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Agreement between Basal Metabolic Rate Measured by Bioelectrical Impedance Analysis and Estimated by Prediction Equations in Obese Groups

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***Abstract*—**Basal metabolic rate (BMR) is widely used and an accepted measure of energy expenditure. Its principal determinant is body mass. However, this parameter is also correlated with a variety of other factors. The objective of this study is to measure BMR and compare it with the values obtained from predictive equations in adults classified according to their body mass index (BMI) values. 276 adults were included into the scope of this study. Their age, height and weight values were recorded. Five groups were designed based on their BMI values. First group (n = 85) was composed of individuals with BMI values varying between 18.5 and 24.9 kg/m^2. Those with BMI values varying from 25.0 to 29.9 kg/m^2 constituted Group 2 (n = 90). Individuals with 30.0-34.9 kg/m^2, 35.0-39.9 kg/m^2, > 40.0 kg/m^2 were included in Group 3 (n = 53), 4 (n = 28) and 5 (n = 20), respectively. The most commonly used equations to be compared with the measured BMR values were selected. For this purpose, the values were calculated by the use of four equations to predict BMR values, by name, introduced by Food and Agriculture Organization (FAO)/World Health Organization (WHO)/United Nations University (UNU), Harris and Benedict, Owen and Mifflin. Descriptive statistics, ANOVA, post-Hoc Tukey and Pearson's correlation tests were performed by a statistical program designed for Windows (SPSS, version 16.0). p values smaller than 0.05 were accepted as statistically significant. Mean ± SD of groups 1, 2, 3, 4 and 5 for measured BMR in kcal were 1440.3 ± 210.0, 1618.8 ± 268.6, 1741.1 ± 345.2, 1853.1 ± 351.2 and 2028.0 ± 412.1, respectively. Upon evaluation of the comparison of means among groups, differences were highly significant between Group 1 and each of the remaining four groups. The values were increasing from Group 2 to Group 5. However, differences between Group 2 and Group 3, Group 3 and Group 4, Group 4 and Group 5 were not statistically significant. These insignificances were lost in predictive equations proposed by Harris and Benedict, FAO/WHO/UNU and Owen. For Mifflin, the insignificance was limited only to Group 4 and Group 5. Upon evaluation of the correlations of measured BMR and the estimated values computed from prediction equations, the lowest correlations between measured BMR and estimated BMR values were observed among the individuals within normal BMI range. The highest correlations were detected in individuals with BMI values varying between 30.0 and 34.9 kg/m^2. Correlations between measured BMR values and BMR values calculated by FAO/WHO/UNU as well as Owen were the same and the highest. In all groups, the highest correlations were observed between BMR values calculated from Mifflin and Harris and Benedict equations using age as an additional parameter. In conclusion, the unique resemblance of the FAO/WHO/UNU and Owen equations were pointed out. However, mean values obtained from FAO/WHO/UNU were much closer to the measured BMR values. Besides, the highest correlations were found between BMR calculated from FAO/WHO/UNU and measured BMR. These findings suggested that FAO/WHO/UNU was the most reliable equation, which may be used in conditions when the measured BMR values are not available.

***Keywords*—**Adult, basal metabolic rate, FAO/WHO/UNU, obesity, prediction equations.

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I. Introduction

BMR is defined as the daily minimum level of calories body requires at resting position in order to function effectively. It is used for estimating required energy content of food during everyday lifestyle activities. BMR gains importance particularly in obesity and diabetes mellitus (DM) [1]-[5]. BMR is measured, however, there are also many predictive BMR formulas [6]-[9]. Equations created for BMR are generally designed for healthy people. Therefore, their evaluation in individuals with obesity and DM is needed.

It was reported that the use of prediction equations was the fastest, simplest and cheapest way to estimate BMR. Gender, age, weight, height are some factors involved in these equations. However, there may be a possibility of the fact that these equations may overestimate or underestimate the results obtained by BMR values measured by several techniques such as bioelectrical impedance analysis, or indirect calorimetry to predict this valuable as well as informative parameter [7]-[11].

There are many studies [1], [5], [8] performed on overweight or obese adults, however, those investigating the performance of prediction equations in the individuals grouped, based upon different BMI intervals, are rare. Therefore, the aim of the present study was to indicate, which selected equation most accurately reflects basal metabolism according to varying degrees of obesity in adult population.

II. Patients and Methods

A. The Study Population

276 adults were involved in the study. Five groups were constituted. Group1 (18.5-24.9 kg/m^2), group 2 (25.0 to 29.9 kg/m^2), group 3 (30.0-34.9 kg/m^2), group 4 (35.0-39.9 kg/m^2) and group 5 (> 40.0 kg/m^2) were composed of 85, 90, 53, 28 and 20 individuals, respectively. Informed consent forms were obtained from the participants and documented. This study was carried out according to the Declaration of Helsinki developed by the World Medical Association.

B. Measurement of BMR

BMR was measured using Bioelectrical Impedance Analysis. TANITA body composition monitor was used to obtain the measurements.

C. Prediction Equations

BMR was estimated by four commonly used prediction equations. Equations derived by Harris & Benedict, FAO/ WHO/UNU, Owen and Mifflin were used for the calculation of BMR values by using weight, height and age values of the individuals. There were different equations created for males and females (Table I) [12]-[15].

TABLE I
SELECTED PREDICTION EQUATIONS FOR ESTIMATING BMR

Equations
HARRIS and BENEDICT
Men: 66.4730 + 13.7516W + 5.0033H - 6.7550A
Women: 655.0955 + 9.5634W + 1.8496H - 4.6756A
FAO/WHO/UNU
Men: 11.6W + 879
Women: 8.7W + 829
OWEN
Men: 879 + 10.2W
Women: 795 + 7.18W
MIFFLIN
Men: 9.99W + 6.25H - 4.92A + 5
Women: 9.99W + 6.25H - 4.92A - 161

W = weight, H = height, A = age.

The difference between BMR estimated by the above equations and BMR measured by bioelectrical impedance analysis was calculated (estimated BMR-measured BMR). The percentage of deviation between estimated BMR values for each prediction equation and the measured BMR were calculated [(eBMR-mBMR)/mBMR]*100. The Bland and Altman method [16] was used to evaluate the agreement between the results of the measured and estimated BMR.

D. Statistical Analysis

Descriptive statistics were performed. Mean values as well as standard deviations of the parameters were recorded. Differences between the means were evaluated by ANOVA and *post hoc* Tukey. One-sample t-test was performed and confidence intervals were determined. Pearson's correlation coefficient was used to assess the correlations between the groups. p value greater than 0.05 was considered as non-significant.

III. RESULTS

Measured BMR values in kcal (mean ± SD) of groups 1, 2, 3, 4 and 5 were 1440.3 ± 210.0, 1618.8 ± 268.6, 1741.1 ± 345.2, 1853.1 ± 351.2 and 2028.0 ± 412.1, respectively. Mean values, differences and percent deviations between the estimated and measured BMR values were tabulated for men as well as women (Tables II and III).

The Bland-Altman charts are shown in Figs. 1 and 2. In these scatterplots, the difference of the two measurements for each sample on the vertical axis and the average of the two measurements on the horizontal axis were drawn. Three horizontal reference lines were superimposed on the scatterplots. In these figures, the agreement between measured BMR and estimated BMR values obtained using FAO/WHO/ UNU formula were shown.

TABLE II
COMPARISON BETWEEN THE ESTIMATED AND MEASURED BMR IN MEN

Variable	Mean ± SD	95% CI
Measured		Lower Upper
BMR (kcal)	1877.6 ± 367.5	1807.1 - 1948.0
	Estimated BMR (kcal)	
Harris & Benedict	1762.2 ± 350.4	1695.1 – 1829.4
Difference	-115.4	(-133.8) – (-96.9)
Deviation%	-6.1	(-7.0) – (-5.1)
FAO/WHO/UNU	1845.0 ± 240.3	1798.9 – 1891.1
Difference	-32.6	(-63.3) – (-1.8)
Deviation%	-0.36	(-1.98) – 1.26
Owen	1728.4 ± 211.3	1687.9 – 1768.9
Difference	-149.2	(-183.9) – (-114.5)
Deviation%	-6.5	(-8.2) – (-4.9)
Mifflin	1690.3±264.1	1639.7 – 1740.9
Difference	-187.3	(-212.6) – (-161.9)
Deviation%	-9.2	(-10.3) – (-8.1)

CI = Confidence Interval.

TABLE III
COMPARISON BETWEEN THE ESTIMATED AND MEASURED BMR IN WOMEN

Variable	Mean ± SD	95% CI
Measured		Lower Upper
BMR (kcal)	1476.9 ± 207.4	1446.4 – 1507.4
	Estimated BMR (kcal)	
Harris & Benedict	1495.3 ± 185.2	1468.1 – 1522.5
Difference	18.4	8.2 – 28.6
Deviation%	1.7	0.9 – 2.5
FAO/WHO/UNU	1494.8±161.4	1471.1 – 1518.5
Difference	17.9	6.5 – 29.4
Deviation%	1.6	0.9 – 2.3
Owen	1344.5 ± 133.2	1324.9 – 1364.1
Difference	-132.4	(-146.2) – (-118.6)
Deviation%	-8.4	(-9.2) – (-7.6)
Mifflin	1411.7 ± 204.3	1381.6 – 1441.7
Difference	-65.2	(-76.4) – (-54.1)
Deviation%	-4.3	(-5.1) – (-3.6)

CI = Confidence Interval.

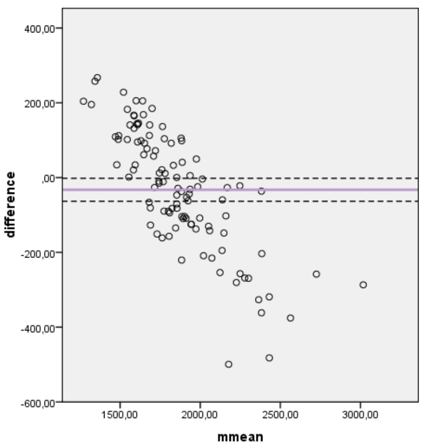

Fig. 1 Analysis of Bland-Altman association in men [difference = estimated $BMR_{FAO/WHO/UNU}$ - measured BMR], [mmean = ½ (estimated $BMR_{FAO/WHO/UNU}$ + measured BMR)]

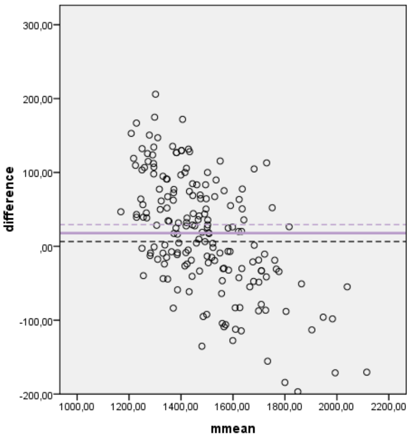

Fig. 2 Analysis of Bland-Altman association in women [difference = estimated $BMR_{FAO/WHO/UNU}$ - measured BMR], [mmean = ½ (estimated $BMR_{FAO/WHO/UNU}$ + measured BMR)]

The comparison of means pointed out that highly significant differences were observed between Group 1 and the other groups. An increasing trend as going from Group 2 to Group 5 was observed. Differences between groups 2 *vs* 3, 3 *vs* 4, and 4 *vs* 5 were insignificant.

Except Mifflin (Group 4 and Group 5), all of the above differences were turned out to be statistically significant upon evaluation of the values calculated by Harris and Benedict, FAO/WHO/UNU and Owen formulas.

The correlation coefficients were calculated for measured as well as prediction equations in all groups. The lowest and the highest correlations were recorded. The lowest correlation coefficients were detected in Group 1 and the highest correlation coefficients were obtained in Group 3.

Upon evaluation of the same parameters, correlation coefficients calculated between measured BMR and estimated BMR values predicted by FAO/WHO/UNU as well as by Owen were found to be the same in each individual group. At the same time, these were the highest correlations in each group.

IV. Discussion

The evaluation of BMR is still being a matter of interest in various groups of population including elderly as well as obese and overweight groups defined as the individuals with excess weight [17], [18].

The studies were generally designed as the comparison of BMR values obtained from a large number of prediction equations with the values measured by various techniques. However, sometimes, there may be more than one suggestion for the formulas to be used as in the case of FAO/WHO/UNU [5], [8], [11]. In many reports, these equations are continuously questioned whether they are in agreement with measured BMR or they overestimate/underestimate measured BMR [8]-[11].

In a recently published article performed on the elderly living in a tropical city of Brazil, all predictive equations were reported as the equations providing biased, inaccurate estimates of BMR values when they are compared to measured BMR [17]. This study was performed on 79 women.

It was reported that increased BMR values observed in overweight and obese patients with type 2 DM compared to the individuals with N-BMI may result from the difference in fat-free mass [1]. Another study performed on 45 women in 2019 studied eleven equations. Of them, five including FAO/ WHO/UNU showed non-significant bias. They concluded that FAO/WHO/UNU equation performed better than the others, since its mean percentage difference was the lowest [18].

In conclusion, the results of our study agreed with the finding of the above study. Equations given for FAO/WHO/ UNU and Owen were extremely similar. However, values calculated from FAO/WHO/UNU equation were the closest to measured BMR values among all. Also, the highest correlations were obtained between these two parameters. According to these findings, both in men and women, FAO/ WHO/UNU has given the most satisfactory results, which may be considered when the BMR values cannot be measured due to the unavailability of the related techniques.

References

[1] M. X. Sun, S. Zhao, H. Mao, Z. J. Wang, X. Y. Zhang, and L. Yi, "Increased BMR in overweight and obese patients with type 2 diabetes may result from an increased fat-free mass," *J. Huazhong Univ. Sci. Technolog. Med. Sci.,* vol. 36, no. 1, pp. 59-63, Feb. 2016.

[2] https://tanita.eu /help-guides/products-manuals/ (Accessed on 01/ 12/ 2019).

[3] S. Aliasgharzadeh, R. Mahdavi, M. Asghari Jafarabadi, and N. Namazi, "Comparison of indirect calorimetry and predictive equations in estimating resting metabolic rate in underweight females," *Iran. J. Public Health,* vol. 44, no. 6, pp. 822-829, Jun. 2015.

[4] E. Pavlidou, D. Petridis, M. Tolia, N. Tsoukalas, A. Poultsidi, A. Fasoulas, et al., "Estimating the agreement between the metabolic rate calculated from prediction equations and from a portable indirect calorimetry device: an effort to develop a new equation for predicting resting metabolic rate," *Nutr. Metab. (Lond).,* vol.15, pp. 41, Jun. 2018.

[5] S. C. Luy, and O. A. Dampil, "Comparison of the Harris-Benedict equation, bioelectrical impedance analysis, and indirect calorimetry for measurement of basal metabolic rate among adult obese Filipino patients with prediabetes or type 2 diabetes mellitus," *J. Asean Fed. Endocr. Soc.,* vol. 33, no. 2, pp. 152, Sep. 2018.

[6] T. E. Nightingale, and A. S. Gorgey, "Predicting basal metabolic rate in men with motor complete spinal cord injury," *Med. Sci. Sports Exerc.,* vol. 50, no. 6, pp. 1305-1312, Jun. 2018.

[7] M. F. Ferreira, F. Detrano, G. M. O. Coelho, M. E. Barros, R. S. Lanzilotti, J. F. N. Neto, et al., "Body composition and basal metabolic rate in women with type 2 diabetes mellitus," *J. Nutr. Metabol.,* vol. 2014, no. 574057, pp. 1-9, Nov. 2014.

[8] R. Miyake, K. Ohkawara, K. Ishikawa-Takata, A. Morita, S. Watanabe, and S. Tanaka, "Obese Japanese adults with type 2 diabetes have higher basal metabolic rates than non-diabetic adults," *J. Nutr. Sci. Vitaminol. (Tokyo),* vol. 57, no. 5, pp. 348-354, 2011.

[9] R. Miyake, S. Tanaka, K. Ohkawara, K. Ishikawa-Takata, Y. Hikihara, E. Taguri, et al., "Validity of predictive equations for basal metabolic rate in Japanese adults," *J. Nutr. Sci. Vitaminol. (Tokyo),* vol. 57, no. 3, pp. 224-232, 2011.

[10] S. Miller, B. J. Milliron, and K. Woolf, "Common prediction equations overestimate measured resting metabolic rate in young Hispanic women", *Top. Clin. Nutr.,* vol. 28, no. 2, pp. 120-135, Apr. 2013.

[11] T. Steemburgo, C. Lazzari, J. B. Farinha, T. P. Paula, L. V. Viana, A. R. Oliveira, et al., "Basal metabolic rate in Brazilian patients with type 2 diabetes: comparison between measured and estimated values," *Arch. Endocrinol. Metab.,* vol. 63, no. 1, pp. 53-61, Feb. 2019.

[12] J. A. Harris, and F. G. Benedict, A Biometric Study of Basal Metabolism in Man, Carnigie Institution of Washington, Boston, Mass, USA, 1919.

[13] Food and Agriculture Organization, World Health Organization, and United Nations University, “Energy and protein requirements,” WHO Technical Report Series 724, WHO, Geneve, Switzerland, 1985.
[14] O. E. Owen, E. Kavle, R. S. Owen, et al., “A reappraisal of caloric requirements in healthy women,” *Am. J. Clin. Nutr.,* vol. 44, no. 1, pp. 1-19, 1986.
[15] M. D. Mifflin, S. T. Jeor, L. A. Hill, B. J. Scott, S. A. Daugherty, and Y. O. Koh, “A new predictive equation for resting energy expenditure in healthy individuals,” *Am. J. Clin. Nutr.,* vol. 51, no. 2, pp. 241-247, 1990.
[16] J. M. Bland, and D. G. Altman, “Statistical methods for assessing agreement between two methods of clinical measurement,” *Lancet,* vol. 327, no. 8476, pp. 307-310, 1986.
[17] M. R. Sgambato, V. Wahrlich, and L. A. D. Anjos, “Validity of basal metabolic rate prediction equations in elderly women living in an urban tropical city of Brazil,” Clin. Nutr. ESPEN, vol 32, pp. 158-164, Aug. 2019.
[18] M. L. Macena, I. R. O. M. Pureza, I. S. V. Melo, A. G. Clemente, H. S. Ferreira, T. M. M. T. Florêncio et al., “Agreement between the total energy expenditure calculated with accelerometry data and the BMR yielded by predictive equations v. the total energy expenditure obtained with doubly labelled water in low-income women with excess weight,” *Br. J. Nutr.,* vol. 122, no. 12, pp. 1398-1408, Dec. 2019.