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Comparison between Measured and Predicted Basal Metabolic Rate in Indonesian Adolescent Female Basketball Players

Perbedaan Basal Metabolic Rate *Berdasarkan Pengukuran dan Formula pada Atlet Bola Basket Remaja Putri Indonesia*

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ABSTRACT

Background: Accurate estimation of energy requirement is significantly crucial for athletes to support performance. Meanwhile, Basal Metabolic Rate (BMR) constitutes the largest component of Total Energy Expenditure (TEE) and is commonly assessed using estimation formulas.
Objectives: This study aimed to compare measured and predicted BMR using Body Impedance Analysis (BIA) and estimation formulas respectively among adolescent female basketball players in the Youth Sports Training Center (PPOP) Special Capital Region (DKI) Jakarta.
Methods: A total of 12 adolescent female basketball players aged 14-18 years were subjected to BIA measurements to obtain BMR and body composition. BMR was compared with 24 formulas using paired t-tests, while mean differences and effect size were analyzed to determine the best predictive formula.
Results: The results showed significant differences between measured (1473.6±201.2 kcal) and the majority of all predicted BMR (p-value<0.05), except for Cunningham (1459.0±102.1 kcal), Harris-Benedict (1441.7±87.0 kcal), IMNA (1398.7±91.1 kcal), and Kim (1384.3±69.6 kcal). The smallest differences between measured and predicted BMR were observed in Cunningham (14.7±113.3 kcal) and Harris-Benedict (31.9±116.2 kcal). Effect size analyses showed large differences in the majority of formulas (>1), while Cunningham (0.129) and Harris-Benedict (0.274) had the smallest effect sizes.
Conclusions: Cunningham and Harris-Benedict may serve as alternative estimations for BMR aside from using BIA in adolescent female basketball players in PPOP DKI Jakarta. Future studies should consider indirect calorimetry methods to enhance BMR measurement accuracy. Similar studies should also be performed on various athletes in Indonesia with larger sample sizes.

INTRODUCTION

Accurate estimation of energy requirements is crucial for athletes, as sufficient energy intake plays a crucial role in maintaining metabolism levels, supporting physiological functions, and enhancing athletic performance[1,2]. The International Olympic Committee (IOC) mentioned energy deficiency as a key indicator of suboptimal athletes health and performance[3]. For instance, female athletes with hormonal regulation disorders, menstrual irregularities, low bone mineral density, and other metabolism-related issues are often associated with inadequate energy intake[4].

Total Energy Expenditure (TEE) comprises three components including Basal Metabolic Rate (BMR), Thermic Effect of Food (TEF), and Physical Activity (PA). BMR represents the least energy requirement needed to sustain vital bodily functions such as respiration, heart function, and body temperature regulation. It contributes 60-70% of TEE in healthy adults[5], and can serve as an indicator of energy intake deficiency in athletes[6]. PA is the most variable component of TEE depending on PA levels[7], hence, energy requirement estimations typically rely on BMR.

Various methods exist for determining energy requirements, but there is no consensus on the most accurate[8]. Common methods for measuring BMR in clinical and study settings include indirect calorimetry, Bioelectrical Impedance Analysis (BIA), and calculation formula estimates[9]. Although indirect calorimetry is well-known as the gold standard to accurately measure BMR[10], this method is notoriously expensive, requires skilled personnel to operate, and is not widely available

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in athletes training facilities[11] leaving most measurements to rely on calculation formula estimates[12].

To minimize both time and costs, numerous calculation formulas have been developed to predict BMR using regression analysis on individual characteristics including weight, height, age, gender, and fat-free mass (FFM). Several examples of BMR calculation formulas include Harris-Benedict[13], Altman and Dittmer[14], Cunningham[15], Bernstein[16], Roza[17], Owen[18], Mifflin[19], Molnar[20], Henry and Rees[21], Nelson[22], Maffeis[23], Liu[24], De Lorenzo[25], Wang[26], Institute of Medicine of the National Academies (IMNA)[27], FAO/WHO/UNU[28], Müller[29], Johnstone[30], Taguchi[31], Kim[32], Jagim[33], Schofield[34], and Watson[35].

The majority of these formulas are not specifically developed for athletes, thereby limiting generalizability. For example, BMR estimation using the Harris-Benedict formula in ultra-endurance athletes[36], as well as the Cunningham and Harris-Benedict formulas in rowing and canoeing athletes[37] were significantly lower compared to measured BMR using indirect calorimetry. Furthermore, a variety of factors influence the validity of BMR estimation, including ethnicity, body composition, medication use, and environmental temperature[10,34,38], making the accuracy non-generalizable across populations.

There are currently no available studies comparing BMR estimates based on BIA measurements and calculation formulas for adolescent female basketball players in Indonesia. Therefore, this study aimed to compare BMR outcomes using BIA measurements and formula estimates in adolescent female basketball players in the Youth Sports Training Center (PPOP) Special Capital Region (DKI) Jakarta.

METHODS

Study Design

This comparative cross-sectional study conducted on adolescent female basketball players compared the results of BMR measurements using BIA (Serenity Ultrasonic Body Fat Analyzer SR-HW05, Indonesia) and formulas for females and/or unisex found in the literature. A total of 24 BMR formulas were used, including Harris-Benedict, Altman and Dittmer, Cunningham, Nelson, Bernstein, Roza, Owen, Mifflin, Molnar, Henry and Rees, Maffeis, Liu, De Lorenzo, Wang, IMNA, FAO/WHO/UNU, Müller, Müller-FFM, Johnstone, Taguchi, Kim, Jagim, Schofield, and Watson (Table 1).

Table 1. BMR Estimation Formulas

Equation	Formula
Harris Benedict	655.1 + [9.56 x weight (kg)] + [1.85 x height (cm)] – [4.68 x age (years)]
Altman and Dittmer	[0.788 x weight (kg) + 24.11] x 24
Cunningham	500 + 22 x FFM (kg)
Nelson (kJ)	1114 + [90.4 x FFM (kg)] + [13.2 x FM (kg)]
Bernstein	236.7 + [19.02 x FFM (kg)] + [3.72 x FM (kg)] – [1.55 x age (years)]
Roza	490.8 – [1.5 x age (years)] + [45.8 x FFM (kg)]
Owen	50.4 + [21.1 x weight (kg)]
Mifflin	[9.99 x weight (kg)] + [6.25 x height (cm)] – [5 x age (years)] – 161
Molnar (kJ)	1629.8 + [51.2 x weight (kg)] + [24.5 x height (cm)] – [207.5 age (years)]
Henry and Rees	239 x [0.084 x weight (kg) + 2.122]
Maffeis (kJ)	1552 + [35.8 x weight (kg)] + [15.6 x height (cm)] – [36.3 x age (years)]
Liu	54.34 + [13.88 x weight (kg)] + [4.16 x height (cm)] – [3.43 x age (years)] – 112.40
De Lorenzo	-857 + (9.0 x weight (kg) + (11.7 x height (cm)
Wang	175 + [24.6 x FFM (kg)]
IMNA	189 - [17.6 x age (years)] + [625 x height (m)] + [7.9 x weight (kg)]
FAO/WHO/UNU	35 + [13.3 x weight (kg)] + [3.34 x height (cm)]
Müller	[0.047 x weight (kg) – 0.01452 x age (years) + 3.31] x 1/4.184
Müller-FFM	[0.052 x FFM (kg) + 0.040 x FM (kg) – 0.012 x age (years) + 2.992] x 1/4.184
Johnstone (kJ)	1613 + 31.6 x FM (kg) + 90.2 x FFM (kg) – 12.2 x age (years)
Taguchi	5 + [27.5 x FFM (kg)]
Kim	730.4 + [15 x FFM (kg)]
Jagim	288 + [21.10 x weight (kg)]
Schofield	200 + [8.361 x weight (kg)] + [4.654 + height (cm)]
Watson	88.1 + [2.53x height (cm)] + [18.42 x weight (kg)] + [1.46 x age (years)]

kg = kilogram; cm = centimeter; FFM = Fat-Free Mass; FM = Fat Mass.

Population and Sample

The population consisted of all adolescent female basketball players in PPOP DKI Jakarta aged 15-18 years. Due to the small population size, this study used total sampling method which included all individuals in the population, hence, 12 samples were included.

Data Collection

Data collection was conducted in two stages, in the first stage, athletes used BIA to measure BMR under resting conditions, while in the second stage, the estimated BMR was assessed using calculation formulas. Anthropometric data such as age, weight, height, and body composition were obtained to estimate BMR using the selected formulas.

Data Analyses

Descriptive analyses were performed to examine the distribution of each observed variable, including age, body weight, height, body mass index (BMI), and body

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composition including fat-free mass (FFM), fat percentage (%), and fat mass (kg). The results were reported as mean±standard deviation (SD), confidence interval (CI), median, minimum, and maximum values to provide an overview of the data distribution. Normality was checked using the Shapiro-Wilk test, and bivariate analysis was performed with Paired t-tests to analyze the difference between measured and predicted BMR. Bivariate analyses were reported as mean±SD, with a statistical significance level set at p-value<0.05. Additionally, mean difference between measured and estimated BMR, as well as effect size, were also analyzed to determine the best predictive formula. Data were analyzed using the Statistical Program for Social Science (SPSS 27, IBM).

RESULTS AND DISCUSSIONS

Table 2 presents the characteristics of 12 female adolescent basketball players in PPOP DKI Jakarta. The parameters examined include age, body weight, height, BMI, BMI-for-age z-score, FFM, fat percentage (%), and fat mass (kg). The mean age of respondents was 16.2±1.1 years with a range of 14 to 18 years, while the average body weight and height were 58.1±8.4 kg and 165.6±5.2 cm, respectively. The mean BMI was 21.1±2.3 kg/m^2, with a range of 17.5 to 25.0 kg/m^2 and the BMI-for-age z-score averaged 0.4±2.3, with a range of -1.3 to 1.3. The mean FFM, fat percentage (%), and fat mass (kg) were 43.6±4.6 kg, 24.6±4.3%, and 14.6±4.4 kg, respectively.

Table 2. Characteristics of Female Adolescent Basketball Players in PPOP DKI Jakarta

Variabel	Mean±SD	Median	Minimal	Maximal
Age (years)	16.2±1.1	16	14	18
Body weight (kg)	58.1±8.4	59.2	43.1	70.7
Height (cm)	165.6±5.2	165.0	157.0	173.9
BMI (kg/m^2)	21.1±2.3	21.4	17.5	25.0
BMI-for-age z-score	0.4±2.3	0.5	-1.3	1.3
Fat-free mass (kg)	43.6±4.6	44.0	35.0	51.6
Fat percentage (%)	24.6±4.3	23.9	18.8	31.3
Fat mass (kg)	14.6±4.4	14.6	8.1	22.1

SD = Standard Deviation; kg = kilogram; cm = centimeter; BMI = Body Mass Index; kg/m^2 = kilogram per square meter; FFM = Fat-Free Mass.

Table 3 compares the variations in BMR between BIA measurements and estimations based on 24 formulas. The results show a significant difference in measured and estimated BMR. The mean BMR assessed with BIA was 1473.6±201.2 kcal, while the estimated BMR values varied across different formulas, ranging from 1095.0±100.6 to 2463.0±212.0 kcal. The bivariate analysis found substantial variations in measured BMR against most estimated formulas (p-value<0.05). Cunningham (1459.0±102.1 kcal), Harris-Benedict (1441.7±87.0 kcal), IMNA (1398.7±91.1 kcal), and Kim (1384.3±69.6 kcal) did not differ significantly from BIA-measured BMR (p-value>0.05). The mean difference in measured BMR and estimated formulas varied from -989.3±79.7 to 378.7±108.6 kcal with Cunningham (14.7±113.3 kcal) and Harris-Benedict (31.9±116.2 kcal) having the smallest difference. The differences between measured and estimated BMR varied according to effect size analysis, with the majority showing significant differences (>1). The formulas with the lowest effect sizes were Cunningham (0.129) and Harris-Benedict (0.274).

Table 3. Bivariate Analyses of the Differences Between Measured and Predicted BMR in Indonesian Adolescent Female Basketball Players

BMR	Mean±SD	p-value	Difference±SD	Effect Size
BIA-Measured BMR	1473.6±201.2			
Harris-Benedict	1441.7±87.0	0.384	31.9±116.2	0.274
Altman & Dittmer	1678.6±159.5	<0.001*	-205.0±49.0	-4.183
Cunningham	1459.0±102.1	0.677	14.7±113.3	0.129
Nelson	1254.0±111.0	<0.001*	219.7±101.5	2.164
Bernstein	1095.0±100.6	<0.001*	378.7±108.6	3.487
Roza	2463.0±212.0	<0.001*	-989.3±79.7	-12.415
Owen	1277.7±178.0	<0.001*	196.0±35.8	5.474
Mifflin	1374.1±110.0	0.007*	99.5±98.0	1.016
Molnar	1268.4±125.4	<0.001*	205.2±106.1	1.935
Henry and Rees	1674.9±169.3	<0.001*	-201.2±41.5	-4.85
Maffeis	1345.6±86.0	0.005*	128.0±119.0	1.076
Liu	1382.6±133.4	0.002*	91.0±73.6	1.236
De Lorenzo	1603.9±128.6	<0.001*	-130.2±90.2	-1.444
Wang	1274.3±114.2	<0.001*	226.3±104.7	2.162
IMNA	1398.7±91.1	0.064	75.0±119.2	0.629
FAO/WHO/UNU	1361.7±126.0	<0.001*	112.0±79.8	1.404
Müller	1388.3±83.8	0.027*	85.3±109.2	0.781
Müller-FFM	1349.8±92.4	0.004*	123.8±110.7	1.118

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BMR	Mean±SD	p-value	Difference±SD	Effect Size
Johnstone	1388.1±125.8	0.007*	85.5±83.9	1.019
Taguchi	1203.7±127.6	<0.001*	270.0±95.9	2.815
Kim	1384.3±69.6	0.059	89.3±139.2	0.642
Jagim	1515.3±178.0	0.003*	-41.6±35.8	-1.162
Schofield	1687.2±142.6	<0.001*	-213.6±63.7	-3.352
Watson	1602.1±166.2	<0.001*	-128.4±44.9	-2.860

SD = Standard Deviation; BMR = Basal Metabolic Rate; BIA = Bioelectrical Impedance Analysis; IMNA = Institute of Medicine of the National Academies; FAO = Food and Agriculture Organization; WHO = World Health Organization; UNU = United Nation University; FFM = Fat-Free Mass; * = significant value using paired t-test (p-value<0.05).

This study aims to compare the differences in BIA-measured and predicted BMR among adolescent female basketball players in PPOP DKI Jakarta. The results show that Cunningham provides the best estimation, followed by Harris-Benedict. This is consistent with The American College of Sports Medicine (ACSM) position on nutrition and PA, stating that Cunningham and Harris-Benedict are recommended formulas for estimating BMR among athletes[39]. However, 20 out of 24 formulas analyzed showed significantly different BMR estimates than those obtained by BIA measurements.

Although Cunningham was originally developed for general, non-athlete population, it outperformed other formulas in predicting BMR in the athletic group. This is consistent with many previous studies showing that Cunningham is one of the most accurate in estimating BMR among athletes, both males and females[36,40–43]. More specifically, Jagim et al. (2018) [33] concluded that Cunningham is the most accurate model for estimating BMR in female athletes. The high accuracy can be attributed to the inclusion of FFM in the calculations. FFM plays an important role in predicting BMR[42] and includes metabolically active physiological components such as bone mass, muscle mass, and organs[44]. Harris-Benedict, which is one of the most widely used formulas, ranks second only to Cunningham in terms of accuracy. It was initially developed in 1918 based on populations of both males and females with normal weight[13], incorporates variables including body weight, height, age, and sex, all of which have been found to correlate with BMR[25,45,46].

This study has several limitations, first, BIA is not a standard method for BMR assessment. Previous studies have identified indirect calorimetry as a reliable and accurate gold standard method[3,36,40,43,47–49]. The use of BIA as a reference for BMR may potentially produce biased results, similar to how body composition assessments frequently result in underestimation or overestimation[50,51]. Second, due to the small number of respondents, regression analysis was not used in this study. Regression analysis is useful for identifying confounding variables, for instance, food consumption and dietary intake before BIA assessment, such as protein and carbohydrates, can have an impact on BMR outcomes[52]. Despite these limitations, this study provides valuable insights into the differences between BMR measurement methods.

CONCLUSIONS

In conclusion, Cunningham and Harris-Benedict formulas may serve as alternative estimations for BMR aside from using BIA in adolescent female basketball players in PPOP DKI Jakarta. Subsequent studies are expected to use indirect calorimetry to improve the accuracy of BMR assessment. Furthermore, higher sample sizes are required for similar studies on other athlete populations in Indonesia to enhance the generalizability of results and provide more robust insight into energy requirements across different sports disciplines.

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AUTHOR CONTRIBUTIONS

MR: responsible for writing the article, conceptualizing, analyzing and interpreting the data, and preparing and revising the manuscript draft; NG: supervised and guided the analysis and interpretation of the data, provided critical feedback, and offered input and suggestions for writing and revising the manuscript; NPDA: supervised and guided the analysis and interpretation of the data, provided critical feedback, and offered input and suggestions for writing and revising the manuscript.

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