©Human Biology Review
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Human Biology Review (ISSN 2277 4424) 5 (2) 2016
Original scientific paper (Thakur and Gautam pp. 146-160)
Revised and Accepted on February 6, 2016

Differential metabolic rates among the school going boys of a Central Indian Town (Sagar)

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Citation: Thakur R and Gautam RK. 2016. Differential metabolic rates among the school going boys of a Central Indian Town (Sagar). Human Biology Review, 5 (2), 146 -160.

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A BS T R A C T

The prime objective of the present study was to estimate the basal metabolic rate (BMR) and resting metabolic rate (RMR) among school going boys of 5-18 year of age. The subjects were recruited from government schools of Sagar town of Madhya Pradesh state of Indian Union. Height and weight of the boys were measured using standard anthropometric techniques. Body mass index (BMI) and metabolic rates (BMR/RMR) were computed for each individual. It was found that mean of BMI varies from 13.8±1.6 Kg m-^{2} among boys of 8 year of age to 19.0±1.9 Kg m-^{2} among boys of 17 year of age. Similarly, mean of Basal metabolic rate (BMR) varies from 1219.0±106.9 K cal/day among boys aged 5 year of age to 2296.3±255.9 K cal/day among 17 year of age. Pre pubertal and pubertal boys have significant difference in their basal metabolic rates as well as stunted, underweight and undernourished boys have significant low BMR. The linear bivariate regression analysis shows that the BMR is dependent on BMI, weight and height. The RMR have highest regression coefficient (r^2=0.935) on BMR, followed by Height (r^2=0.664), weight (r^2=0.631) and body mass index (r^2=0.368). The similar trends can be seen for RMR also. The BMR is highly dependent on RMR followed by height, weight and BMI.

Key words: *Stature, stunted, underweight, overweight, undernourished, body mass, total energy expenditure (TEE), resting energy expenditure (REE), regression.*

INTRODUCTION

Human body is like an open system, for its functioning it requires energy which is obtained from food. The excess of energy obtained is stored in the form of adipose tissues. The energy requirement of each individual is different based on his body dimension, age and gender. It is known as basal metabolic rate (BMR). Further, "Basal metabolism comprises a series of functions that are essential for life, such as cell function and replacement; the synthesis, secretion and metabolism of enzymes and hormones to transport proteins and other substances and molecules; the maintenance of body temperature; uninterrupted work of cardiac and respiratory muscles; and for the function of brain, nervous system, kidneys, liver, intestine, sex organs, muscles and skin. The amount of energy used for basal metabolism in a period of time is called the basal metabolic rate (BMR). Depending on age and lifestyle, BMR represents 45 to 70 percent of daily total energy expenditure (TEE), and it is determined mainly by the individual's age, gender, body size and body composition" (FAO/WHO/UNU 1985, 2004).

"Energy requirement is the amount of food energy needed to balance energy expenditure in order to maintain body mass, body composition and level of physical activity consistent with long-term good health. This includes the energy needed for the optimal growth and development of children, for the deposition of tissues during pregnancy, and for the secretion of milk during lactation, consistent with the good health of both mother and child" (FAO/WHO/UNO, 1985, 2004; IoM, 2005; SCF 1993).

"The average requirement (AR) for energy can be established by two approaches: measurements of energy intake or expenditure of healthy reference populations. Because the day-to-day variation in energy intake is considerably larger than the day-to-day variation in total energy expenditure (TEE) in a steady state of body mass, measurements or estimates of TEE were chosen by experts from FAO/WHO/UNU (1985, 2004) and the US Institute of Medicine (IoM, 2005) as the criterion on which to base the average requirement for energy".

Resting energy expenditure (REE) is the energy expended when the body is at rest. In many studies, for practical reasons since conditions for measuring BEE are more stringent, REE instead of BEE is measured. Changes in REE are used to measure the expenditure of many processes such as thermoregulation, eating and excess post-exercise oxygen consumption. Practically, REE is measured in conditions less stringent than the ones that prevail for measurement of BEE, so that REE is usually slightly higher than BEE (up to 10 %). In this Opinion, REE is used as a proxy for BEE, as most studies measure REE.

The early work of Harris and Benedict (1919) showed that the BMR could be derived using body surface area (computed from height and weight), age and sex. The requirement of energy is compensated by the amount of food taken. This includes the energy needed for the optimal growth and development of children.

The body mass index (BMI) is accepted as one of the best indicators of the nutritional status. It is based on the measurement of height and body weight. Further, Body weight increases due to growth in the fat or water content of the body. It is compound mass of muscles, fat, bones and internal organs. Weighing is considered as the main anthropometric measurement to evaluate physical growth and nutritional status of an individual, similarly height is the largest composite measurement, which is largely dependent on the heredity and to a lesser extent on environment (Gautam et al, 2006, 2014, 2015).

The present study leads to postulate age wise average energy requirement of the target population, which was not reported earlier. This study would be helpful for manage the diet.

BMR and RMR estimated to know how much energy requirement for total energy expenditure (maintain body mass, body composition and level of physical activity and normal growth). Earlier BMR and RMR were not estimated for growing boys for particular region. The objective of the present study was to estimate the basal metabolic rate (BMR) and resting metabolic rate (RMR) as per their level of nutrition among boys of 5-18 year of age of a central Indian Town-Sagar. This study would also be helpful to rid off from the problem of undernutirion, stunting and wasting.

MATERIAL AND METHODS

The sample for the present study was collected from ten government schools of the city of Sagar of Madhya Pradesh State of Indian Union. It is a district and commissioner headquarter, the district is spread between 23^0 10' and 24^0 27' north latitude and between 78^0 4' and 79^0 21' east longitude, the district has a truly central location in the country. The tropic of cancer passes through the southern part of the district. The sample consisted of 300 boys, aged 5–18 years belonging to the similar socio-economic status and family background i.e. lower middle class families. Purposive sampling method was used for the selection of the school and the priorities were given to schools which had good strength of boys aged 5–18 years whereas random sampling method was adopted for sample selection. The anthropometric measurements were taken from September to November 2013.

Age was ascertained in completed years of each subject through school admission records. If the subject was 5 year and 6 month old, it was rounded to 5 year, at the same time; the

subjects of 5 year 7 month old were rounded to the age group of 6 years. Height and weight were taken on each child following the standard procedure as described by Gibson (1990). Before fieldwork we calculated TEM and standardization of instruments were done. The TEM was obtained by carrying out a number of measurements on the subject. The following equation is used to find out TEM:

$$\text{TEM} = \frac{\sqrt{\sum D^2}}{2n}$$; Where D is the difference between measurement, and N is the number of individuals.

The measurements were taken with all possible caution maintaining uniformity and accuracy in the techniques, after undergoing extensive training. Portable digital weighing scale and Anthropometer rod were used to measure the various anthropometric measurements. A semi-structured schedule was used to collect the information about socio-economic status and family background. A detailed description of the study is available elsewhere (Thakur and Gautam 2014 and 2015). After collecting data, three conventional anthropometric indicators of childhood undernutrition were used: low height-for-age (stunting), low weight-for-age (underweight) and low BMI-for- age (undernourished or thinness) following the calculation procedure provided by Thakur and Gautam (2014, 2015a & 2015b).

Estimation of BMR and RMR

For estimation of BMR, equation given by Harris and Benedict (1919) and for RMR, equation given by Mifflin et al. (1990) was used. The formula estimates how many calories are burned within 24 hours while doing nothing. This is the amount of energy required to keep heart beating, lungs breathing and maintain your body temperature. It utilizes height, weight, age, and gender in its calculation (Harris & Benedict 1919, 1928; Roza & Shizgal, 1984). The formula of estimating Resting Metabolic Rate (RMR) to assess the calories needed by individuals is based on height, weight, age and gender (Mifflin et al., 1990).

RESULTS

The age wise descriptive statistics of height, weight, BMI, BMR and RMR is presented in Table 1. It is evident that there is progressive increment in these variables as per growing age. The average height was 103.4±6.7cm to 166.1± 5.8cm among boys of 5 and 18 years of age respectively. Similarly the mean weight was 15.28±2.11 kg to 52.03±6.38 kg among boys of 5 and 18 years of age. The similar trend can be seen for BMI, BMR and RMR also with an exception in case of BMI for boys aged 8 years of age. The mean BMR was 1219.0±106.9kcal which increased to 2296.3±255.9 kcal among boys of 5 and 17 years of age and the mean RMR was 779.2±61.4 kcal to 1456.1±139.0 kcal among boys of 5 and 17

years of age. Age wise mean basal metabolic rate and resting metabolic rate presented in Figure 1

Table 1. Age wise mean and standard deviation of height, weight, Body Mass Index (BMI), Basal metabolic Rate (BMR) and Resting Metabolic Rate (RMR).

Age	N	Height	Weight	BMI	BMR	RMR
5	20	103.4±6.7	15.28±2.11	14.2±0.8	1219.0±106.9	779.2±61.4
6	22	108.4±6.6	16.55±2.00	14.1±1.0	1283.6±107.9	818.1±58.9
7	23	112.9±7.3	18.28±2.76	14.3±1.0	1360.5±123.3	858.3±71.6
8	23	118.7± 7.8	19.54±3.14	13.8±1.6	1399.7±138.5	902.6±74.8
9	23	122.7± 9.4	21.90±5.02	14.4±1.8	1503.5±192.9	946.0±104.3
10	23	129.6± 5	24.77±3.52	14.7±1.4	1580.8±173.1	1012.8±62.7
11	22	134.9± 6.3	27.42±4.41	15.0±1.4	1687.8±171.4	1067.5±81.0
12	22	141.5±11	30.72±7.36	15.1±1.8	1808.4±250.5	1136.5±140.5
13	20	145.2±5.3	33.76±5.71	15.9±1.9	1877.7±213.0	1185.2±85.0
14	22	151.0± 8.9	37.34±7.26	16.2±1.7	1950.5±262.4	1252.2±124.0
15	20	156.3± 8	40.00±6.93	16.3±1.8	2052.4±242.9	1306.9±114.6
16	20	161.2± 7.3	46.28±5.69	17.8±1.2	2203.8±221.9	1395.4±98.0
17	20	164.0± 11	51.12±7.84	19.0±1.9	2296.3±255.9	1456.1±139.0
18	20	166.1± 5.8	52.03±6.38	18.8±1.9	2294.4±208.2	1473.3±89.2

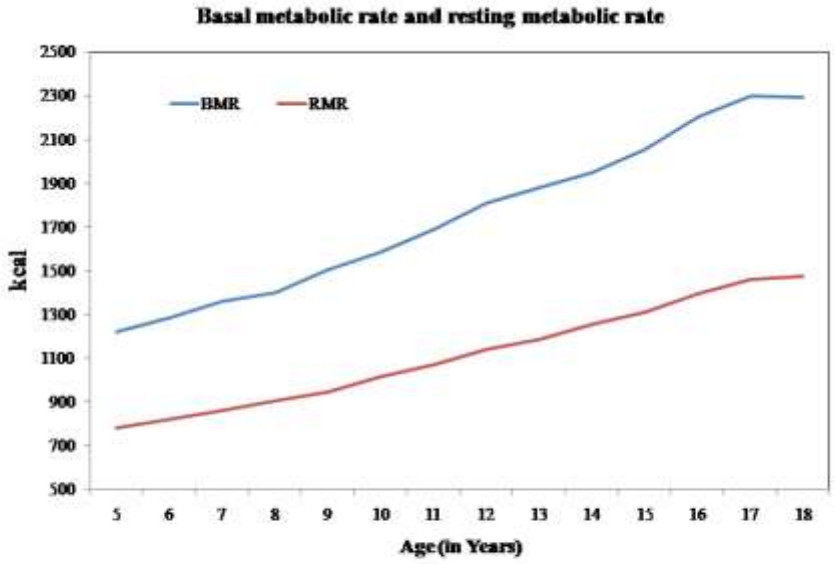

Figure 1. Age wise basal metabolic rate and resting metabolic rate of school going boys (5-18 years)

Table 2 Average BMR as per nutritional status among pre and post pubertal school going boys.

Nutritional Status	Mean BMR with standard deviation			
	Pre puberty	F-value	Pubertal	F-value
Under Weight	1104.25 ±102.12		1635.14 ±167.33	
Normal Weight	1293.78±152.43	16.5	1913.99±287.49	15.5
Over Weight	1629.4±300.80		2340.20±238.92	
Stunted	1140.91±104.86		1655.06±185.17	
Normal Height	1296.37±161.27	9.9	1927.65±290.26	7.1
Tall statured	1416.7		2228.8±187.10	
Undernourished	1174.5±122.99		1749.86±278.97	
Normal	1291.63±160.60	3.4*	1909.15±292.50	6.7
Obese	1582.8		2217.73±108.07	

F-value are significant at 1% level ($p<0.001$) except asterisk marked value which is significant at 5% level ($p<0.05$).

To understand the variation of basal metabolic rate among normal and malnourished children they are divided into three groups: Underweight, Normal weight and Overweight; on the basis of their body mass viz. pre-pubertal and post-pubertal, than again on the basis of nutritional status. Table 2 display the differential BMR among the normal and malnourished subjects. It is apparent that the underweight, stunted and undernourished boys have significant low BMR as compared to normal, overweight and tall boys. For further elucidation error bar diagramme constructed (Figure 2, 3 and 4). It is evident that the pre-pubertal boys have significant low level of BMR as compared to pubertal boys (underweight, normal weight) (Figure 2). To understand the role of stature the subjects were divided into stunted, normal height and tall statured. As apparent from Figure 3, the stunted boys have comparatively low BMR as compared to normal and tall boys in both the group; further the pre pubertal boys have significant low level of BMR than the pubertal boys.

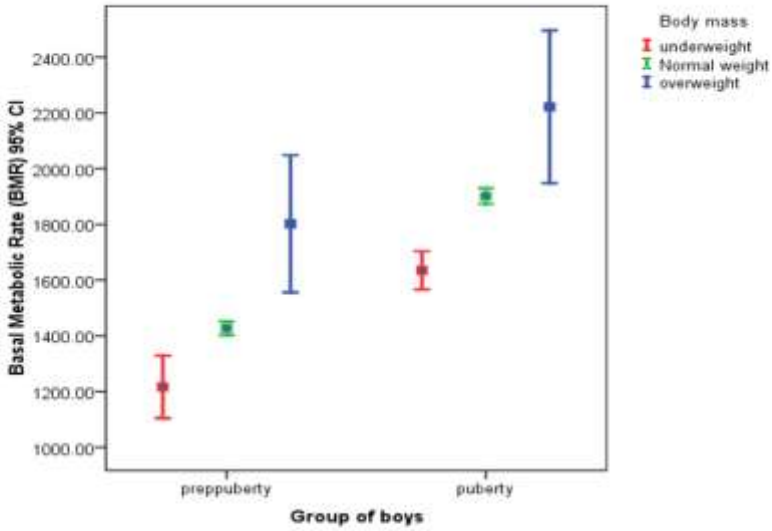

Figure 2. Error bar diagramme showing 95% confidence intervals of mean BMR among prepubertal and pubertal boys as well as comparison of means between three different categories of body mass.

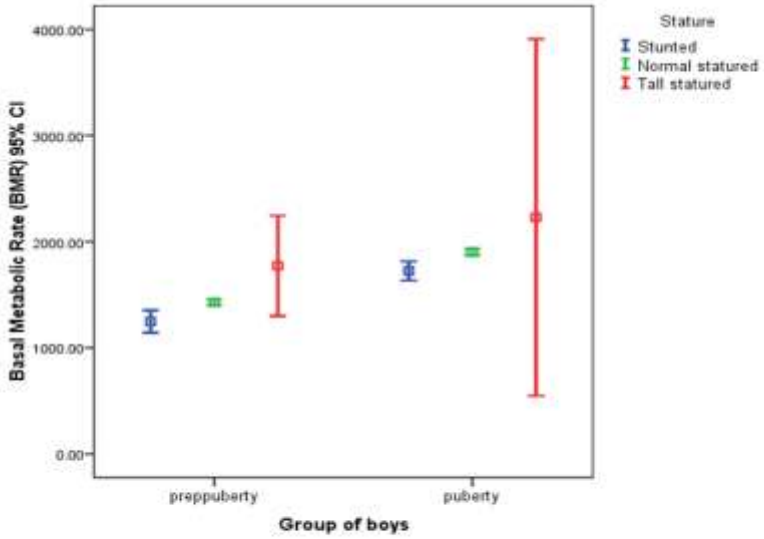

Figure 3. Error bar diagramme showing 95% confidence intervals of mean BMR among prepubertal and pubertal boys as well as comparison of means between three different categories of stature.

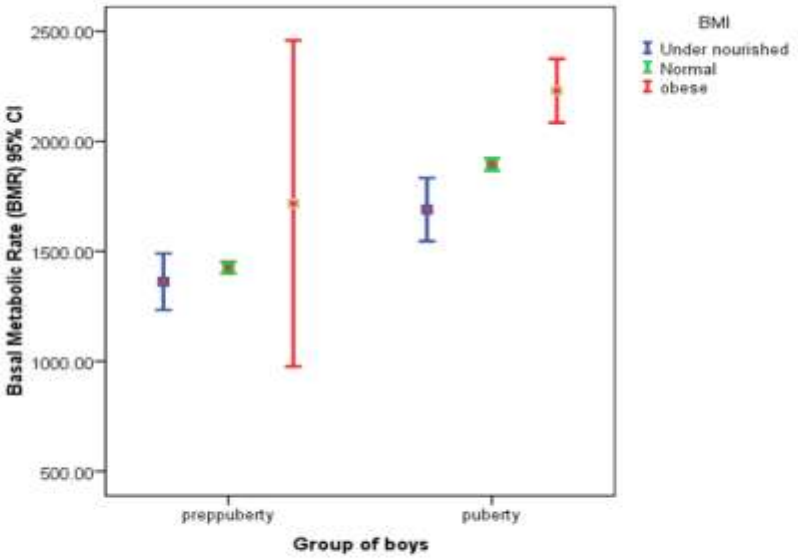

Figure 4. Error bar diagramme showing 95% confidence intervals of mean BMR among prepubertal and pubertal boys as well as comparison of means between three different categories of BMI (body mass index).

BMI is a composite index and widely used for assessment of level of nutrition. On the basis of Z score of BMI, the boys were categorized into three groups viz. undernourished (-2SD), normal (-2SD to 2SD) and obese (>3SD). It is apparent from error bar diagramme (Figure 4) that in pre pubertal group the difference of metabolic rate is insignificant; but at same time there is clear-cut significant difference among pubertal group. The pubertal undernourished boys were having significantly low BMR than normal and obese boys (Figure 4).

Table 3 Regression coefficient and F-statistics of metabolic rates (BMR and RMR) and body dimension.

S.N.	Independent Variables	Coefficients of regression					F-statistics	
		R	R^2	B	SE	*t* Value	F Change	P Value
	Dependent variable BMR							
1.	Height	0.815	0.664	15.142	0.624	24.25	588.21	0.001
2.	Weight	0.794	0.631	24.463	0.794	22.57	509.55	0.001
3.	BMI	0.606	0.368	109.198	8.298	13.16	173.19	0.001
4.	RMR	0.967	0.935	1.593	0.024	65.23	4245.43	0.001
	Dependent variable RMR							
1.	Height	0.863	0.745	9.736	0.330	29.50	870.043	0.001
2.	Weight	0.842	0.709	15.734	0.585	26.91	724.386	0.001
3.	BMI	0.635	0.403	69.403	4.893	14.19	201.208	0.001

To understand the correlation between need of energy (i.e. BMR and RMR) and body dimension linear bivariate regression analysis was computed as presented in Table 3.

Initially, BMR was selected as dependent variable and height, body weight, body mass index and resting metabolic rate were selected one by one as independent variables. Later on RMR was selected as dependent variable and height, weight and body mass index were selected as independent variables to ascertain their regression. It was found that the RMR have highest regression coefficient (r^2=0.935), followed by height (r^2=0.664), weight (r^2=0.631) and body mass index (r^2=0.368). The similar trends can be seen for RMR also. It means that the BMR is determined by height, weight and BMI (figure 5). For further elucidation the scattered plot diagram were constructed between age and BMR; and BMI and BMR (Figure 6 and 7).

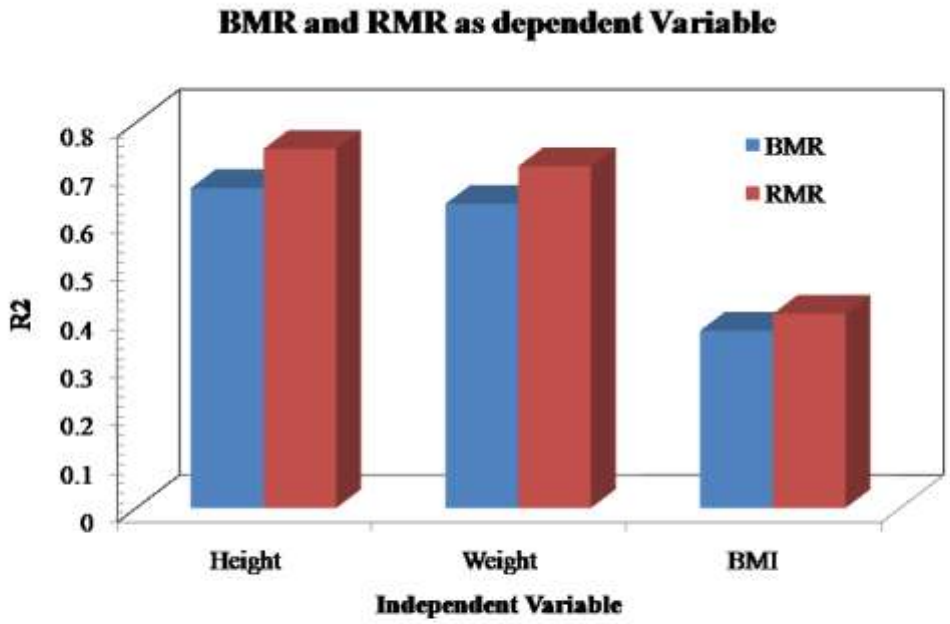

Figure 5. Comparative bar diagramm showing regression coefficient (r^2) of BMR and RMR on height, weight and BMI.

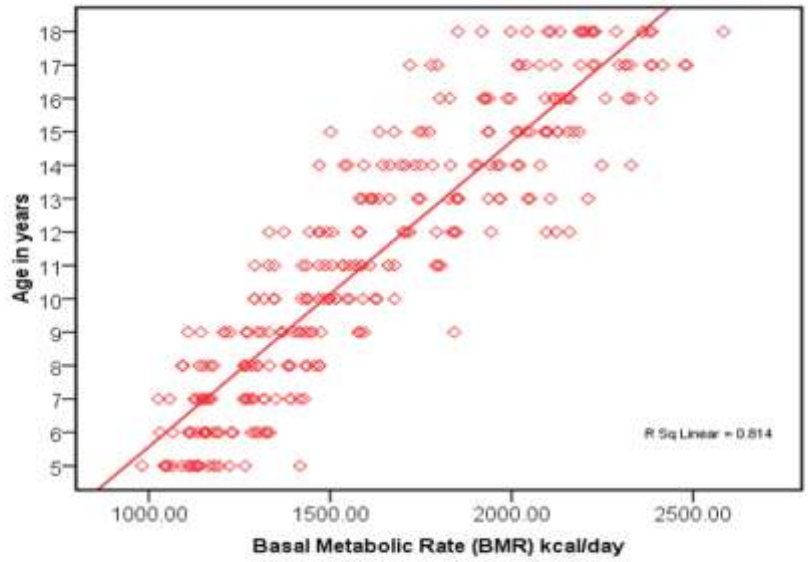

Figure 6. Scattered plot diagram showing age wise basal metabolic rate (BMR) of school going boys (5-18 years) and its regression and correlation.

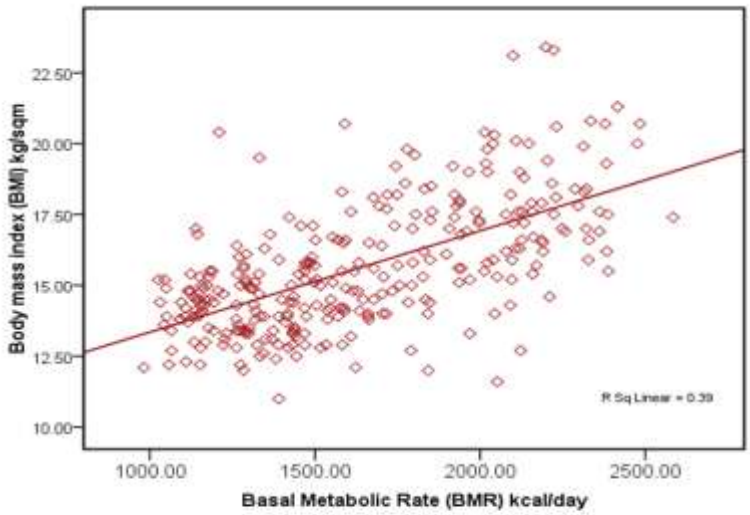

Figure 7. Scattered plot diagram showing correlation of body mass index and basal metabolic rate of school going boys (5-18 years)

DISCUSSION

This study has attempted to find out the differentials of basal metabolic rate (BMR) and resting metabolic rate (RMR) of school going boys on the basis of their age, stature, body weight and body mass index. It is apparent that the body dimension of children increases as

they grow, and as per their increasing body size, the need of energy also increases. In this way, the basal metabolic rate and resting metabolic rate is determined by age, stature and body mass.

In this study, it was found that BMR is significantly determined by BMI ($p < 0.01$). It is apparent that the underweight, stunted and undernourished boys have significant low BMR as compared to normal, overweight and tall boys. Earlier some studies have investigated energy expenditure (EE) in overweight children (Tershakovec et al. 2002 and Burel et al. 2004), few have directly compared overweight and non-overweight children. These studies (Goran et al. 1998, Treuth et al. 2000, Spandano et al. 2005) have not shown major defects in EE in normal-weight children of obese parents. One study was investigated the differences in energy metabolism between non-overweight and over- weight children (Butte et al. 2007). Another study by Weyand et al. (2010) have estimated mass-specific energy cost of human walking in this study basal metabolic rates for stature, calculated from the Schofield equations. Similar study by Nancy et al. 2015 also used Energy Expenditure and Physical Activity in Preschool children of 3- 5 year of age.

Among children, regular physical activity along with good nutrition is associated with their good health, adequate growth and well-being, which also lead to improved academic performance and probably with lower risk of disease in adult life (Boreham and Riddoh 2001; Tarun and Viteri, 1994; Viteri and Tarun 1981). Children who are physically active, explore their environment and interact socially more than their less active counterparts. There may also be a behavioural carry-over into adulthood, whereby active children are more likely to be active adults, with the ensuing health benefits of exercise (Boreham and Riddoh, 2001).

In the present study, age wise mean BMR and RMR was computed and it was found that the Basal metabolic rate varies 1219.0±106.9 K cal/day among boys of 5 years of age to 2296.3±255.9 K cal/day among boys of 17 year of age and the mean RMR of boys of 5 years of age is 779.2±61.4 kcal, which increased to 1456.1±139.0 kcal for boys of 17 years of age. Previous studies Johnstone et al., (2005) have reported that BMR from 1027 kcal per day (4301 kJ/day) to 2499 kcal/day (10455 kJ/day); with a mean BMR of 1500 kcal/day (6279 kJ/day). In another study, resting metabolic rate found to be varied from 1155.6 to 2238.8 kcal/day with mean of 1480.7 kcal/day among diabetic patients, whereas among non-diabetic subjects it varies from 1057.3 to 1787.3 kcal/day with a mean of 1362.4 kcal/day (Alawad et al., 2013). In the present study school going boys are studied for their energy requirement as per their body dimension and nutritional status probably, this is first reporting of this kind.

Differences in BMR have been observed when comparing subjects with the same lean body mass. Another study comparing individuals with the same lean body mass, the top 5% of BMR were 28-32% higher than the lowest 5% BMR (Speakman et al., 2004). Further, they reported a case where two individuals with the same lean body mass of 43 kg had BMR of 1075 kcal/day (4.5 MJ/day) and 1790 kcal/day (7.5 MJ/day). This difference of 715 kcal/day (67%) is equivalent to one of the individuals completing a 10 kilometer run every day. However, they did not account for the sex, height, fasting-state, or body fat percentage of the subject. As apparent from scattered plot diagramme, in present study too; such variation exists. The individuals with same body mass index have varying degree of BMR (figure 7).

Conclusion

The present study leads to postulate age wise average energy requirement of the target population, which was not reported earlier. Although, energy requirement vary from individual to individual, even in the same age and sex, based on their physical activity level, occupation and body dimensions. Still the information of average requirement for a particular group has practical implications. In the era o-communicable diseases, where childhood obesity has taken the form of global pandemic with higher prevalence in disadvantageous groups and developed countries; there is diet consciousness arising, and in such a condition, there is no information for such parents that how to manage the diet of their ward. The findings of this study would certainly be helpful at mass scale; and beyond that it will further encourage the similar studies of mass application. It would also be helpful to rid of from the problem of undernutirion, stunting and wasting. In Government schools, the mid day meal provided, could also be planned on the basis of such studies.

Acknowledgement

The Authors are grateful to all the children for their cooperation during the data collection. Authors are also thankful to the district authorities and Principle, Head Masters/Mistress and teachers of schools who have given their consent and provided basic facility during data collection, without their permission it would not have been possible at all.

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Conflict of Interest: The Author declares that there is no conflict of interest.

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