Original Article

Body composition and basal metabolic rate in pre-school children: no sex difference

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ABSTRACT

Background: Previous studies have suggested that sex may be a factor influencing basal metabolic rate (BMR) in adults and school age children. However, few data are available about the effects of sex on BMR in pre-school children. In the present study, we investigated whether sex differences contribute to variations in BMR in pre-school age children.

Methods: Measurements were made on thirty children aged 2-6 years (14 male and 16 female). Measurements were taken of height, age, weight, and total body composition, which was determined using both dual-energy X-ray absorptiometry (DXA) and deuterium dilution. The DXA was also used to determine body composition in different regions of the body. BMR was measured by indirect calorimetry.

Results: We found no significant sex differences with respect to age ($F = 0$, $p = 0.998$), weight ($F = 0.02$, $p = 0.884$), height ($F = 0.33$, $p = 0.570$), and body mass index standard deviation score ($F = 0.51$, $p = 0.480$). In addition, no significant difference was found between boys and girls for total fat free mass (FFM) ($F = 1.30$, $p = 0.265$) and fat mass (FM) ($F = 3.16$, $p = 0.090$) measured by DXA, and total FFM ($F = 0.79$, $p = 0.380$) and FM ($F = 3.38$, $p = 0.080$) obtained by deuterium dilution. There was no significant difference between pre-school boys and girls for BMR ($F = 0.16$, $p = 0.690$). In a multiple regression analysis, only log weight was significantly associated to BMR. The explain variation was 75.3%.

Conclusion: In conclusions we found no significant differences in body composition between pre-school boys and girls and no sex effect on BMR in this age group.

Introduction

Basal metabolic rates (BMR), the largest

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component of energy expenditure accounts for 60-80% of the observed total energy expenditure [1-3]. Therefore, it can play a considerable role in the regulation of energy balance. Many researchers [3-9] have studied sex differences in adult and adolescent BMR. However, our knowledge regarding the effect of sex on BMR in pre-school children is limited. It is

well-established that many other factors can influence BMR including age [3, 10], genetics [11, 12], hormone levels [13], ethnicity [14, 15], and body composition [9, 16]. Among these factors, the body composition seems to be the main determinant of BMR across all age ranges. Previous studies have suggested that males have higher BMR than females independent of sex differences in body composition [7, 10]. However, some studies suggest that once the effects of both fat-free mass (FFM) and fat mass (FM) are accounted for the impact of sex is not significant [9]. In contrast to the large amount of data on sex effects in adults, little is known of the effect of sex in pre-school children. This could be due to the difficulties of assessing BMR in children [17]. Because body composition or fat distribution changes with age, and sex differences become most obvious after puberty, the effect of sex on BMR in young children has been an issue of interest.

Most previous pediatric studies of the impact of sex on BMR have been performed on older children, but there are few studies on children aged 2-6 years [1, 18]. Measuring BMR in children is made difficult by the propensity of children to make spontaneous physical movements during measurement [17, 19] and problems of fasting young children prior to measurement. On the basis of the above considerations, we decided to study the influence of sex on BMR in pre-school children attempting to control for these factors.

Methods
Subjects
A total of 30 healthy Caucasian children (14 boys and 16 girls) participated in the study. This study was part of the Rowett Assessment of Childhood Appetite and metabolism, which was approved by the Grampian Research Ethics Committee. Subjects aged 2-6 were recruited from Aberdeen, NE Scotland, UK. Before participation, written informed consent was provided for all subjects from their parents or guardians and verbal consent was obtained from the child. All participants were healthy, and not taking any medication that affected body composition or BMR. All of the measurements were carried out at the Human Nutrition Unit, Rowett Research Institute, Scotland, UK.

Body composition
Total and regional body compositions were measured by using dual-energy X-ray absorptiometry (DXA), a valid method for assessing body composition in children. The principles and operating procedures of DXA have been described elsewhere [20-23]. All DXA assessments were performed exclusively on one instrument (Norland XR-26, Mark II high-speed pencil beam scanner equipped with dynamic filtration, with version 2.5.2 of the Norland software; Norland Corporation, Fort Atkinson, WI). Before each measurement, the DXA was calibrated using the procedures provided by the manufacturer. The coefficients of variation (CV) for repeated measurements by this machine in a total-body scan have been reported previously [9]. The CVs of variation for the assessment of mineral determination and FM by DXA were also reported as 1.4% and 2.6% for this machine, respectively [21, 22]. Children were scanned in light clothing while lying flat on their backs with arms by the side. Total and regional body FFM and FM were calculated.

Total body water (TBW) was determined by the isotope dilution technique, using deuterium in the form of labeled water (D_2O). An oral dose of deuterium oxide (99.9%) equivalent to 0.5 g/kg body weight was given to each subject. Urine samples were collected at baseline and 2, 4, and 6 hours after dosing. Samples were frozen until analysis at the stable isotope laboratory of the Rowett Research Institute. Deuterium enrichment of urine samples was determined by gas isotope-ratio mass spectrometry as described previously [24]. Each sample was analyzed in duplicate and the mean value was used for analysis. Deuterium dilution space was calculated as described elsewhere [25]. FFM was calculated from TBW using age and sex specific constants for children [26].

Height and weight
Height was measured to the nearest 0.1 cm using a standard stadiometer (Holtain Ltd., Crymych, Dyfed, Wales). The weight of the subjects, who were wearing light clothes, was measured to the nearest 50 g with a high precision electronic scale (OHAUS Corporation, Pine Brook, USA, Model: CD11). Body mass index (BMI) was calculated as weight (kg)/height^2 (m). However, BMI was expressed as a standard deviation score (SDS) normalized for age and sex, based on UK 1990 population reference data [27, 28].

BMR
Basal energy expenditure was measured in

ambient temperature of 22-24 °C by an open-circuit indirect calorimeter (Deltatrac II, MBM-200; Datex, Instrumentarium Corporation, Helsinki, Finland). Calibrations of the gas analyzers were performed immediately before the measurements, against standard mixed reference gases. The CV of within-children variations for measured BMR on 3 consecutive days by using the same protocol was 6.8 [5]. On the day of the experiments, subjects arrived at the Rowett Research Institute in the early morning following an overnight fast and measurements were performed for around 20 minutes. Subjects were instructed to lie as still as possible and remain awake and they were allowed to watch their favorite videos to minimize fidgeting. Children were observed continuously and their fidgeting and activities were recorded. Data were carefully reviewed after each measurement and the first 10 minutes of data were omitted and BMR during the remaining still minutes (no moving, laughing, speaking or yawning) was calculated. Energy expenditure was measured from VO_2 and VCO_2 using the Weir equation [29].

Statistics

All statistical analyses were performed using MINITAB software version 14.12 (Minitab Inc, State College, PA). Mean, SD, and frequencies were presented. This included weight, abdomen FM, arms FM and total FM measured by DXA and deuterium. One-way analysis of variance was used to compare the means. For all results, $p < 0.050$ were considered significant

Results

Descriptive characteristics of the children

Subject characteristics are presented in table 1. No significant sex differences were found with respect to age ($F_{1,28} = 0$, $p = 0.998$), weight ($F_{1,28} = 0.02$, $p = 0.884$), height ($F_{1,28} = 0.33$, $p = 0.570$), BMI SDS ($F_{1,28} = 0.51$, $p = 0.480$), and BMR ($F_{1,28} = 0.16$, $p = 0.690$). No significant difference was found between boys and girls for total FFM ($F_{1,28} = 1.30$, $p = 0.265$) and FM ($F_{1,28} = 3.16$, $p = 0.090$) measured by DXA, and total FFM ($F_{1,28} = 0.79$, $p = 0.380$) and FM ($F_{1,28} = 3.38$, $p = 0.080$) obtained with deuterium dilution after correction for age effects.

Associations between BMR and other variables

Figure 1 depicts the association between BMR and age ($r^2 = 15.8\%$; $p < 0.050$), body weight ($r^2 = 75.3\%$; $p < 0.001$), height ($r^2 = 46.7\%$; $p < 0.001$), BMI SDS ($r^2 = 56.5\%$; $p < 0.001$), total FFM measured by DXA ($r^2 = 70.8\%$; $p < 0.001$), and total FM measured by DXA ($r^2 = 51.4\%$; $p < 0.001$). There was also a significant association of BMR with FFM ($r^2 = 70.9\%$; $p < 0.001$) and FM ($r^2 = 45.3\%$; $p < 0.001$) measured by deuterium dilution. Weight and FFM measured by deuterium dilution (Figure 2) had the strongest relationships with BMR. BMR variations explained by FFM and FM were not the identical because of differences in the methods for body composition measurement. FFM and FM measured by DXA together explained 75.5% of the variation in BMR, whereas the cumulative variance in BMR explained by FFM and FM measured by deuterium dilution was 75%. The best-fit least-squares regressions for explaining BMR from FFM and FM measured by DXA and deuterium dilution were as follows:

DXA: BMR (kJ/d) = 382 + 109 FFM + 56 FM

Deuterium: BMR (kJ/d) = 364 + 108 FFM + 60.2 FM

Table 1. Physical characteristics of pre-school children involved in the study

Characteristics	Boys			Girls			Total		
	Mean ± SD	Median	Range	Mean ± SD	Median	Range	Mean ± SD	Median	Range
Age (y)	4.83 ± 1.32	5	2-6	4.83 ± 1.17	5	2-6	4.83 ± 1.22	5	2-6
Weight (kg)	19.4 ± 4.4	18.1	14.4-28.7	19.7 ± 6.4	17.8	10.8-32	19.6 ± 5.43	18.5	10.8-30
Height (m)	1.1 ± 0.09	1.1	0.97-1.28	1.08 ± 0.11	1.08	0.85-1.24	1.09 ± 0.10	1.1	0.85-1.28
BMI SDS	-0.12 ± 1.06	-0.5	-1.43-2.68	0.23 ± 1.57	0.17	-3.5-2.9	0.07 ± 1.34	-0.02	-3.5-2.9
FM (DXA) (kg)	6.22 ± 2.58	4.32	1.12-8.91	7.63 ± 3.85	5.4	2.13-13.2	6.97 ± 3.34	4.53	3.84-13.2
FFM (DXA) (kg)	12.7 ± 2.58	14	10.4-2.0	11.6 ± 2.98	14.2	7.30-21.1	12.1 ± 2.8	14.1	11.7-21.1
FM (Due) (kg)	4.88 ± 1.74	4.32	1.33-8.61	5.98 ± 3.40	5.36	1.92-13.1	5.45 ± 2.77	4.37	3.74-13.1
FFM (Due) (kg)	14.67 ± 2.77	13.8	11.3-19.8	13.7 ± 3.9	14.2	8.7-20.8	14.1 ± 2.92	14.0	11.9-20.1
BMR (kJ)	2117 ± 476	2117	1481-3097	2244 ± 608	2244	1447-3378	3177 ± 780	2234	1815-3378

Deut = Deuterium, for comparison between boys and girls, FFM and FM have been corrected for age effect, BMR = Basal metabolic rate, FFM = Fat-free mass, FM = Free mass, BMI = Body mass index, SD= Standard deviation, DXA = Dual-energy X-ray absorptiometry, BMI = Body mass index, SDS = Standard deviation score
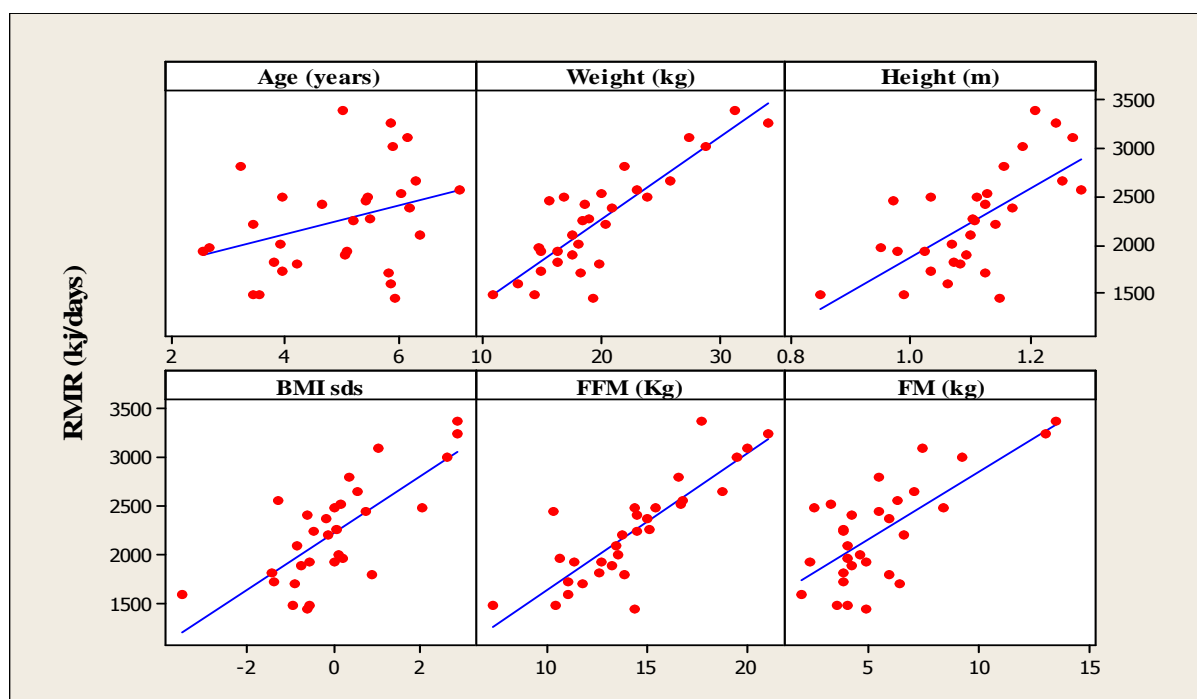
Figure 1. Scatterplot of association between basal metabolic rate with age (r² = 15.8%; p < 0.001), weight (r² = 75.3%; p < 0.001), height (r² = 60%; p < 0.001), body mass index standard deviation score (r² = 56.5%; p < 0.001), total fat free mass (FM) (r² = 70.8%; p < 0.001), and total FM measured by dual-energy X-ray absorptiometry (r² = 51.4%; p < 0.001) in pre-school children (n = 30)
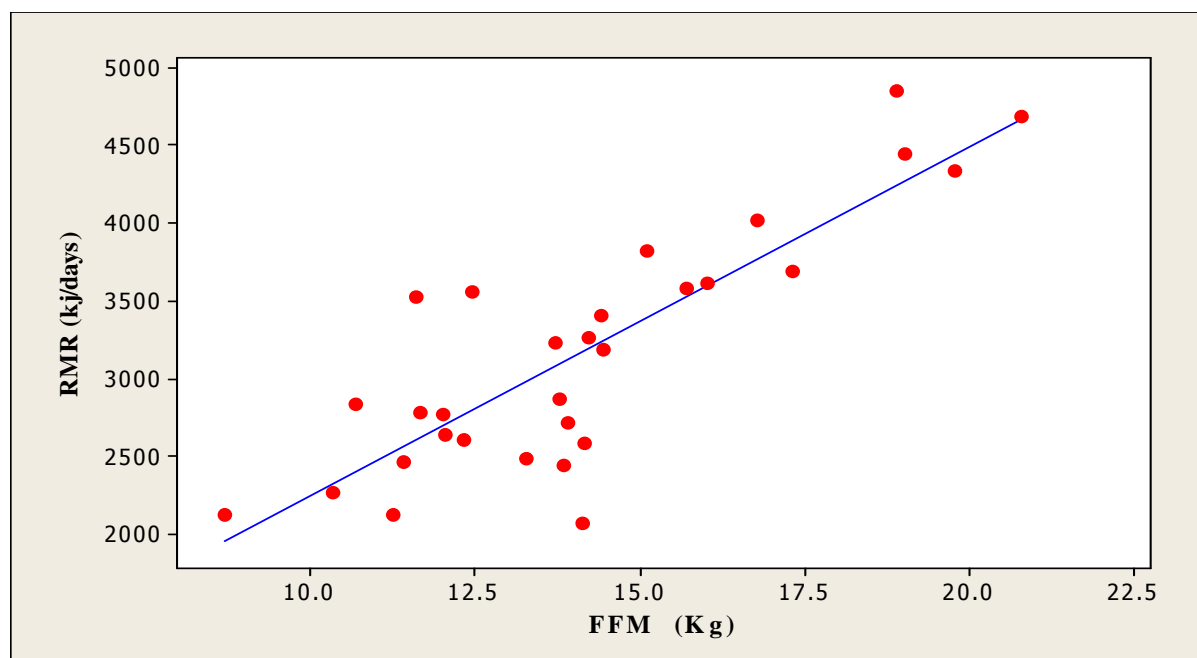
Figure 2. Scatterplot of association between basal metabolic rate and total fat-free mass (r² = 70.9%; p < 0.001) measured by deuterium in pre-school children (n = 30)

No significant differences were found between boys and girls for BMR after normalizing for FFM and FM measured by DXA ($F_{1,28}$ = 0.09, p = 0.765) or deuterium dilution ($F_{1,28}$ = 0.40; p = 0.531). In a multiple regression analysis, including all the variables, only body weight was statistically significant, explaining 75.3% of the variation in BMR. After removing the effects of this variable, no association was found between BMR and any of the other measured parameters.

Discussion
The primary aim of this study was to explore

the influence of sex on BMR in pre-school children. When analysis of covariance has been used to control for FFM or the combination of FFM and FM, a sex difference in BMR has been reported in several previous studies in adults [4, 7, 8] and children [1, 30], although in some studies the effect of sex disappeared after correction for FFM and FM [9]. In one previous study, when BMR of pre-pubertal boys and girls were adjusted for their FFM and age, boys had higher BMR than girls [31]. In contrast, our study indicated no sex effect in children, which is consistent with other studies of children prior to puberty [32, 33].

Few studies have investigated associations of body composition measured by DXA with basal energy expenditure in children. The results of this study show that FFM and FM are the dominant factors influencing variation in BMR. This result is consistent with previous reports for adults [9, 34] and children [1, 2, 14, 35]. All of these studies were performed on older children except one, conducted in children aged 3.9-7.8 [1]. These previous studies have reported conflicting data regarding the contribution of FM to BMR. There may be an independent role for FM in variability of BMR [1, 2, 9, 14, 34], or alternatively there may be no influence of FM [12, 36]. In this study, the contribution of FM measured by either DXA or deuterium dilution explained a smaller fraction of the variability of BMR compared with FFM, and the derived multiple regression analysis indicated that each kilogram of FFM explained around 2 times more of the variation in BMR than each kilogram of FM in children. This ratio is higher than that reported in adults [9]. There are several possible explanations for this discrepancy between the results of different studies, which include biological variation in FFM and FM, techniques for assessing BMR and body composition and age group of population. In addition, adipocytes are not merely fat-storing cells and their secretions such as hormones and other bioactive substances may contribute to the variation of BMR [6]. Although FFM is the main determinant of BMR, changes in BMR per kilogram of FFM were not constant over the whole range of FFM in adult [2, 20, 37]. The variable composition of FFM may explain this phenomenon. FFM is a heterogeneous compartment of body mass with organs and tissues differing widely in masses and heat-producing components [38]. Therefore, the variation in mass and metabolic activity of organs and tissues can be a potential explanation for the variability in BMR within and between individuals and it can remain as an open field for further investigation [39, 40].

The current understanding regarding the contribution of regional body composition and organs to BMR is mainly based on adult studies and animal experiments. Future technological advances should aim at using non-invasive methods for measuring tissue/organ-specific metabolic rates directly in different age groups along with applying advanced statistical methods, in order to model the contribution of different organs to the total metabolism [41].

Conclusion

We found that there is no effect of sex on the variation of BMR, before or after adjustment for FFM and FM. The results of this study show that FFM was the main contributors to the variation of BMR, while FM has a small but independent effect on BMR variability in this age group.

Conflict of interest

None of authors have conflict of interest.

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