Athetosis increases resting metabolic rate in adults with cerebral palsy

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ABSTRACT

Objectives To determine whether resting metabolic rate (RMR) is higher or lower in adults with cerebral palsy compared with the RMR of control subjects and to further examine physical characteristics of cerebral palsy that might affect RMR.

Design Twenty-one adults with cerebral palsy (9 women, 12 men) were compared with 50 control subjects (25 men, 25 women) within the same age range (18 through 50 years). The following measurements were made: RMR by indirect calorimetry, anthropometrics, body composition, and habitual physical activity patterns. The study was conducted at the University of Vermont General Clinical Research Center and the Ball State University Human Performance Laboratory.

Statistical analyses Mean values±standard deviations, *t* tests, Pearson product-moment correlation coefficients, analysis of covariance, and stepwise multiple correlation regression analysis were used to examine the relationships among variables of interest.

Results No significant differences were found in body weight, body mass index, fat mass, percentage body fat, and measured RMR between the two groups. The subjects with cerebral palsy were significantly shorter, had less fat-free mass, and expended fewer kilocalories in leisure time activities than the control subjects. After statistical adjustment for differences in fat-free mass, the subjects with cerebral palsy had a 14% ($P<.001$) higher adjusted RMR (1,742 kcal/day) compared with that of the control subjects (1,534 kcal/day). According to stepwise regression analysis, RMR was best predicted in the entire sample by fat-free mass and the presence or absence of athetosis (multiple $R=.83$, $P<.001$). The presence of cerebral palsy alone was not significantly correlated with RMR.

Conclusions The increased energy requirements of adults with cerebral palsy can be partially explained by athetotic movements. In this sample, the presence of athetosis increased RMR by an average of 524 kcal/day. *J Am Diet Assoc. 1995; 95:145-148.*

Adults with cerebral palsy are known to exhibit a broad spectrum of leanness and fatness (1), which suggests that their energy needs may be altered differentially by the disability. The limited research that has been performed on the energy requirements of people with cerebral palsy has been directed at children; thus, practitioners have little understanding of energy needs in the adult population. Early investigators reported energy requirements as high as 6,000 kcal/day in children with severely involved athetoid cerebral palsy. Athetosis is defined as continuous involuntary movement that is slow, wormlike, or writhing and usually involves all four extremities, the neck, face, and trunk (2). Average energy needs for children with spastic cerebral palsy have been estimated at 1,500 kcal/day (3,4). Spastic cerebral palsy involves increased muscle tone, persistent primitive reflexes, and increased deep-tendon reflexes in the involved extremities (2). These early estimates of energy requirements were problematic, however, because accurate methods of measuring energy expenditure were not used, and there was heavy reliance on questionable dietary intake data. More recently, investigators developed prediction formulas to calculate energy requirements in children with cerebral palsy (5). These formulas were not based on direct measures of energy needs and were tested on a sample of institutionalized children, most of whom were tube fed. Bandini et al (6) used the doubly labeled water technique to measure total energy expenditure in a small sample (n=9) of adolescents with cerebral palsy and found it to be significantly lower than total energy expenditure in adolescent control subjects.

To date, no information has been available on energy needs of adults with cerebral palsy, in spite of the fact that the majority of even the most severely involved children with cerebral palsy survive to adulthood (7,8). Currently, clinicians use an assortment of methods to estimate the energy needs of people with cerebral palsy, including the Recommended Dietary Allowances (9), formulas based on estimates of resting metabolic rate (RMR), and clinically derived formulas (5). None of these prevailing approaches is based on direct measurement of energy expenditure in people with cerebral palsy. Thus, it has been unclear whether extremes of leanness and fatness observed in adults with cerebral palsy are caused by a

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Table 1
Subject characteristics (mean±standard deviation)

Characteristic	Subjects with cerebral palsy (n=21: 9 women, 12 men)	Control subjects (n=50: 25 women, 25 men)
Age (y)	28±7	27±6
Height (cm)	162.5±11.0	170.5±9.6*
Weight (kg)	61.4±16.9	67.1±11.2
Body mass index[a]	24.3±8.5	23.0±2.4
Fat mass (kg)	13.6±10.9	10.6±4.1
Fat-free mass (kg)	47.9±10.4	56.6±11.3*
Percentage body fat	19.6±11.2	16.0±6.1
LTA (kcal/day)[b]	330±268	490±265*
RMR (kcal/day)[c]	1,626±524	1,583±250
RMR adjusted for fat-free mass	1,742±210	1,534±208***

[a]Calculated as kg/m^2.
[b]LTA=leisure-time activity.
[c]RMR=resting metabolic rate.
*$P\leq.05$ by independent t test.
***$P\leq.001$ by analysis of covariance.

hypometabolic or hypermetabolic state compared with able-bodied adults or by inadequate or excessive energy intake.

The objectives of this study were to determine whether RMR was higher or lower in adults with cerebral palsy compared with the RMR of healthy control subjects after adjusting for variations in physiologic measurements and to further examine characteristics of cerebral palsy that might affect RMR.

METHODS

Subjects

Twenty-one adults with cerebral palsy (9 women, 12 men) were compared with 50 control subjects (25 women, 25 men) within the same age range (18 through 50 years). Subjects were recruited from people attending a camp for adults with cerebral palsy at Ball State University (n=11) and from volunteer associations serving people with cerebral palsy (n=10). The control subjects were drawn from a larger database of healthy volunteers who have participated in our ongoing studies of energy metabolism. Written informed consent, on forms approved by duly constituted ethics committees, was obtained from each subject before the investigation.

Measurements of Physical Characteristics

Cerebral palsy status A physician conducted a neurodevelopmental examination to determine the extent of cerebral palsy involvement in each of the subjects. Subjects were classified by type of motor impairment (spastic, athetoid, or mixed) and by degree of paralysis (diplegia, hemiplegia, triplegia, or quadriplegia). Because Bandini et al (6) demonstrated that ambulation status was a determinant of total energy expenditure in adolescents with cerebral palsy, the subjects were also classified as ambulatory or nonambulatory.

Resting metabolic rate RMR was measured by indirect calorimetry using a ventilated hood system, as previously described (10). All subjects were familiarized with the hood during a practice session the evening before the actual testing. RMR was measured for 45 minutes in the early morning upon waking, after an overnight fast and abstention from vigorous exercise for 12 hours. Resting energy expenditure was calculated using the Weir equation (11).

Anthropometrics and body composition Height was recorded to the nearest 0.5 cm using a stationary, inflexible measuring tape and head board. For subjects with cerebral palsy who were unable to stand, functional height was recorded. Body weight was measured to the nearest 0.5 kg using a calibrated beam-balance scale. Nonambulatory subjects with cerebral palsy were weighed in a preweighed wheelchair, and the weight of the wheelchair was subtracted from the total.

Skinfold thickness measurements were taken from seven sites (triceps, axilla, subscapular, chest, abdomen, thigh, suprailium) with Lange calipers (Cambridge Scientific Instruments, Cambridge, Mass). Each skinfold value represents the mean of three consecutive measurements taken on the right side of the body. If subjects with cerebral palsy had bilateral involvement, skinfold measurements were taken on the least affected side. The Jackson-Pollock sex-specific equations were used to estimate fat-free mass, fat mass, and percent body fat (12).

Leisure time activity The energy cost of leisure time activities during the previous 12-month period was estimated using the Minnesota Leisure Time Physical Activity Questionnaire (13,14). This questionnaire consists of a structured interview that assesses the frequency and duration of participation in recreational activities during the previous 12-month period. Each activity is assigned an intensity code (eg, walking for pleasure=3.5; cross-country skiing=8.0) that is multiplied by the total estimated minutes in the year spent performing the activity. The cumulative energy cost for leisure-time activity over the previous year was averaged and expressed as kilocalories per day. The questionnaire was adapted for the disabled subjects with cerebral palsy by selecting an intensity code for an activity that most closely resembled the motion performed. For example, propelling a wheelchair was given the same intensity code as rowing, self-transfers and pulling up stairs were given intensity codes equal to weight lifting, and wheelchair basketball was coded the same as noncompetitive basketball. If the volunteer was unable to complete the interview, his or her primary caretaker assisted in completing the task.

Statistics

Mean values±standard deviations are presented for all measures. Differences between subjects with cerebral palsy and control subjects were assessed using independent t tests. The Pearson product-moment correlation coefficient was used to derive the level of association between pairs of variables. Analysis of covariance was used to determine the difference in RMR between the subjects with cerebral palsy and control subjects, adjusting for fat-free mass. Stepwise multiple correlation regression analysis was done to determine the relative contribution of selected independent variables to the variation in the dependent variable (RMR). All statistics were performed using either Clinfo (version 2.1, 1989, BBN Software Products Corp, 1989, Cambridge, Mass) or BMDP (1990, BMDP Statistical Software, Berkeley, Calif) software packages.

RESULTS

Physical Characteristics

The 21 volunteers with cerebral palsy represented a broad range of the disorder. In terms of motor impairment, 10 had spasticity, 6 had athetosis, and none were mixed; 5 had no impairment. In terms of paralysis, 9 had diplegia, 2 had hemiplegia, 1 had triplegia, and 7 had quadriplegia; 2 had no paralysis. Eight of the subjects with cerebral palsy were ambulatory and 13 were nonambulatory. Table 1 compares the physical characteristics of the subjects with cerebral palsy with those of the control subjects. The subjects with cerebral palsy and the control subjects were similar with respect to age, weight, body mass index, fat mass, percentage body fat, and measured RMR. The subjects with cerebral palsy were significantly shorter, had less fat-free mass, and expended fewer kilocalories in leisure-time activities than the control subjects.

Resting Metabolic Rate

Because the groups differed in their absolute amount of fat-free mass (Table 1), the comparison of absolute rates of RMR was biased. Therefore, an analysis of covariance was performed to remove the linear effect of fat-free mass on RMR and to take into account that the correlation between RMR and fat-free mass was not r=1.0 and that the mathematical relationship between the variables had an intercept different from zero. The equality-of-slopes assumption was met in all analyses, which suggests that the effect of the covariate (fat-free mass) was similar between groups. After the adjustment for fat-free mass, the adjusted RMR was different between the two groups (Table 1); that is, subjects with cerebral palsy showed a 14% (P<.001) higher adjusted RMR (1,742 kcal/day) compared with control subjects (1,534 kcal/day).

Bivariate Associations Between Physical Characteristics and Resting Metabolic Rate

Bivariate associations between the dependent variable, RMR, and the independent physical characteristics measured in the study are summarized in Table 2. As expected, fat-free mass was the strongest correlate with RMR (r=.65), followed by sex, height, presence or absence of athetosis, weight, and percentage body fat. Cerebral palsy status, spasticity, and ambulation status were not significantly correlated with RMR.

Multivariate Associations Between Physical Characteristics and Resting Metabolic Rate

Stepwise multiple correlation regression analysis was used to determine the strongest predictors of RMR in the sample. RMR was the dependent variable; the six variables that were significantly correlated with RMR on a bivariate basis (fat-free mass, sex, height, athetosis, weight, and percentage body fat) were entered as independent variables in the analysis. The first variable selected by the model was fat-free mass (r=.65), followed by athetosis (multiple R=.83), generating this equation:

$$RMR=616.2+(72.2\times FFM)+(524.2\times athetosis)$$

$$\text{Multiple } R=0.83,\ R^2=0.68,\ F=72.14,\ P\leq.001$$

where RMR=resting metabolic rate measured in kilocalories per day and FFM=fat-free mass measured in kilograms; athetosis was coded 0=absent and 1=present. Adding sex, weight, height, or percentage body fat to the model did not significantly add to the amount of variation explained in RMR.

DISCUSSION

To our knowledge, this study represents the first attempt to determine whether RMR is higher or lower in adults with cerebral palsy compared with control subjects after adjusting for variations in physical characteristics. Three major findings resulted. First, after adjusting for variations in fat-free mass, we found that adults with cerebral palsy had a higher RMR than age-matched control subjects. Second, without differentiating by type of motor impairment (the presence or absence of athetosis), cerebral palsy status was not an independent predictor of RMR. Third, the presence of athetosis significantly increased RMR. These findings suggest that people with cerebral palsy characterized by athetosis are hypermetabolic in comparison with age-matched control subjects.

Table 2
Bivariate correlation coefficients between resting metabolic rate (RMR) and physiologic variables in 21 subjects with cerebral palsy and 50 control subjects

Physiologic variable	RMR
Age	.02
Sex[a]	−.54***
Height	.49***
Weight	.41***
Body mass index	.16
Fat mass[b]	−.08
Fat-free mass[b]	.65***
Percentage body fat[b]	−.30***
LTA[c]	.18
Cerebral palsy status[d]	.07
Ambulation status[e]	.03
Athetosis[f]	.44***
Spasticity[g]	−.15

[a]Sex coded: 0=male, 1=female.
[b]Estimated from skinfold thicknesses.
[c]LTA=leisure-time activity measured in kilocalories per day.
[d]Cerebral palsy status coded: 0=absent, 1=present.
[e]Ambulation status coded: 0=ambulatory, 1=nonambulatory.
[f]Athetosis coded: 0=absent, 1=present.
[g]Spasticity coded: 0=absent, 1=present.
***$P\leq$.001.

Several physical differences were noted between the subjects with cerebral palsy and the control subjects. The subjects with cerebral palsy were significantly shorter in stature, which indicates that the growth retardation seen in children with cerebral palsy persists with age. This finding is corroborated by our earlier work in which we found that in a sample of 86 adults with cerebral palsy, 40% had heights below the 5th percentile for their age and gender compared with national averages (1).

The subjects with cerebral palsy had a lower amount of fat-free mass in comparison with the control subjects. Fat-free mass was determined from skinfold measurements using a formula (15) developed from people without disabilities because of the lack of an established prediction formula for people with cerebral palsy. Bandini et al (6) found that skinfold measurements were highly correlated with direct measures of body fatness determined by total body water in adolescents with cerebral palsy, thereby providing evidence to support their use as indicators of body composition among people with cerebral palsy. The practical limitations of underwater weighing of people with cerebral palsy excluded its potential for use in ascertaining body composition in this population. Other more easily administered, yet costly, measures of body composition such as dual-energy x-ray absorptiometry were not feasible for this study. Skinfold measurements offered an easily administered, inexpensive alternative.

The subjects with cerebral palsy expended less energy over a 1-day period in leisure-time activities — not a surprising finding given that 62% of the subjects with cerebral palsy were nonambulatory. In fact, the amount of energy expended in leisure-time activities was significantly different (t=2.68, P<.05) for the ambulatory subjects (467 kcal/day) in comparison with the nonambulatory subjects (328 kcal/day). We have previously shown that in elderly subjects the leisure-time activity questionnaire is highly correlated ($r=.83$, $P<.001$) with the energy expended in physical activity as measured by the difference between total energy expenditure (by doubly labeled water) and RMR (by indirect calorimetry) (16).

The subjects with cerebral palsy had a lower amount of fat-free mass in comparison with the control subjects. Because energy needs are a function of the metabolically active cell mass, a person's RMR must be evaluated relative to fat-free mass, not just relative to total body weight. After statistical adjustment for individual differences in fat-free mass, the subjects with cerebral palsy had an RMR that was 14% higher than that of the control subjects. Because cerebral palsy is a condition that presents itself in diverse ways, it was important to further investigate the characteristics of cerebral palsy that may have contributed to this elevation in RMR.

The major finding of this study was that in a multivariate model, cerebral palsy status in and of itself was not a significant predictor of RMR. This finding was masked in our earlier study in which we used a smaller sample and did not qualify the sample by type of cerebral palsy (17). When cerebral palsy status was further distinguished by the presence or absence of athetosis, this characteristic was a significant predictor of RMR. On average, athetosis is present in 16% of people with cerebral palsy (18). We found that after adjusting for variations in fat-free mass, athetosis contributed 524 kcal/day to RMR.

Bandini et al (6) found that both RMR and total energy expenditure as measured by doubly labeled water were lower in nine adolescents with cerebral palsy compared with control subjects. Because of the small sample size, the investigators were not able to categorize the type of cerebral palsy further for the statistical analysis, nor could they adequately compare the relationship between RMR and fat-free mass.

Total energy expenditure consists of three major components: RMR, the thermic effect of feeding, and the thermic effect of physical activity (19). In people without disabilities, RMR accounts for 60% to 75% of total energy expenditure, and the thermic effect of feeding accounts for approximately 10% of total energy expenditure (19). Bandini et al (6) found that ambulation status was associated with total energy expenditure in adolescents with cerebral palsy. However, in our study leisure-time activity and ambulation status were not associated with RMR. RMR, by design, does not include measurement of the thermic effect of physical activity. Nevertheless, the adults with cerebral palsy had a lower estimated thermic effect of physical activity (as measured by the leisure-time activity questionnaire) than the control subjects. Thus, RMR may account for an even greater portion of the total daily energy expenditure of adults with cerebral palsy and be an even greater determinant of total daily energy requirements. Further studies are needed using doubly labeled water to measure total energy expenditure under free-living conditions in adults with cerebral palsy to clarify the relationship between the major components of energy expenditure and total energy expenditure, and to develop well-founded recommendations for total daily energy intake in adults with cerebral palsy.

APPLICATIONS

In the study sample, the presence of athetosis increased RMR by an average of 524 kcal/day. Thus, the resting energy needs of adults with cerebral palsy who have athetosis will be underestimated if traditional methods are used (Recommended Dietary Allowances or formulas based on the resting energy needs of adults without disabilities). We recommend that dietetics practitioners verify the type of motor impairment present in their patients with cerebral palsy. If indirect calorimetry is not available to measure RMR directly, the increased energy cost of athetosis must be taken into account when estimating energy needs to prevent energy imbalance and subsequent weight loss. ■

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