Estimation of Resting Energy Expenditure in Children With Spinal Cord Injuries

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Abstract

Background/Objective: Resting energy expenditure (REE) is the amount of energy needed to maintain energy balance. Prediction equations exist to estimate REE for adults. Recommended dietary allowances (RDA) can be used to estimate energy needs for children but may not be suitable for children with spinal cord injury (SCI). Limited information is available on energy expenditure of children with SCI. Research is needed to determine a method to estimate energy needs for children with SCI.

This research project was designed to determine REE in children with SCI who attended an SCI clinic at a children's hospital, determine variables that are correlated to REE in children with SCI, and determine a regression equation to estimate REE in children with SCI.

Methods: A sample of convenience was obtained from children attending the SCI clinic at Shriners Hospitals for Children–Chicago. The REE was measured after a 4-hour fast using a portable hand-held MedGem device to perform indirect calorimetry. Data including height, weight, age, months since injury, level of injury, gender, race, American Spinal Injury Association (ASIA) Motor Score, ASIA Impairment Score, and body mass index were obtained as covariates.

Results: Regression equations to predict REE were developed for boys and girls. The REE varied significantly from results obtained using both RDA and the Harris-Benedict equation. Height and level of injury were the only variables that correlated with REE in this sample.

Conclusions: Measured REE was lower than the results of prediction equations. A regression equation was developed to estimate REE in children with SCI based on height and level of injury. Further validation studies are needed.

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Key Words: Spinal cord injuries; Child; Metabolism

INTRODUCTION

Energy is required to sustain various functions in the body, including respiration, circulation, digestion, performance of physical work, maintenance, and core body temperature. Resting energy expenditure (REE) is defined as the amount of energy needed to maintain energy balance at rest. To estimate REE for normal-weight ambulatory adults, prediction equations were developed using total daily energy expenditure obtained via the doubly labeled water technique as the outcome variable and factors such as age, gender, weight, height, and level

of physical activity as the covariates (1). Since these energy expenditure equations were estimated based on the physiology of adults, their usefulness in determining energy needs of children is limited.

Recommended dietary allowances (RDAs) are the primary reference standards available to health professionals for determining the adequacy of dietary intake with respect to specific nutrients for individuals of a given gender and age. The RDAs can also be used to estimate energy needs (2). However, use of the RDAs to determine energy needs may not be suitable for children with spinal cord injury (SCI), given their muscle atrophy and limited functional status, as demonstrated by studies in adults with SCI (3–7). Despite a recent study of 27 children with SCI, limited information is available on energy expenditure of children with SCI. The data published by

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Table 1. Demographic Data

Parameter	Boys (n = 31)			Girls (n = 28)		
	Mean $\pm$ SD	Min	Max	Mean $\pm$ SD	Min	Max
Age (y)	14.8 $\pm$ 3.7	4	20	15.7 $\pm$ 3.4	8	21
Weight (kg)	64.4 $\pm$ 25.0	20	119	51.3 $\pm$ 20.2	22	102
Height (cm)	163.6 $\pm$ 17.3	109	185	156.1 $\pm$ 12.6	122	175
Body mass index	24.1 $\pm$ 6.7	15	41	21.8 $\pm$ 6.8	13	40
Level of Injury	13.7 $\pm$ 5.5	4	23	14.5 $\pm$ 6.5	4	23
ASIA Motor Score	54.0 $\pm$ 15.7	1	97	51.2 $\pm$ 12.9	18	84
ASIA Impairment Score	2.0 $\pm$ 1.3	1	5	1.4 $\pm$ 1.1	1	5
Months since injury	64.2 $\pm$ 48.1	2	173	68.0 $\pm$ 56.1	4	190

Liusuwan et al (8) illustrate that the RDAs are inaccurate in estimating caloric requirements for children and adolescents with SCI. Research is needed to determine a method to more accurately estimate energy needs for children with SCI in the clinical setting.

The purpose of this study was to: (a) determine the REE in children with SCI attending an SCI clinic at a children's hospital, (b) determine variables that are correlated to REE in children with SCI, and (c) determine a regression equation to estimate REE in children with SCI based on measures that can be readily determined in a clinical setting.

METHODS

A sample of convenience was obtained from children attending the SCI clinic at Shriners Hospitals for Children–Chicago. Prior to their scheduled appointments, the potential subjects were contacted by phone and the study was briefly explained, including the requirement to fast for 4 hours prior to the testing. On the dates of their scheduled clinic appointments, consent was obtained for the subjects and they were assessed for inclusion and exclusion criteria. Inclusion criteria included willingness to participate, freedom from secondary diagnosis as listed in the exclusion criteria, and ability to complete the measurement successfully. Exclusion criteria included the presence of a pressure sore or a tracheostomy, active urinary tract infections, and active respiratory infections. Impairment was measured using neurological level as defined by the International Standards for the Neurological Classification of Spinal Cord Injury (9). A total of 68 eligible children and adolescents from 4 to 21 years of age and/or their parents or guardians consented to participate, according to the Institutional Review Board of Shriners Hospitals for Children–Chicago.

A MedGem device (HealtheTech, Inc, Golden, CO) was used to measure REE. It is a handheld, portable indirect calorimeter that measures oxygen consumption and determines REE. MedGem has been validated against the “gold standard” Douglas Bag Method to demonstrate accurate measurement of oxygen consumption and REE (10–13). MedGem was studied measuring resting meta-

bolic rate while simultaneously using Delta Trac calorimetry (Sensormedics, Yorba Linda, CA). That study concluded that MedGem accurately measures resting metabolic rate and oxygen consumption in situations in which a traditional metabolic cart would not be practical or cost-effective (14). Research that included 59 children ranging in age from 7 to 13 years also concluded that the MedGem device is a reliable and valid system that is quick and convenient for measuring oxygen consumption and resting metabolic rate in children (15). The MedGem device, by design, measures oxygen consumption for only a 10-minute period; the device then stops the measurement. Therefore, all MedGem testing has a duration of only 10 minutes (16).

Eligible subjects were interviewed regarding 4 hours of fasting prior to their testing and were at rest for 10 to 15 minutes prior to performance of the measurement. Subjects were instructed to sit quietly and breathe regularly while holding the MedGem device with attached face mask to cover their nose and mouth for the duration of the test. For younger subjects and those with tetraplegia who were unable to hold the device independently, caregivers or parents held the device in order to decrease stress and fears of claustrophobia. Subjects were offered a light snack after completion of the test due to the fasting required.

Data on each subject's height, weight, age, neurological level, gender, race, American Spinal Injury Association (ASIA) Motor Score, ASIA Impairment Score, and body mass index as well as the number of months since injury were obtained and used as covariates. Each subject's REE was also compared with results obtained using traditional methods such as the RDA and Harris-Benedict Equation (HBE) to estimate caloric needs in children with SCI. Stepwise regression analysis was used to determine a regression equation to estimate REE in children with SCI.

RESULTS

A total of 68 participants were enrolled in the study. A total of 59 participants met the criteria of completing the study with results (31 boys and 28 girls) and were

Figure 1. Neurological level of spinal cord injury.

included in the study. Table 1 describes the demographic and impairment data for the sample. Nine participants were unable to complete the test; this included 5 participants who showed REE less than 500 Kcal/d and 4 participants who stopped before completing the testing due to feelings of claustrophobia. The MedGem cannot measure calories less than 500 Kcal/d or 72 mL/min of oxygen consumption; therefore, the 5 participants registering this error message on the device were unable to be measured by this device and could not be included in the study (16). The 4 participants with claustrophobia expressed anxiety that they were unable to obtain adequate air and stopped the testing prematurely. The 9 participants unable to complete the testing showed no patterns in age, gender, or level of injury. The participants who met criteria included 31 boys from 4 to 20 years old and 28 girls from 8 to 21 years old.

Height, weight, and level of injury were significantly correlated with REE for both boys ($P < 0.05$) and girls ($P < 0.01$). This correlation could be expected because all 3

of these variables (height, weight, and level of injury) directly affect lean body mass. Lean tissue has been shown by studies in both adult and pediatric SCI to be a strong determinant of REE (8,17–20). In addition, BMI was significantly associated with REE for girls ($P < 0.01$). Height and level of injury were the only independent variables that correlated with REE to predict energy expenditure in this sample. See Figure 1 for neurological level of injury. The regression equations are listed below:

Boys— $931.23 + (11.7 \times \text{height in cm}) + (30.7 \times \text{level of injury})$

Girls— $1036.42 + (12.4 \times \text{height in cm}) + (21.8 \times \text{level of injury})$

Comparisons of the measured REE with results from traditional equations show that both the RDA and HBE overestimate the caloric needs of young individuals with SCI. There was a significant difference between mean measured REE and the mean RDA for both boys and girls ($P < 0.001$). There was also a significant difference between mean measured REE and mean caloric requirements estimated by the HBE for boys and girls ($P < 0.001$). There was no significant relationship between measured REE and estimated caloric needs based on RDA for boys ($P = 0.17$), but there was a significant relationship between measured REE and estimated caloric needs based on the HBE for boys ($r = 0.39$; $P < 0.05$). Refer to Table 2 for mean REE compared with HBE, RDA, and the new equation. Both estimated needs based on RDA and HBE were significantly correlated to measured REE in women ($r = 0.55$ and $r = 0.52$, respectively; $P < 0.01$). There was a strongly significant relationship between measured REE and the HBE as well as measured REE and RDA for women ($P < 0.01$). The correlation between the measured REE and the new equation for men was $r = 0.55$; $P < 0.01$ and for women was $r = 0.65$; $P < 0.01$. See Table 3 for correlations of estimated vs measured REE.

DISCUSSION

Our results demonstrate that the methods currently in use for the estimation of energy expenditure in children are inaccurate. Both the HBE and RDA overestimate the caloric needs in the pediatric SCI population. Adult

Table 2. Mean REE compared with other methods used to estimate caloric needs in children with SCI

Type of equation or measurement	Boys (n = 31)			Girls (n = 28)		
	Mean $\pm$ SD	Min	Max	Mean $\pm$ SD	Min	Max
REE measured	1403 $\pm$ 475	590	2950	1208 $\pm$ 358	632	2240
HBE	1663 $\pm$ 381	858	2474	1378 $\pm$ 214*	1042	1886
RDA	2996 $\pm$ 813*	1737	4928	2162 $\pm$ 761*	1108	4068
New equation	1402 $\pm$ 263	768	1847	1210 $\pm$ 229	710	1608

*Measured REE is significantly different ($P < 0.05$) than RDA in boys and significantly different ($P < 0.05$) than RDA and HBE in girls.

Table 3. Correlation of estimated vs measured energy requirements of participants with SCI

Comparison of equations	Boys (n = 31)		Girls (n = 28)	
	Correlation	P value	Correlation	P value
REE vs HBE	0.385	< 0.05	0.520	< 0.01
REE vs RDA	0.251	= 0.17	0.549	< 0.01
REE vs new equation	0.555	< 0.01	0.647	< 0.01

research demonstrates decreased lower-extremity oxygenation in subjects with paraplegia due to muscle atrophy (20). There is a direct linear relationship between REE in SCI and measures of lean mass regardless of paralysis (18). In addition, loss of fat-free mass correlates with decreases in REE in adults (3,17,19). Despite this published work on energy expenditure in adults, work is only recently beginning in pediatric SCI, and no guidelines exist for the estimation of caloric needs in children with SCI. Practitioners working in this area are left to common sense and trial and error when making their recommendations.

MedGem was a user-friendly and cost-accessible alternative for measurement of energy expenditure that was well tolerated by 87% of the patient population tested. Benefits include that it is small enough to carry to and from a clinic and is simple to use, without the requirements for calibration of a metabolic cart. Deficits include user complaints of odor when using the face mask, feelings of claustrophobia in users, and potential for air leaks. The face mask system was reported by a small portion of our subjects to have a disagreeable odor; however, this was not enough to keep those subjects from completing the test. In addition, 4 of the subjects were unable to complete the test due to a feeling of claustrophobia. Limitations to this study included the potential for air leaks at the face-to-face-mask seal, which may have, in some instances, led to falsely low REE readings. The MedGem device has a built-in air leak detection trigger, but this is not triggered if the air leak is constant. Studies validating the use of the face mask as compared with the nose clip and mouthpiece in children were reviewed, but no validation measure was included in this study (21).

Many facilities and practitioners do not have access to full metabolic cart analysis, and a well-validated equation would allow practitioners working with the youth SCI population to appropriately estimate caloric needs. A well-validated equation would prevent the need for metabolic cart studies to assess the caloric needs of healthy children with SCI.

We are recommending that the regression equation be reorganized as follows to allow for a better flow and simplicity in use:

Boys $(11.7 \times \text{height in cm}) + (30.7 \times \text{level}) - 931.23$
Girls $(12.4 \times \text{height in cm}) + (21.8 \times \text{level}) - 1036.42$

There was a good correlation between the new equation and REE for both boys and girls. We are recommending further study with larger groups to begin validation of these equations.

CONCLUSION

In conclusion, our study provides further evidence that current standards are inappropriate for use in children with SCI. Practitioners working with this population are at a loss for useful guidance when making recommendations for their patient population. In consideration of the current pediatric obesity epidemic and the long-term health implications for not only these children but our society, these simple equations would go far in assisting practitioners to guide children with SCI and their families when making recommendations for dietary intake. Further research needs to be done in an attempt to validate and refine the proposed equations.

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