



## Agreement between bioelectrical impedance analysis and predictive equations for assessing resting metabolic rate in Palestinian boys aged 6–9 Years

*Acuerdo entre el análisis de bioimpedancia eléctrica y las ecuaciones predictivas para evaluar la tasa metabólica en reposo en niños palestinos de 6 a 9 años*

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### Abstract

**Introduction:** Resting metabolic rate (RMR) is the largest component of daily energy expenditure and is essential for maintaining energy balance during childhood growth.

**Objective:** This study evaluated the agreement between bioelectrical impedance analysis (BIA) and common predictive equations for estimating RMR in Palestinian boys aged 6–9 years and aimed to develop a population-specific equation based on fat-free mass (FFM).

**Methodology:** A total of 1,100 boys from 11 West Bank governorates were randomly selected. Anthropometric measurements and RMR were assessed, and predictive equation estimates were compared with BIA values.

**Results:** Mean RMR was 1117.65 kcal/day. The WHO (1985) equation showed the closest agreement with BIA. FFM was a strong independent predictor of RMR, leading to the equation:  $RMR \text{ (kcal/day)} = 376.015 + (34.120 \times FFM)$  ( $R^2 = 0.88$ ).

**Discussion:** Growth and RMR values were within normal ranges, though differences from international standards likely reflect genetic, nutritional, socioeconomic, climatic, and activity factors.

**Conclusion:** The FFM-based equation offers a practical tool for monitoring growth, guiding nutrition, and designing physical activity programs to prevent obesity and related diseases in Palestinian children.

### Keywords

Bioelectrical impedance analysis; boys; fat-free mass; resting metabolic rate; Palestine; predictive equations.

### Resumen

**Introducción:** La tasa metabólica en reposo (RMR) es el componente más grande del gasto energético diario y es esencial para mantener el equilibrio energético durante el crecimiento infantil.

**Objetivo:** Este estudio evaluó la concordancia entre el análisis de bioimpedancia eléctrica (BIA) y las ecuaciones predictivas comunes para estimar la RMR en niños palestinos de 6 a 9 años, y buscó desarrollar una ecuación específica para la población basada en la masa libre de grasa (FFM).

**Metodología:** Se seleccionaron aleatoriamente 1,100 niños de 11 gobernaciones de Cisjordania. Se realizaron mediciones antropométricas y de RMR, y se compararon las estimaciones de las ecuaciones predictivas con los valores obtenidos mediante BIA.

**Resultados:** La RMR media fue de 1117,65 kcal/día. La ecuación de la OMS (1985) mostró la mayor concordancia con BIA. La FFM fue un predictor independiente fuerte de la RMR, dando lugar a la ecuación:

$RMR \text{ (kcal/día)} = 376,015 + (34,120 \times FFM)$  ( $R^2 = 0,88$ ).

**Discusión:** Los valores de crecimiento y RMR estuvieron dentro de rangos normales, aunque las diferencias respecto a los estándares internacionales probablemente reflejan factores genéticos, nutricionales, socioeconómicos, climáticos y de actividad física.

**Conclusión:** La ecuación basada en FFM ofrece una herramienta práctica para monitorear el crecimiento, guiar la nutrición y diseñar programas de actividad física para prevenir la obesidad y enfermedades relacionadas en niños palestinos.

### Palabras clave

Análisis de bioimpedancia eléctrica; niños; masa libre de grasa; tasa metabólica en reposo; Palestina.

## Introduction

Total daily energy expenditure (TDEE) reflects the total amount of energy the body requires each day to sustain vital physiological functions and support activities such as growth, physical and cognitive performance, digestion, and responses to illness. Accurate assessment of these requirements is essential for understanding energy needs across different life stages (Fernández et al., 2024). Among the components of TDEE, resting metabolic rate (RMR) accounts for the largest share, approximately 60–75% of total daily energy expenditure, and plays a key role in maintaining energy balance (Huang et al., 2025). RMR, also known as resting energy expenditure (REE), represents the energy expended by the body at rest to maintain basic physiological functions including respiration, circulation, and thermoregulation (Acar-Tek et al., 2023). Evidence indicates that in children, RMR contributes a larger proportion of TDEE compared with energy derived from physical activity or the thermic effect of food (Sampriti et al., 2018).

Estimating RMR in children remains challenging, particularly when using predictive equations across different BMI categories (Acar-Tek et al., 2023). Advances in indirect calorimetry protocols have improved measurement efficiency and reliability in pediatric populations (Pretorius et al., 2025), while validation studies emphasize the need for population-specific equations that account for sex, activity level, and individual metabolic differences (Prado-Nóvoa et al., 2024). Genetic and metabolic variations, such as those linked to the DNAJC6 gene, have been associated with RMR differences among children with overweight or obesity (Shin et al., 2024). Additionally, commonly used predictive equations may show significant variability in pediatric populations, underscoring the need for careful evaluation when applying these models in clinical nutrition (Marderfeld et al., 2023). Recent studies further highlight the importance of precise estimation methods that consider variations in diet, lifestyle, and environmental factors across populations (García-Guzmán et al., 2025; De Cosmi, 2020).

Most predictive equations rely primarily on anthropometric measures such as height and body mass, which are influenced by both genetic and environmental factors. Genetic factors account for approximately 80–90% of height variability (Sovio et al., 2009), while environmental factors explain up to 20% (Iju & Hari, 2018). Considering that RMR equations often use height and weight, it is important to include peak height velocity (PHV) and peak weight velocity (PWV) when assessing growth and energy requirements. Recent studies demonstrate that both the timing and magnitude of PHV and PWV vary across populations and sexes. For example, longitudinal research in Korean adolescents showed that boys reach maximum annual weight gain around 12.4 years and girls around 11.3 years, with notable differences in growth patterns relative to body composition (Chun et al., 2024; 2025). Similar findings were reported in Kosovo and African pediatric cohorts, confirming that PHV and PWV are influenced by genetic, environmental, and possibly cultural factors (Rexhepi & Brestovci, 2020; Madanhire et al., 2025). These observations highlight the importance of using locally relevant growth references in pediatric assessments.

Indirect calorimetry remains the gold standard for measuring RMR, but discrepancies have been observed between measured and predicted RMR, especially in children with obesity (Vlasa et al., 2026). Incorporating body composition, particularly fat-free mass, improves predictive accuracy. Bioelectrical impedance analysis (BIA) is a valid and practical method for estimating body composition (Fuentes et al., 2021), but indirect calorimetry remains costly and impractical for large-scale studies (Acar-Tek et al., 2023). Consequently, predictive equations remain widely used, despite limitations (Owen et al., 1986).

The rising prevalence of childhood fatness and obesity further underscores the importance of this topic. Over 42 million children under five are estimated to be overweight or obese globally, with numbers now affecting around 188 million children and adolescents (Charlotte et al., 2018; UNICEF, 2025). Early childhood, particularly between 6 and 9 years, is a critical period of rapid growth and heightened sensitivity to nutritional and environmental factors, with errors in energy requirement estimation potentially impacting long-term health outcomes (Ortiz-Maron et al., 2023).

Despite the recognized importance of accurately estimating resting metabolic rate (RMR) in children, research on RMR and body composition among Palestinian children aged 6–9 years remains very limited. Reliance on international predictive equations may result in inaccurate estimations due to differences in anthropometry, lifestyle, diet, and environmental conditions (Gitsi, 2024). While



bioelectrical impedance analysis (BIA) offers a practical method to estimate RMR at the population level, its accuracy can vary between individuals at different growth stages or with atypical body weights.

The main research question is to what extent do internationally developed predictive equations accurately estimate RMR in Palestinian boys aged 6–9 years, and how does measure body composition, particularly fat-free mass (FFM), influence these estimations? To address this question, the present study aims to a) Assess body composition and RMR among Palestinian boys aged 6–9 years, b) evaluate the agreement between RMR measured using BIA and values predicted by international predictive equations, and c) develop a population-specific RMR predictive equation based on fat-free mass for this age group.

## Method

### Design

The study adopted a quantitative cross-sectional design with a correlational approach, in alignment with its primary objective of examining the nature and strength of the relationships among the study variables. This design was deemed the most appropriate methodological framework, as it allows for the investigation of naturally occurring associations without manipulating or influencing the variables under consideration.

### Participants

The study sample consisted of boys (males) enrolled in the first four grades of public schools across eleven governorates in the West Bank, Palestine. According to the Ministry of Education, the total number of boys in this age group was 98,994. All participants were prepubescent, as puberty generally begins after the age of 11, which aligns with trends in most Arab countries. This is supported by the study of Al Alwan et al. (2010) in Saudi Arabia, which reported that the average onset of puberty occurs at 11.4 years. The boys included in the study engaged in physical education class twice a week and followed the typical diet of most Palestinian families. The sample was limited to males and consisted of 1,100 boys selected from different governorates, representing approximately 0.6% of the total population of boys. For children aged 6 to 9 years, the mean values were as follows: height 1.26 meters, body mass 26.99 kg, fat-free mass 21.73 kg, body mass index (BMI) 16.67 kg/m<sup>2</sup>, body surface area 0.97 m<sup>2</sup>, and resting metabolic rate 1,117.65 kcal/day.

Given the homogeneity of the population and the similarity in living conditions, the sample was considered representative. A stratified random sampling method was applied according to age, with 100 students selected from each governorate and evenly distributed across the first four grades, resulting in 275 students per age group.

### Procedures

The data collection process involves a structured form and standardized measurement protocols to ensure accuracy and reliability. The data collection form included fields for each participant's name, age, height, body mass (BM), body mass index (BMI), body surface area (BSA), fat free mass (FFM) and resting metabolic rate (RMR).

#### *Anthropometric Measurements*

Height and body mass were measured using a calibrated mechanical scale with an integrated stadiometer (Detecto, USA). Measurements were performed under standardized conditions, with participants barefoot and wearing light clothing. Height was recorded to the nearest 1 cm, and body mass to the nearest 0.1 kg.

#### Body Surface Area (BSA)

BSA (m<sup>2</sup>) was calculated using the formula proposed by Furqan and Haque (2009):

$$BSA = \frac{(4 \times \text{Weight}) + 7}{90 + \text{Weight}}$$



## Body Mass Index (BMI)

BMI was calculated using the conventional formula:

$$\text{BMI (kg/m}^2\text{)} = \frac{\text{Weight (kg)}}{\text{Height (m)}^2}$$

## Resting Metabolic Rate and Body Composition

Body composition and resting metabolic rate (RMR) were assessed using the Tanita DC-360 body composition analyzer (Tanita, Tokyo, Japan), which relies on bioelectrical impedance analysis. This device operates based on differences in water content between tissues; muscle tissue contains 70–75% water, resulting in lower electrical resistance compared to adipose tissue, which contains 20–25% water, allowing accurate differentiation between tissue types (Kyle et al., 2004). A study by Kabiri et al. (2015) confirmed the validity and reliability of the Tanita DC-360 in assessing body composition and RMR in children. Recent studies support the use of bioelectrical impedance analysis as a precise, non-invasive tool for evaluating body composition and metabolic rate. A comprehensive review published in 2023 showed that this technique remains reliable when properly applied and clinical standards are considered (Ohara et al., 2023).

All measurements were conducted between 8:00 and 10:00 AM, prior to breakfast, following a standardized protocol:

- The device was connected to a power source and powered on.
- Participant information, including clothing weight, sex, age, and height, was entered into the system.
- Participants stepped onto the device when prompted, ensuring both feet were in full contact with the metal electrodes.
- The analysis took approximately 30 seconds, during which participants remained standing without external intervention.
- Results were automatically generated and printed.

The complete measurement process, including height and body mass assessment, required approximately 2–3 minutes per participant.

## Predictive Equations for RMR Measurement

Several predictive equations have been selected to estimate resting metabolic rate (RMR). The existence of multiple equations reflects the lack of a single, universally applicable equation due to variations in nutritional status, habitual physical activity, environmental conditions, age, sex, body composition, ethnicity, metabolic stress, muscle tension, body temperature (Jésus et al., 2015), and other population-specific factors. The predictive equations used in this study are presented in Table 1.

Table 1. Predictive Equations for RMR Measurement Used in the Study

Referencies	Equations*	Notes
WHO, 1985 (Male 3–10 yrs)	$\text{RMR} = (22.7 \times \text{BM}) + 495$	BM: kg
Schofield, 1985 (Male 3–10 yrs)	$\text{RMR} = (19.589 \times \text{BM}) + (1.302 \times \text{HT}) + 414.7$	BM: kg, HT: cm
IOM, 2004 (Male 3–18 yrs)	$\text{RMR} = 68 - (43.3 \times \text{AGE}) + (7.12 \times \text{HT}) + (19.2 \times \text{BM})$	BM: kg, HT: cm, AGE: years
Kim, 2012 (All 4–11 yrs)	$\text{RMR} = 632.4 + (15.66 \times \text{AGE}) + (9.53 \times \text{BM})$	BM: kg, AGE: years
Henry, 2007 (Male 3–10 yrs)	$\text{RMR} = (15.1 \times \text{BM}) + (0.742 \times \text{HT}) + 306$	BM: kg, HT: cm
Acar-Tek et al., 2023 (All 6–18 yrs)	$\text{RMR} = 505.412 + (24.383 \times \text{FFM})$	FFM: kg

\*We changed Weight WT to Body Mass BM.

## Measurement Conditions

All measurements were taken between 8:00 and 10:00 A.M. at the selected schools, before breakfast and any physical activity. All predictive equations used are based on body height, body mass and fat free mass, represent relative measurements, and have been validated in internationally published scientific research.



## Data Entry and Processing

The collected data was entered into and analyzed using the SPSS statistical software for social sciences. Body surface area (BSA), body mass index (BMI), and resting metabolic rate (RMR) values derived from the predictive equations were calculated using the Compute function based on the initial measurements (height, BMI, and lean mass). The data were then preprocessed before statistical analysis.

## Data analysis

Data analysis was performed using SPSS software (version 27) and MedCalc (version 23). Descriptive statistics were expressed as means and standard deviations. Paired t-test was used to determine the differences between measured RMR using BIA and predictive equation. Agreement between RMR values obtained by BIA and predictive equations was evaluated using the Bland–Altman method (Bland & Altman, 1986). In addition, simple linear regression analysis ( $R^2$ ) was conducted to develop a predictive equation, with fat free mass as the independent variable and RMR measured by BIA as the dependent variable. Statistical significance was set at  $p < .05$ .

## Results

To address the first objective of the study, which aimed to identify height, body mass, fat-free mass, body mass index (BMI), body surface area, and resting metabolic rate, descriptive statistics were calculated for each variable. Table 2 presents the means and standard deviations of these measurements across the different age groups (6–9 years).

Table 2. Means and standard deviations of height, body mass, fat-free mass, body mass index (BMI), body surface area, and resting metabolic rate across age groups (6–9 years) (N = 1100)

Variables	6 Years		7 Years		8 Years		9 Years		Total		increase
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Height (m)	1.17	.052	1.23	.052	1.29	.056	1.34	.062	1.26	.084	16.83 cm
Body mass (kg)	22.25	3.967	25.10	5.055	28.30	6.698	32.31	7.654	26.99	7.080	10.06 kg
Fat free mass FFM (kg)	17.83	2.33	20.24	2.74	22.90	3.36	25.96	4.13	21.73	4.41	7.69 kg
Body mass index BMI (kg/m <sup>2</sup> )	15.93	2.03	16.30	2.51	16.80	3.04	17.67	3.23	16.67	2.81	1.74 kg/m <sup>2</sup>
Body surface area BSA(m <sup>2</sup> )	.85	.10	.92	.12	1.00	.15	1.10	.17	.97	.16	0.25 m <sup>2</sup>
Resting metabolic rate RMR (Kcal/d)	1010.02	90.03	1074.67	114.749	1147.47	152.046	1238.45	173.75	1117.65	160.71	228.43 kcal/day

SD: Standard Deviation

Table 2 presents the overall mean values for Palestinian boys aged 6–9 years. The mean height was 1.26 m, body mass 26.99 kg, fat-free mass 21.73 kg, body mass index 16.67 kg/m<sup>2</sup>, body surface area 0.97 m<sup>2</sup>, and resting metabolic rate 1117.65 kcal/day. Across the age range from 6 to 9 years, these variables showed progressive increases of 16.83 cm in height, 10.06 kg in body mass, 7.69 kg in fat-free mass, 1.74 kg/m<sup>2</sup> in body mass index, 0.25 m<sup>2</sup> in body surface area, and 228.43 kcal/day in resting metabolic rate.

Regarding the second objective of the study, which aimed to examine the level of agreement between resting metabolic rate (RMR) values measured using the bioelectrical impedance analysis (BIA) method and those estimated using predictive equations, Table 3 presents the results of the paired t-test assessing the significance of differences between the measured and estimated RMR values. In addition, Figure 1 illustrates the Bland–Altman plot used to evaluate the agreement between the RMR values obtained by BIA and those predicted by the equations.

The results shown in Table 3 revealed statistically significant differences ( $P \leq 0.05$ ) between the RMR values measured by BIA and those estimated using all predictive equations, except for the WHO 1985 equation, for which no statistically significant differences were observed. The Bland–Altman analysis further supported this finding, demonstrating good agreement between the RMR values measured by



BIA and those predicted by the WHO 1985 equation. All data points fell within the limits of agreement ( $-1.96$  to  $+1.96$ ), with a mean difference of 10 kcal/day and comparable standard error values. Figure 1 visually confirms this pattern of agreement.

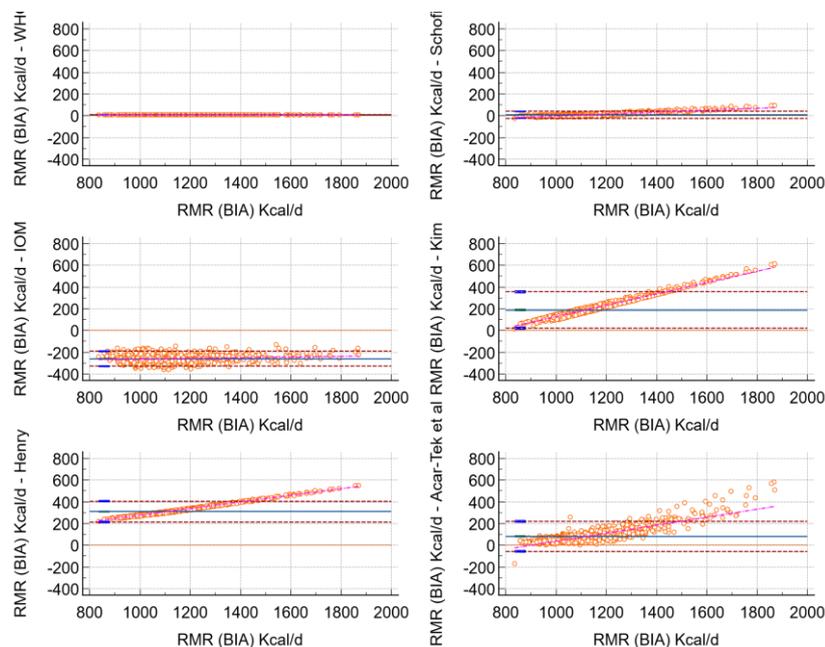
Overall, these findings indicate that the WHO 1985 equation provides the most valid estimation of resting metabolic rate for this age group and can be considered a suitable alternative for RMR assessment when direct measurement devices are not available.

Table 3. Results of the paired t-test examining differences in resting metabolic rate between values measured by bioelectrical impedance analysis and predictive equations (n = 1100)

Measures of RMR Kcal/d	Mean	Std. Deviation	Std. Error Mean	Diff. means	T. Value	Sig.*
Measured BIA	1117.65	160.71	4.84	-	-	-
WHO 1985	1107.65	160.72	4.85	10.00	0.004	0.99
Schofield 1985	1108.55	147.28	4.44	9.10	19.61	0.000*
IOM 2004	1377.73	159.84	4.81	260.08	-243.7	0.000*
Kim 2012	928.75	78.14	2.35	188.89	73.43	0.000*
Henry 2007	807.31	111.73	3.36	310.34	209.08	0.000*
Acar-Tek et al 2023	1035.40	107.73	3.24	82.25	28.76	0.000*

\*Significant differences,  $p < .05$ .

Figure 1. Summary of Bland – Altman plot for the agreement between BIA and predictive equations for RMR in Palestinian children aged 6–9 years



With respect to the third objective of the study, which aimed to develop a predictive equation for estimating resting metabolic rate (RMR) measured by bioelectrical impedance analysis (BIA) based on fat free mass, a simple linear regression analysis was conducted, as presented in Table 4. The analysis revealed a coefficient of determination ( $R^2$ ) of 0.88, indicating that FFM accounts for 88% of the variance in RMR. Furthermore, the results shown in Table 5 present the parameters of the derived regression equation.

Table 4. Results of one-way ANOVA for determining the regression coefficient of fat free mass in predicting resting metabolic rate among Palestinian males aged 6–9 years

Model	Sum of Squares	df	Mean Square	F	Sig.*
Regression	24979540.324	1	24979540.324	8047.779	<.001 <sup>b</sup>
Residual	3408087.506	1098	3103.905		
Total	28387627.830	1099			
( $R^2$ )	0.88				

\*Significance at  $p < .05$ , a. Dependent Variable: RMR (BIA) Kcal/d, b. Predictors: (Constant), FFM (KG).

Table 5. Results of the t-test and beta coefficients for the derived regression equation used to predict resting metabolic rate based on fat-free mass (FFM)

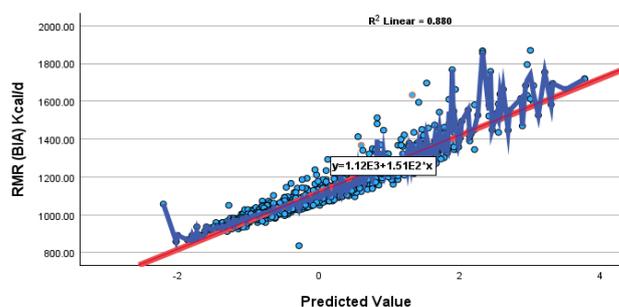
Parameters	B	Std. Error	Beta	t	Sig.*
(Constant)	376.015	8.436		44.572	<.001
FFM (kg)	34.120	.380	.938	89.709	<.001

\*Significance at  $p < .05$ , standard error of the estimate (SEE) was approximately  $\pm 55.7$  kcal/day.

Table 5 indicates that the regression equation describing the predictive contribution of fat-free mass (FFM) to resting metabolic rate (RMR) among Palestinian males aged 6–9 years was refined based on the regression analysis. The standard error of the estimate (SEE) was approximately  $\pm 55.7$  kcal/day, indicating that the average deviation between the observed and predicted resting metabolic rate (RMR) values based on fat-free mass (FFM) was about 55.7 kcal/day. Given that the coefficient of determination was high ( $R^2 = 0.88$ ), the standardized beta coefficient was 0.938, and the overall regression model was statistically significant ( $F = 8047.779$ ,  $p < .001$ ), the model demonstrates strong explanatory power with a relatively low estimation error. These findings indicate that FFM is a very strong predictor of RMR among Palestinian boys aged 6–9 years. Accordingly, a new predictive equation was derived as follows:

$$\text{RMR (kcal/day)} = 376.015 + (\text{FFM} \times 34.120)$$

Figure 2. Illustrates the effectiveness of the regression equation derived in predicting resting metabolic rate based on fat-free mass.



## Discussion

Resting metabolic rate (RMR) is a central physiological variable closely linked to multiple anthropometric measures and aspects of body composition in children, including height, body mass, fat-free mass (FFM), body mass index (BMI), and body surface area (BSA) (Jésus et al., 2015). These parameters are influenced by population-specific factors such as nutritional status, habitual physical activity, prevalence of being overweight and obesity, and environmental conditions (Henry, 2007). Consequently, various predictive equations have been developed to estimate RMR, considering the growth patterns and metabolic characteristics of each population.

The results of the present study revealed that Palestinian boys aged 6 to 9 years had an average height of 1.26 m, an average body mass of 26.99 kg, lean body mass of 21.73 kg, a body mass index (BMI) of 16.67 kg/m<sup>2</sup>, and a body surface area (BSA) of 0.97 m<sup>2</sup>. Height increased gradually at a rate of 5–6 cm per year, consistent with prepubertal growth patterns, with a total increase of approximately 16.83 cm between ages 6 and 9, and mean heights of 117.87, 123.74, 129.37, and 134.61 cm for ages 6, 7, 8, and 9, respectively. Compared with regional and international data, the average height at age nine was higher than reported in Saudi Arabia (Al-Hazzaa, 2007), Oman (Anne et al., 2018), and eastern India (Sampriti et al., 2018), but lower than averages in many European countries, where nine-year-old children typically range between 135.6 and 140.5 cm (Trudy et al., 2014), as well as lower than values reported in Sweden (Albertsson et al., 2002). This variation likely reflects the interaction of genetic, nutritional, and socio-economic factors. Genetics accounts for 80–90% of final adult height, while environmental factors contribute up to 20% of childhood height variability (Sovio et al., 2009; Iju & Hari, 2018). Timing and rate of peak growth also differ across populations, with peak growth velocity in males ranging from 7.6 to 10.3 cm/year, typically between ages 12 and 13 (Tanner & Davis, 1985; Tanaka et

al., 1988; Tian et al., 2004; Dabas et al., 2018). The observed annual growth rate of 5–6 cm aligns with expected norms from age five until puberty onset (Rogol et al., 2002).

Similarly, body mass increased gradually by 2–3 kg per year, while lean body mass increased by 1.5–2.5 kg annually, reflecting normal muscular and skeletal development. BMI increased progressively from 15.93 to 17.67 kg/m<sup>2</sup> between ages 6 and 9, higher than values reported in India and Bahrain (Sampriti et al., 2018; Nadia & Parveen, 2009), but lower than those recorded in Chile, Saudi Arabia, and New Zealand (Aguirre et al., 2014; Al-Hazzaa, 2007; Rush et al., 2008). BSA also increased gradually, though values remained lower than some European and East Asian populations (Lito & Young, 2018). These findings highlight the influence of genetic and environmental factors, including nutrition, physical activity, and socio-economic status, on children's physical growth. Furthermore, recent studies emphasize the importance of considering peak height velocity (PHV) and peak weight velocity (PWV) when assessing growth and energy requirements in children, particularly when using resting metabolic rate (RMR) equations that rely on height and weight. Longitudinal research in Korean adolescents showed that boys reach maximum annual weight gain at 12.4 years and girls at 11.3 years, with notable differences in growth patterns according to body composition (Chun et al., 2024; 2025). Similar findings in Kosovo and African pediatric cohorts confirmed that PHV and PWV are influenced by genetic, environmental, and cultural factors (Rexhepi & Brestovci, 2020; Madanhire et al., 2025), underscoring the importance of using locally relevant growth references for pediatric assessments.

RMR demonstrated a statistically significant increase with age, with a mean of 1,107.65 kcal/day and an annual increase of 70–100 kcal/day, resulting in a total difference of 228.43 kcal/day between ages 6 and 9. These RMR values were higher than those reported in Indian schoolchildren (Thakur & Gautam, 2016), likely due to the higher body mass and FFM in the current sample. When comparing measured RMR using bioelectrical impedance analysis (BIA) with predictive equations using Bland-Altman plot, the WHO equation (1985) emerged as the most accurate. This likely reflects the simplicity of the equation and its reliance on body mass, a key determinant of RMR in young children. Body mass closely reflects metabolically active tissue during early growth, and simpler weight-based models often perform as well as, or better than, more complex models in narrow age ranges (Acar-Tek et al., 2023).

Validation studies support the principle that prediction equations perform best when applied to populations like those from which they were derived (Bedogni et al., 2020). Age specificity also matters: broad equations, such as the Institute of Medicine (2004) model, may be less precise for narrow age ranges like 3–10 years due to rapidly changing growth dynamics and energy needs (Fuentes-Servín et al., 2021). Equations based on FFM theoretically improve prediction because metabolically active tissue largely determines energy expenditure. However, practical accuracy depends on measurement precision; in field settings, BIA introduces variability that may reduce accuracy compared to high-precision techniques like DEXA (Acar-Tek, 2023). Therefore, the WHO equation's simplicity and reliance on easily measured variables likely contributed to its superior performance in this sample.

Our regression analysis confirmed that FFM is the strongest predictor of RMR in Palestinian boys aged 6–9 years, explaining approximately 88% of the variance ( $R^2 = 0.88$ ) with a standard error of estimation SEE  $\pm 55.7$  kcal/day. These results align with earlier studies reporting that FFM accounts for 80–84% of RMR variance (Arciero et al., 1993; Molnar & Schutz, 1997; Sparti et al., 1997), and more recent research reinforces that incorporating body composition—particularly FFM—significantly improves predictive accuracy compared to weight-based models alone (Delgadillo et al., 2022; O'Neill et al., 2023; Jagim et al., 2023).

Physiologically, this relationship reflects the high metabolic activity of skeletal muscle, which constitutes most FFM, in maintaining essential processes such as homeostasis, ion regulation, and protein turnover. In contrast, adipose tissue contributes relatively little to daily energy expenditure. Each additional kilogram of muscle mass may increase RMR by 13–30 kcal/day (Wang et al., 2010; Speakman & Selman, 2007). These findings underscore the importance of assessing fat-free mass (FFM) when estimating energy requirements and developing nutritional recommendations for children, because FFM is a major predictor of resting energy expenditure and explains a large portion of individual variability in energy needs (Acar-Tek et al., 2023).

Overall, this study highlights that accurate RMR estimation in children requires consideration of FFM, body mass, age, sex, dietary habits, physical activity, and population-specific factors. A comprehensive



approach incorporating these variables enhances predictive accuracy and supports tailored nutritional guidance to promote healthy growth and energy balance.

## Conclusions

The results of this study indicate that the growth patterns of Palestinian boys aged 6–9 years fall within normal physiological ranges, although there are clear differences when compared to international reference data. These differences are primarily attributed to variations in genetic background, nutritional status, socioeconomic conditions, climate, and habitual level of physical activity. These population-specific differences explain the wide range of predictive equations currently used to estimate resting metabolic rate and the absence of a universal optimal equation. Accordingly, a population-specific predictive equation for resting metabolic rate, based on fat-free mass, was developed for Palestinian boys aged 6–9 years. The high explanatory power of fat-free mass highlights its crucial role in assessing children's resting metabolic rate.

These findings are recommended for dissemination to primary school teachers and health authorities, given their practical importance in growth monitoring, nutritional planning, physical activity programs, and the prevention of sedentary behaviors during early childhood for prevention from obesity, and to reduce the impact of sedentary and hypo-kinetic diseases.

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