงานขณะพักโดยวิธีการวัดพลังงานทางอ้อม โดยเครื่อง *indirect calorimetry* และคำนวณค่าพลังงานขณะพักด้วยสูตรพลังงานทั้งหมด 5 สูตร คือ *Food and Agriculture/World Health Organization/United Nations University (FAO/WHO/UNU)*, *Schofield-Weight*, *Schofield-Weight/Height*, *Harris Benedict* และ *Harris Benedict-Infant* โดยหาความสอดคล้อง (*agreement*) ด้วยวิธี *Bland-Altman*

ผลการศึกษา: ผู้เข้าร่วมการศึกษาทั้งหมด 18 ราย (อายุเฉลี่ย 6 เดือน) มี 16 ราย ที่มีน้ำหนักน้อยกว่า -2 SD โดยค่าเฉลี่ยของ *weight for age Z-score*, *height for age Z-score* และ *weight for length Z-score* มีค่าเท่ากับ -3.0 , -3.1 และ -1.9 ตามลำดับ ค่าเฉลี่ยของค่าพลังงานขณะพักโดยวิธีการวัดพลังงานทางอ้อมมีค่าเท่ากับ 53.8 กิโลแคลอรีต่อกิโลกรัมต่อวัน (IQR 47.5-72.6 กิโลแคลอรีต่อกิโลกรัมต่อวัน) สูตรพลังงาน *Schofield-Weight/Height* มีค่าเฉลี่ยความแตกต่างของการวัดน้อยที่สุดคือ 0.94 กิโลแคลอรีต่อกิโลกรัมต่อวัน โดยมีค่าความน่าเชื่อถือ 95% ของความต่างที่ -44.4 ถึง 46.3 กิโลแคลอรีต่อกิโลกรัมต่อวัน

สรุป: ค่าการใช้พลังงานขณะพักของเด็กโรคปอดเรื้อรัง ควรได้รับการวัดโดยวิธีการวัดพลังงานทางอ้อม *indirect calorimetry* เพื่อให้พลังงานอาหารที่เหมาะสมในเด็กกลุ่มนี้ และจากผลการศึกษาพบว่า สูตรพลังงาน *Schofield-Weight/Height* เป็นสูตรที่มีค่าใกล้เคียงกับค่าพลังงานที่วัดโดยวิธี *indirect calorimetry* มากที่สุดในผู้ป่วยเด็กโรคปอดเรื้อรัง
