

Measured Versus Predicted Resting Metabolic Rate in Obese Diabetic and Obese Non-Diabetic Subjects

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Abstract: Predictive equations provide the basis for estimating energy needs for different individuals; however, accuracy of these equations has been questioned in tropical countries. The current study determined which of the commonly used predictive equations is most suitable for estimating resting metabolic rate (RMR) in a random sample of obese diabetic and obese non-diabetic subjects in Sudan. Two matched samples of 40 obese diabetic and 40 obese non-diabetic subjects, aged 35 to 50 years old, were randomly selected. The PowerLab 8/35 with a gas analyzer (ADInstruments, Castle Hill Australia) was used for measurement of O₂ consumption and CO₂ production for each participant. RMR was derived from these parameters using Weir's formula. Three predictive equations (Harris-Benedict, Mifflin and Food and Agriculture Organization/ World Health Organization/ United Nations University (FAO/WHO/UNU) were compared with the measured RMR to determine their accuracy in predicting RMR for the two groups. Unlike the other two equations, Mifflin's equation showed insignificant statistical difference between measured and predicted RMR in obese diabetic patients; however, none of the three equations gave accurate results for the obese non-diabetic individuals. It is recommended that a new predictive equation should be developed for estimating RMR in the obese non-diabetic individuals.

Keywords: Obesity, Diabetes mellitus, Resting metabolic rate, Indirect calorimetry, Weir's formula, Predictive equations

I. INTRODUCTION

Resting metabolic rate (RMR) is the amount of energy released from a resting subject per unit time. The release and utilization of energy in this state is sufficient primarily for functioning of the vital organs. Measurement of RMR is essential for nutritional assessment, weight loss planning and management of various medical conditions. Because of the increasing worldwide awareness about its importance, a free metabolic rate calculator, based on one of the predictive equations, was recently released as a new application for advanced mobile phones [1]. In addition to providing an easy and rapid calculation of basal metabolic rate, this software program application serves to spread knowledge about energy expenditure to a large number of people, especially those who use this sort of modern technology.

The primary method for metabolic rate measurement is indirect calorimetry whereby oxygen consumption and carbon dioxide production in expired air are directly measured for calculation of energy expenditure. RMR is derived from these parameters with the Weir formula which is widely used for metabolic rate calculations [2,3]. Predictive equations like Harris-Benedict [4,5], Food and Agriculture Organization/World Health Organization/United Nations University(FAO/ WHO/UNU)[6], and Mifflin [7] equations, which were introduced in 1918, 1985 and 1990 respectively, are still widely used for calculation of resting energy expenditure. These equations are simple, easy to use, and universally available. However, in spite of their extensive use, they have been found to be inaccurate in a variety of clinical settings [8,9]. While the Harris-Benedict equation had been used for estimating the basal metabolic rate, previous studies have found that it estimates RMR rather than basal metabolic rate, due to the test subjects not spending the night at the test facility [10]. The Mifflin equation, tested in different settings worldwide, has been shown to produce more accurate estimations for RMR than other predictive equations [8-11]. It has been recommended as the standard equation for calculating RMR in healthy obese and non-obese adults [10]. However, contradictory results have been recently reported from data obtained in tropical countries [12]. FAO/WHO/UNU equations, which are based on the work of Schofield *et al*, were developed from older research conducted in western communities [13]. Their validity in the estimation of resting energy expenditure worldwide needs to be re-evaluated.

In clinical practice, predictive equations provide the basis for estimating energy needs for different individuals. However, a number of predictive equations were found to be inaccurate in obese subjects especially those with diabetes [5,14,15]. In Sudan, there is paucity of data regarding which equation should be used. On the other hand, the finding that basal metabolic rate values in African Americans were lower than values in Caucasians [16], has indicated a genetic variation in energy expenditure between individuals. Consistence with this, a previous survey showed lower basal metabolic rate values of people in the tropics as compared to values

estimated with WHO predictive equations [17]. The researchers recommended further evaluation of energy requirements in people living in tropical climates. Thus, the aim of the current study was to determine which predictive equation does not differ from indirect calorimetry in estimating RMR in both obese diabetic and obese non-diabetic subjects.

II. METHODS

This study was conducted in Jabir Abu-Eliz centre in Khartoum- Sudan, in the period between January to August 2012. A random sample of 40 obese diabetic patients and 40 obese non-diabetic subjects were selected from patients attending for follow up of their diabetes and from their healthy relatives respectively. Inclusion criteria for both groups were adult, 35 to 50 years old, body mass index ≥ 30 , non-smoker, normotensive, afebrile and with no symptoms or signs of acute or chronic infection. Cases were known to be diabetic for at least one year, whereas controls were non-diabetic. Both groups were matched according to age, sex, height, weight, surface area and area of residence. Each participant completed an anonymous interviewer-based questionnaire; to obtain information about present health status. Clinical examination excluded presence of abnormal clinical signs. Height and weight of each participant was measured using standardized height and weight scales. The PowerLab 8/35 (ADInstruments, Castle Hill Australia) data acquisition system, comprising hardware and software, was used with bio amplifier, thermistor, spirometer, gas analyzer, gas mains chamber and a computer windows 7 program to record and analyze physiological signals from participants. The system allowed measurement of oxygen consumption (VO₂), carbon dioxide production (VCO₂), respiratory ventilation (VE) and respiratory exchange ratio (RER). All participants fasted overnight and were allowed to rest in a thermally neutral room for 30 min before measurements. Each test took about 20 min, with at least 5 min steady state. The steady state was defined as minimal variation (< 10%) in VO₂, VCO₂, VE and RER. RMR was calculated using Weir's formula [2,3] as follows: $RMR \text{ (kcal/day)} = 5.46 \text{ VO}_2 + 1.75 \text{ VCO}_2$. Three predictive equations ("Harris-Benedict", "FAO/WHO/UNU" and "Mifflin" were assessed for their accuracy in predicting RMR among all participants in the study. RMR (kcal/day) using:

The Harris-Benedict equation [4,5]:

$$(13.7516wt/1kg + 5.0033ht/1cm - 6.7550age/1year + 66.4730) \text{ for men}$$

$$(9.5634wt/1kg + 1.8496ht/1cm - 4.6756age/1year + 655.0955) \text{ for women}$$

The FAO/WHO/UNU equation [6]:

$$(11.6 \times \text{weight} + 879) \text{ for males in the age group from 31 to 60 years old}$$

$$(8.7 \times \text{weight} + 829) \text{ for females in the age group from 31 to 60 years old}$$

The Mifflin equation [7]:

$$(10.0wt/1kg + 6.25ht/1cm - 5.0age/1year + s); \text{ where } s \text{ is } +5 \text{ for males and } -161 \text{ for females}$$

All procedures conformed to the ethical principles of medical research as developed by the World Medical Association Declaration of Helsinki [18]. Ethical clearance was given by the institutional Research Committee (Faculty of Medicine/ University of Al-Neelain- Sudan) and approval was obtained from the Ministry of Health. Written consents were obtained from each participant before entry into the study. All data obtained were analysed using the Statistical Package for the Social Sciences V.16 (SPSS Inc.). Differences in mean RMR between diabetic and non-diabetic individuals were analysed with the independent student's t tests. Comparisons between measured and predicted RMR were determined with paired student's t tests. Statistical significance was accepted for $p \leq 0.05$.

III. RESULTS

Table 1 describes characteristics of participants in the study group. The two groups did not differ in age, gender, height, weight, body mass index and surface area. Table 2 shows measured and predicted RMR in diabetic and non-diabetic participants. Measured RMR (mean \pm SD in kcal/day) was significantly higher ($p=0.027$) among diabetic (1480.7 ± 274.2) as compared to the non-diabetic (1362.4 ± 184.8) patients. No differences were found between the two groups in predicted RMR with the three equations. Among the diabetic patients, the difference in means between predicted and measured RMR was 11% for Harris-Benedict equation (table 3), 4.5% for Mifflin equation (table 4), and 14% for FAO/WHO/UNU equation (table 5). Among the non-diabetic participants, the mean differences were 24%, 17%, and 26% for Harris-Benedict, Mifflin and FAO/WHO/UNU equations respectively. In obese diabetic patients, no difference was seen between measured RMR and that predicted with Mifflin equation (table 4).

Table 1: Characteristics of participants in the study group

Parameter	Study group	P value
Age (mean ± SD) y	Diabetics: 45.03 ± 5.09 Non-diabetics: 44.33 ± 5.69	0.564
Gender (Male: Female) ratio	Diabetics: 2: 3 Non-diabetics: 2: 3	1.000
Height (mean ± SD) cm	Diabetics: 1.63 ± 0.08 Non-diabetics: 1.66 ± 0.08	0.094
Weight (mean ± SD) kg	Diabetics: 85.00 ± 7.70 Non-diabetics: 86.52 ± 11.35	0.486
BMI kg/m ²	Diabetics: 32.04 ± 2.08 Non-diabetics: 32.29 ± 2.06	0.328
Surface area (mean ± SD) m ²	Diabetics: 1.96 ± 0.128 Non-diabetics: 2.01 ± 0.126	0.078

The two groups did not differ in age, gender, height, weight, body mass index and surface area.

Table 2: Comparison in resting energy expenditure between obese diabetic and obese non-diabetic participants

Measurement method/equation	Study group	Resting metabolic rate (mean ± SD) kcal/day	Confidence intervals kcal/day	P value
Indirect calorimetry	Diabetics (n=40)	1480.7 ± 274.2	1393.0-1568.4	0.027
	Non-diabetics (n=40)	1362.4 ± 184.8	1303.3-1421.5	
Harris-Benedict	Diabetics (n=40)	1646.6 ± 176.4	1590.1-1703.0	0.308
	Non-diabetics (n=40)	1689.3 ± 195.7	1627.0-1751.9	
Mifflin	Diabetics (n=40)	1547.6 ± 170.3	1493.2-1602.1	0.198
	Non-diabetics (n=40)	1598.1 ± 177.0	1541.5-1654.6	
FAO/WHO/UNU	Diabetics (n=40)	1691.6 ± 194.6	1629.3-1753.8	0.528
	Non-diabetics (n=40)	1719.2 ± 195.1	1656.8-1781.6	

Indirect calorimetry showed significantly higher ($p=0.027$) resting metabolic rate in obese diabetic patients as compared to the non-diabetic, while no differences were found between the two groups with the three predictive equations.

Table 3: Indirect calorimetry versus Harris-Benedict's equation in calculation of resting metabolic rate

Parameter	Resting metabolic rate (kcal/day)			
	Obese diabetic (n= 40)		Obese non-diabetic (n= 40)	
	Indirect Calorimetry	Harris-Benedict's equation	Indirect Calorimetry	Harris-Benedict's equation
Minimum	1155.6	1403.5	1057.3	1465.4
Maximum	2238.8	2085.0	1787.3	2189.6
Mean ± SD	1480.7 ± 274.2	1646.6 ± 176.4	1362.4 ± 184.8	1689.3 ± 195.7
Difference	11%		24%	
P value	0.001		0.000	

The Harris-Benedict equation significantly overestimates ($p<0.05$) resting metabolic rate in the two groups.

Table 4: Indirect calorimetry versus Mifflin's equation in calculation of resting metabolic rate

Parameter	Resting metabolic rate (kcal/day)			
	Obese diabetic (n= 40)		Obese non-diabetic (n= 40)	
	Indirect Calorimetry	Mifflin's equation	Indirect Calorimetry	Mifflin's equation
Minimum	1155.6	1260.3	1057.3	1354.0
Maximum	2238.8	1941.3	1787.3	2023.8
Mean ± SD	1480.7 ± 274.2	1547.6 ± 170.3	1362.4 ± 184.8	1598.1 ± 177.0
Difference (%)	4.5%		17%	
P value	0.164		0.000	

In obese diabetic participants, but not the obese non-diabetic, no difference was seen between measured RMR and that predicted with the Mifflin equation.

Table 5: Indirect calorimetry versus FAO/WHO/UNU equation in calculation of resting metabolic rate

Parameter	Resting metabolic rate (kcal/day)			
	Obese diabetic (n= 40)		Obese non-diabetic (n= 40)	
	Indirect Calorimetry	FAO/WHO/UNU equation	Indirect Calorimetry	FAO/WHO/UNU equation
Minimum	1155.6	1429.3	1057.3	1507.6
Maximum	2238.8	2097.0	1787.3	2097.0
Mean ± SD	1480.7 ± 274.2	1691.6 ± 194.6	1362.4 ± 184.8	1719.2 ± 195.1
Difference (%)	14%		26%	
P value	0.000		0.000	

The FAO/WHO/UNU equation significantly overestimates ($p<0.05$) resting metabolic rate in the two groups.

IV. DISCUSSION

The measurement of energy expenditure is an important element in estimation of energy requirements. In addition to its importance in scientific research, it has become an essential tool in maintenance of a healthy body weight. Obese subjects, especially those with type II diabetes mellitus, may need special consideration because insulin resistance in these individuals is associated with abnormal metabolic reactions in skeletal muscle, liver, and adipose tissue that alters their metabolic rate. In the present study, we found that RMR was significantly higher among obese diabetic patients as compared to the non-diabetic controls. A similar finding was reported by Weyer and colleagues, who described a progressive increase in RMR with progressive deterioration of glucose tolerance [19]. Other researchers have attributed weight loss that is often observed in Type 2 diabetic subjects to higher energy expenditure in addition to the energy loss from glycosuria [20]. Additional similar results have been recently reported in severely obese diabetic patients [21]. These researchers suggested a new predictive equation for calculation of RMR in diabetic patients using gender, age, height, weight and diabetes mellitus as variables [21]. In an earlier study, race had been suggested as a key variable [22] while fasting blood sugar has also been suggested [23]. The inconsistent results and the different variables suggested in these studies indicate that estimation of RMR in obese diabetic patients using predictive equations may be misleading and requires further investigations.

Several mechanisms have been proposed to explain the rise in resting energy expenditure among diabetic patients. One of these mechanisms is an increase in gluconeogenesis [24]. A positive correlation has been reported between free fatty acid concentration in the plasma and release of glucose from the liver in diabetic patients [19,25]. Furthermore, previous studies reported a reduction in resting energy expenditure following improvement in glycemic control [26]. Other proposed mechanisms for the higher RMR in diabetic patients include abnormal protein metabolism [27], increased sympathetic activity [28] and hyperglucagonaemia [29].

Calculation of RMR using Weir's derivation showed a difference between diabetic and non-diabetic subjects, whereas no difference emerged when the three predictive equations were used. These equations are not expected to detect difference in energy expenditure between two matched groups because of similar variables. For this reason, development of new predictive equations that include diabetes mellitus or fasting blood sugar as additional variables is justified [21,23].

The mean RMR values estimated with these predictive equations were higher in both diabetic and non-diabetic subjects as compared to the mean values measured with indirect calorimetry. This finding confirms results of previous studies that described overestimation of RMR when calculated with predictive equations [30,31]. According to our results, the Harris-Benedict equation overestimated the RMR among diabetic patients by about 11%, FAO/WHO/UNU equations by 14%, and the Mifflin equation overestimated it by only 4.5%. Statistical analysis confirmed that the Mifflin equation is more suitable than the other equations for estimating RMR among obese diabetic patients. Similar findings were reported in many previous studies [8-11,30,31]. On the other hand, although differences between measured and predicted RMR in obese non-diabetic individuals is lowest for Mifflin equation, statistical analysis showed significant difference between the two methods. This indicates the need for developing new predictive equation for RMR estimation in obese people living in the tropics.

V. CONCLUSION

This study showed that the RMR rate is higher in obese diabetic patients compared to obese non-diabetic individuals. Predictive equations were unlikely to detect difference in RMR between diabetic and non-diabetic subjects. The Mifflin equation is more reliable than Harris-Benedict and FAO/WHO/UNU equations in estimating RMR in obese diabetic patients. A new predictive equation is needed for obese non-diabetic individuals.

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