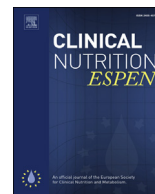




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Original article

Validation of resting metabolic rate equations in obese and non-obese young healthy adults



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SUMMARY

Background and aims: Although validating resting metabolic rate (RMR) prediction equations in different populations is warranted to estimate total energy requirements, there are no data about the accuracy and applicability of RMR predictive equations in young healthy Jordanians. This study aimed to test the validity of predicted RMR using four prediction equations and its agreement with RMR measured using indirect calorimetry in healthy young obese and non-obese Jordanian adults.

Methods: Predicted RMR was tested for agreement with indirect calorimetry. Harris–Benedict, Food and Agriculture Organization/World Health Organization/United Nations University, Mifflin and Owen equations were used to predict RMR. A total of 406 (200 females, 206 males) normal bodyweight, overweight, and obese healthy young adults aged 18–25 years were included.

Results: Of all tested equations, Harris–Benedict equation showed no significant differences compared to measured RMR using indirect calorimetry ($p > 0.05$) in normal bodyweight (1374.1 ± 72.5 vs. 1347.6 ± 333.4), overweight (1513.1 ± 66.8 vs. 1492.9 ± 374.8) and obese (1673.5 ± 178.4 vs. 1736.4 ± 386.9) females. While significant differences ($p < 0.05$) were found in all male participants. The other studied equations showed significant differences ($p \leq 0.05$) compared to measured RMR in gender based groups with different bodyweight status.

Conclusion: Only Harris–Benedict equation was the most accurate in predicting RMR among females regardless of bodyweight status. Apart from that, these equations did not perform well at the group level. The tested prediction equations further underestimated RMR. Future studies aiming at validating RMR prediction equations in different populations are warranted in order to understand the factors that could affect the accuracy of RMR prediction.

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1. Introduction

Resting metabolic rate (RMR) is described as the quantity of energy released from an individual at resting state per unit of time; however, the utilized and released energy in this state is sufficient for vital organs functioning [1]. Measuring RMR is essential for determining both resting energy expenditure and total energy requirements. Thus, it has become an increasingly important tool in nutrition status assessment and care plan, maintaining healthy

bodyweight as well as scientific research, in order to estimate total energy requirements [2].

The traditional indirect calorimetry is the “golden standard” method for assessing RMR by which RMR is estimated in vivo from carbon dioxide and oxygen exchange measurements [3]. Using indirect calorimetry could not be feasible in every setting since it is time consuming and requires specialized equipment. Therefore, practical measures such as using prediction equations in estimating total energy expenditure remain necessary [4]. Although the prediction equations provide an easy method to estimate RMR, the accuracy of which likely varies across individuals and group levels, thus, validating RMR prediction equations could marginally provide means to calculate energy requirements in various populations. Food and Agriculture Organization/World Health Organization/United Nations University (FAO/WHO/UNU) [5], Mifflin [6], Harris–Benedict [7], and Owen [8] equations are among a

Abbreviations: RMR, resting metabolic rate; FAO/WHO/UNU, Food and Agriculture Organization/World Health Organization/United Nations University; BMR, basal metabolic rate; WC, waist circumferences; HC, hip circumferences; WHR, Waist -to-hip ratio; BMI, body mass index.

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wide range of widely used, simple, quick and easy to perform RMR prediction equations.

Harris–Benedict equation was first introduced in 1919 for estimating basal metabolic rate (BMR). Nevertheless, a previous report suggested that Harris–Benedict equation estimates RMR rather than BMR since the study participants did not spend the night in the test facility [9]. FAO/WHO/UNU equations are based on the work of Schofield and colleagues [10], which were developed based on Western populations [10]. Additionally, Owen [8] and Mifflin [6] equations were more recently introduced. While Owen equation [8] was based on a small sample size with wide range of body sizes and ages, Mifflin equation [6] was more accurate in predicting RMR in different settings and populations worldwide as compared to the other tested RMR prediction equations [9,11]. Accurate determination of RMR using various prediction equations and the reliability of these equations in different populations and different settings remain inconsistent and requires further validation [12].

The rampant increase of overweight and obesity in both developed and developing populations, regardless of geographic location, socioeconomic status or age groups, has been described as a global pandemic, which highlights an alarming worldwide health challenge. The global combined prevalence of overweight and obesity rose by 47.1% for children and 27.5% for adults [13]. This could be attributed, at least in part, to discrepancies in the accurate determination of RMR, which could lead to overestimate the total energy requirement of healthy, overweight and obese individuals, thereby, predisposing children and young adults to the development of obesity-related comorbidities. Consequently, it is pivotal not only to determine the dietary and non-dietary risk factors of overweight and obesity in young populations, but also to accurately determine RMR and total energy requirements as well as to identify possible confounding factors that could influence the accuracy of the predicted RMR, including, but not limited to genetic variation [14] and lean body mass [15], which might be the first step toward the prevention or at least amelioration of obesity and its sequelae [3,14].

Validating RMR predication equations in different populations is warranted, on the other hand, studies that examine the accuracy and applicability of RMR predictive equations in young healthy populations remain scarce [4]. Validating RMR prediction equations in young, healthy Jordanians has yet not been investigated. Therefore, this study aimed in determining the accuracy of Harris–Benedict, FAO/WHO/UNU, Mifflin, and Owen predictive RMR equations in a group of young obese and non-obese healthy Jordanians. The findings of this study would then be used to plan for appropriate public health policies and dietary interventions; such as calculating energy requirements among youth, help establish vigorous models of weight gain and loss and expedite the calibration of individualized medical nutrition interventions.

2. Materials and methods

2.1. Study design and human participants

This study was carried out in Jordan at the Obesity and Metabolomics Laboratory, Hamdi Mango Center for Scientific Research at the University of Jordan. A total of 406 (200 females and 206 males), apparently healthy university undergraduate students (18–25 years) were recruited from all 19 academic faculties of the University of Jordan, which is the largest state university in Jordan with more than 42,000 enrolled undergraduate students admitted from all over the country. The current sample size was allocated according to the population of the University of Jordan using the population sample size equation provided by Oveson [16].

The investigators of the study directly contacted potential participants either in person, by giving a presentation to a group or on the internet postings. In addition, advertisements, flyers, information sheets and notices were posted on faculties' bulletin boards, after the text was approved by the Deanship of Students Affairs, the University of Jordan.

Participants gave a written consent before inclusion and were provided with a brief verbal explanation regarding the objectives and methods of the study. Students with acute or chronic illnesses, receiving any medical treatments, having weight alteration within the last three months of the study or were underweight (BMI <18.5 kg/m²) were excluded from the study, likewise, pregnant or lactating females were also excluded [4,9].

In a follow-up session, body weight (kg) and height (cm), waist circumference (WC), and hip circumference (HC) were measured using standard procedures. Waist-to-hip ratio (WHR) and body mass index (BMI) were calculated. Male and female participants were categorized into three groups: normal bodyweight, overweight and obese according to the WHO classifications [18]. All measurements were performed according to WHO protocol [19]. The study protocol was approved by the Human Research Ethics Committee of Hamdi Mango Center for Scientific Research.

2.2. Resting metabolic rate

Resting metabolic rate (RMR) was measured between 9 and 12 a.m. at two sessions in non-consecutive days using indirect calorimeter (MetaCheck, KORR Medical Technologies Inc, UT, USA) which was calibrated before each test. Measurements were performed following an overnight fasting (10–12 h) under thermo-neutral conditions that keep body temperature at an optimum point at which the least amount of oxygen is consumed for metabolism (in a 22–25 °C room temperature) [20]. Participants were asked to breathe through a sterile mouthpiece with nostrils occluded attached to a sensor that measures the volume and oxygen extraction. Measurements were performed while participants were at rest in a supine position for at least 10 min.

This paper will refer to “predicted RMR” for RMR predicted by the RMR prediction equations, and “measured RMR” for RMR measured by indirect calorimetry. Four equations were used to predict RMR: Harris–Benedict [7], FAO/WHO/UNU [5], Mifflin [6] and Owen [8]. RMR predicted values (kcal/day) were calculated. All equations were performed using weight in kg, height in cm, and age in years.

Harris–Benedict equation [7]

$$\begin{aligned} \text{RMR (for males)} = & 66.473 + [13.752 \times \text{Weight}] \\ & + [5.003 \times \text{Height}] - [6.755 \times \text{Age}] \end{aligned}$$

$$\begin{aligned} \text{RMR (for females)} = & 655.096 + [9.563 \times \text{Weight}] \\ & + [1.850 \times \text{Height}] - [4.676 \times \text{Age}] \end{aligned}$$

FAO/WHO/UNU equation (18–30 years) [5]

$$\text{RMR (for males)} = 15.3 \times \text{weight} + 679$$

$$\text{RMR (for females)} = 14.7 \times \text{weight} + 469$$

Mifflin equation [6]

$$\text{RMR (for males)} = 9.99 \times \text{weight} + 6.25 \times \text{height} - 4.92 \\ \times \text{age} + 5$$

$$\text{RMR (for females)} = 9.99 \times \text{weight} + 6.25 \times \text{height} - 4.92 \\ \times \text{age} - 161$$

Owen equation [8]

$$\text{RMR (for males)} = 879 + 10.2 \times \text{weight}$$

$$\text{RMR (for females)} = 795 + 7.2 \times \text{weight}$$

2.3. Statistical analysis

Statistical analysis was performed using SPSS software (SPSS Inc. Released 2008. SPSS Statistics for Windows, Version 17.0. Chicago: SPSS Inc.). Data are expressed as mean $\pm$ standard deviation. Mean difference of continuous variables were examined using one way ANOVA. Differences among groups were examined using post hoc Tukey test. Comparisons between measured and predicted RMR values were determined using paired student's *t* tests. All *p*-values of equal or less than 0.05 were considered statistically significant.

3. Results

Age and anthropometric measurements are outlined in Table 1. There was no significant age difference among all groups ($p > 0.05$). With the exception for height in males, all anthropometric indicators were significantly ($p < 0.001$) higher in overweight and obese male and female participants than that in normal body-weight counterparts. Similarly, mean WC, HC and WHR were significantly ($p < 0.001$) higher in both overweight and obese students as compared to normal weight participants regardless of gender.

Table 2 shows major variations between predicted RMR using the four tested RMR prediction equations as compared to measured RMR in normal weight, overweight and obese male participants. Harris–Benedict equation in male participants was significantly lower compared to indirect calorimetry regardless of weight status ($p \leq 0.05$). FAO/WHO/UNU equation was valid to predicted RMR as compared to that measured RMR in obese males ($p = 0.31$) only, but significant differences ($p \leq 0.05$) between measured and FAO/WHO/UNU equation were found in normal and overweight participants. The mean predicted RMR

using Mifflin and Owen equations were significantly lower ($p \leq 0.05$) than measured RMR in normal body weight, overweight and obese males.

Table 3 shows major variations between predicted RMR using the three tested RMR prediction equations as compared to measured RMR in normal weight, overweight and obese female participants. Compared to RMR predicted using Mifflin, FAO/WHO/UNU, and Owen equations, only Harris–Benedict equation in females was valid to predicted RMR as compared to measured RMR regardless of weight status ($p > 0.05$). Mean predicted RMR using FAO/WHO/UNU equation was significantly lower than measured RMR in normal females ($p = 0.03$). FAO/WHO/UNU equation was valid to predict RMR as compared to that measured RMR in overweight and obese females ($p > 0.05$). Mifflin equation was valid to predict RMR in normal and overweight females ($p > 0.05$), but significant difference ($p \leq 0.05$) between measured and Mifflin equation was observed in obese females. Mean predicted RMR using Owen equations were significantly lower ($p \leq 0.05$) than measured RMR in normal body weight, overweight and obese females. Table 4 compares between the different RMR predictions equations in male and female participants. There was no significant differences ($p > 0.05$) between the four prediction equations in all groups.

Figure 1 illustrates the percent difference in measured RMR with reference to the predicted RMR. Percent difference in RMR was consistently higher in male students than that in female students, regardless of weight group with the highest percent change in overweight males.

4. Discussion

Modern food environment encourages passive over-consumption of caloric-dense diets, which causes a persistent imbalance between energy input and energy output, which in turn leads to a chronic failure in various complex homeostatic mechanisms that firmly regulate body weight ultimately resulting in overweight and obesity [21,22]. Although imbalance in feeding mechanisms could possibly be regarded as a failure in the adaptation mechanisms in persons with obesity on caloric-dense diets and sedentary lifestyle [21,23], the underlying mechanisms that lead to imbalance in energy intake and energy expenditure that cause obesity have yet been elucidated [24]. In Jordan, overweight and obesity have reached 71% in men and 75% in women over the age of 20 years, and 25% in young people under the age of 20 years [13]. In the current study, overweight and obese participants presented 49% of the sample.

Accurate determination of RMR using various prediction equations and the reliability of these equations in different populations and different settings could provide means to control over-estimation of RMR and total energy requirements [12], also provide

Table 1
Anthropometric characteristics of the participants.

Variable ^a	Males				Females			
	Normal (n = 105)	Overweight (n = 64)	Obese (n = 37)	<i>p</i> -value	Normal (n = 103)	Overweight (n = 63)	Obese (n = 34)	<i>p</i> -value
Age (year)	19.9 $\pm$ 1.7	20.1 $\pm$ 1.6	20.7 $\pm$ 2.3	0.630	20.4 $\pm$ 1.3	20.1 $\pm$ 1.4	20.9 $\pm$ 2.0	0.742
Weight (kg)	65.3 $\pm$ 8.2	81.9 $\pm$ 6.5	101.8 $\pm$ 12.4	0.001	54.7 $\pm$ 6.9	68.8 $\pm$ 6.0	86.3 $\pm$ 13.2	0.001
Height (cm)	172.6 $\pm$ 6.6	172.3 $\pm$ 13.4	174.4 $\pm$ 7.1	0.510	157.8 $\pm$ 6.2	160.2 $\pm$ 5.8	158.9 $\pm$ 4.9	0.037
BMI (kg/m ²)	21.9 $\pm$ 1.8	27.1 $\pm$ 1.5	33.5 $\pm$ 3.2	0.001	21.4 $\pm$ 1.9	26.8 $\pm$ 1.2	34.1 $\pm$ 4.1	0.001
WC (cm)	78.9 $\pm$ 6.6	90.4 $\pm$ 7.5	104.9 $\pm$ 9.0	0.001	70.1 $\pm$ 6.6	78.0 $\pm$ 7.3	92.9 $\pm$ 17.5	0.001
HC (cm)	96.6 $\pm$ 4.9	107.4 $\pm$ 7.7	117.3 $\pm$ 6.8	0.001	95.4 $\pm$ 8.8	101.9 $\pm$ 18.2	112.3 $\pm$ 18.0	0.001
WHR	0.82 $\pm$ 0.05	0.84 $\pm$ 0.06	0.89 $\pm$ 0.06	0.001	0.73 $\pm$ 0.05	0.76 $\pm$ 0.06	0.83 $\pm$ 0.06	0.001

Variables were compared using one way ANOVA. *p*-value is significant for values equal or less than 0.05. *p*-value represents the difference between bodyweight groups. BMI, body mass index; WC, waist circumference; HC, hip circumference; WHR, waist-to-hip ratio.

^a Values are presented as mean $\pm$ standard deviation (SD).

Table 2
Comparison between measured and predicted resting metabolic rate of the male participants.

	Normal (n = 105)		Overweight (n = 64)		Obese (n = 37)	
	Indirect calorimetry	Harris and Benedict	Indirect calorimetry	Harris and Benedict	Indirect calorimetry	Harris and Benedict
Mean $\pm$ SD (kcal/day)	1881.7 $\pm$ 538.7	1694.9 $\pm$ 136.4	2164.8 $\pm$ 501.9	1921.5 $\pm$ 111.8	2416.5 $\pm$ 776.7	2165.8 $\pm$ 232.1
p-value	0.007		0.001		0.018	
	Indirect calorimetry		Indirect calorimetry		Indirect calorimetry	
	FAO/WHO/UNU		FAO/WHO/UNU		FAO/WHO/UNU	
Mean $\pm$ SD (kcal/day)	1881.7 $\pm$ 538.7	1678.1 $\pm$ 177.5	2164.8 $\pm$ 501.9	1932.1 $\pm$ 140.6	2416.5 $\pm$ 776.7	2277.25 $\pm$ 275.3
p-value	0.001		0.001		0.31	
	Indirect calorimetry		Indirect calorimetry		Indirect calorimetry	
	Mifflin		Mifflin		Mifflin	
Mean $\pm$ SD (kcal/day)	1881.7 $\pm$ 538.7	1638.2 $\pm$ 162.4	2164.8 $\pm$ 501.9	1800.7 $\pm$ 199.83	2416.5 $\pm$ 776.7	2010.2 $\pm$ 221.9
p-value	0.001		0.001		0.003	
	Indirect calorimetry		Indirect calorimetry		Indirect calorimetry	
	Owen		Owen		Owen	
Mean $\pm$ SD (kcal/day)	1881.7 $\pm$ 538.7	1545.1 $\pm$ 118.3	2164.8 $\pm$ 501.9	1714.4 $\pm$ 93.8	2416.5 $\pm$ 776.7	1917.4 $\pm$ 178.8
p-value	0.001		0.001		0.003	

Values are presented as mean $\pm$ standard deviation (SD).

Variables were compared using paired t test. p-value is significant for values equal or less than 0.05, which represents the difference between RMR values measured using indirect calorimetry and predicted using RMR equations: Harris–Benedict, FAO/WHO/UNU, Mifflin, and Owen.

Table 3
Comparison between measured and predicted resting metabolic rate of the female participants.

	Normal (n = 103)		Overweight (n = 63)		Obese (n = 34)	
	Indirect calorimetry	Harris and Benedict	Indirect calorimetry	Harris and Benedict	Indirect calorimetry	Harris and Benedict
Mean $\pm$ SD (kcal/day)	1347.6 $\pm$ 333.4	1374.1 $\pm$ 72.5	1492.9 $\pm$ 374.8	1513.1 $\pm$ 66.8	1736.4 $\pm$ 386.9	1673.5 $\pm$ 178.4
p-value	0.43		0.67		0.28	
	Indirect calorimetry		Indirect calorimetry		Indirect calorimetry	
	FAO/WHO/UNU		FAO/WHO/UNU		FAO/WHO/UNU	
Mean $\pm$ SD (kcal/day)	1347.6 $\pm$ 333.4	1273.1 $\pm$ 143.4	1492.9 $\pm$ 374.8	1480.4 $\pm$ 124.7	1736.4 $\pm$ 386.9	1737.65 $\pm$ 274.43
p-value	0.034		0.8		0.99	
	Indirect calorimetry		Indirect calorimetry		Indirect calorimetry	
	Mifflin		Mifflin		Mifflin	
Mean $\pm$ SD (kcal/day)	1347.6 $\pm$ 333.4	1325.4 $\pm$ 155.1	1492.9 $\pm$ 374.8	1428.7 $\pm$ 126.3	1736.4 $\pm$ 386.9	1591.5 $\pm$ 215.9
p-value	0.54		0.2		0.05	
	Indirect calorimetry		Indirect calorimetry		Indirect calorimetry	
	Owen		Owen		Owen	
Mean $\pm$ SD (kcal/day)	1347.6 $\pm$ 333.4	1188.9 $\pm$ 20.2	1492.9 $\pm$ 374.8	1290.4 $\pm$ 60.1	1736.4 $\pm$ 386.9	1416.4 $\pm$ 134.4
p-value	0.001		0.001		0.001	

Values are presented as mean $\pm$ standard deviation (SD).

Variables were compared using paired t test. p-value is significant for values equal or less than 0.05, which represents the difference between RMR values measured using indirect calorimetry and predicted using RMR equations: Harris–Benedict, FAO/WHO/UNU, Mifflin, and Owen.

Table 4
Comparison between prediction RMR equations in male and female participants.

	RMR (kcal/day)				p-value
	Harris and Benedict	FAO/WHO/UNU	Mifflin	Owen	
Males					
Normal body weight (n = 105)	1694.9 $\pm$ 136.4 ^a	1678.1 $\pm$ 177.5 ^a	1638.2 $\pm$ 162.4 ^b	1545.1 $\pm$ 118.3 ^c	0.67
Overweight (n = 64)	1921.5 $\pm$ 111.8 ^a	1932.1 $\pm$ 140.6 ^a	1800.7 $\pm$ 199.83 ^b	1714.4 $\pm$ 93.8 ^c	0.33
Obese (n = 37)	2165.8 $\pm$ 232.1 ^a	2277.25 $\pm$ 275.3 ^a	2010.2 $\pm$ 221.9 ^b	1917.4 $\pm$ 178.8 ^b	0.54
Females					
Normal body weight (n = 103)	1374.1 $\pm$ 72.5 ^a	1273.1 $\pm$ 143.4 ^b	1325.4 $\pm$ 155.1 ^a	1188.9 $\pm$ 20.2 ^c	0.74
Overweight (n = 63)	1513.1 $\pm$ 66.8 ^a	1480.4 $\pm$ 124.7 ^a	1428.7 $\pm$ 126.3 ^b	1290.4 $\pm$ 60.1 ^c	0.63
Obese (n = 34)	1673.5 $\pm$ 178.4 ^{a,b}	1737.65 $\pm$ 274.43 ^a	1591.5 $\pm$ 215.9 ^b	1416.4 $\pm$ 134.4 ^c	0.53

Values are presented as mean $\pm$ standard deviation (SD).

Variables were compared using one way ANOVA. p-value is significant for values equal or less than 0.05, which represents the difference between RMR prediction equations. Different letters within the same row indicate statically significant differences (p $\leq$ 0.05).

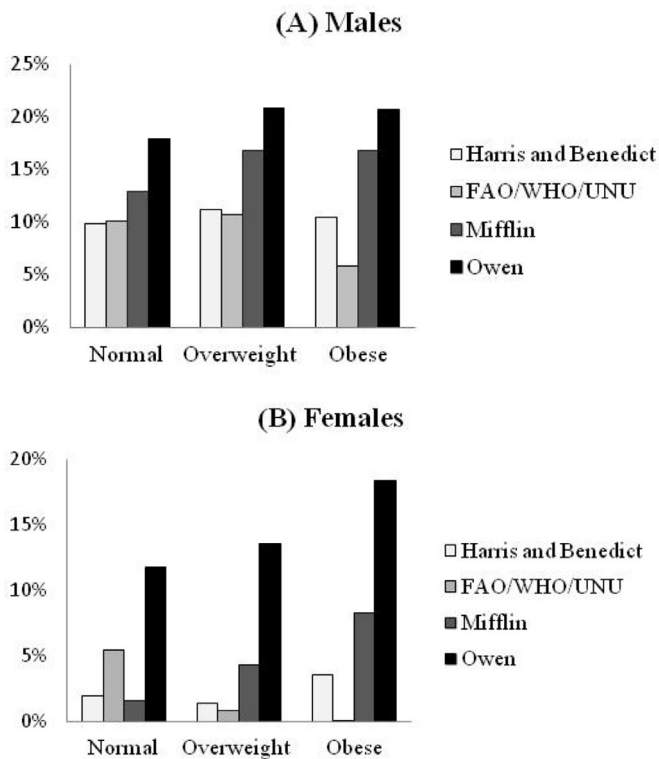


Fig. 1. Percent difference in measured RMR with reference to that predicted in males (A) and females (B). Mean percent difference = (measured RMR–predicted RMR/measured RMR × 100%).

accurate energy requirements to healthy individuals and individuals with obesity and obesity-related diseases alike [25]. Yet, studies for evaluating the validity of RMR prediction equations against measured RMR using indirect calorimetry among young healthy individuals not only remain scarce [4] but also the available findings are inconsistent among different populations [26]. Using indirect calorimetry to measure RMR in the general population may not be feasible. Practical and valid tools for accurate measurement of RMR are needed. Therefore, this study aimed at investigating the accuracy of predicted RMR as compared to that measured by indirect calorimetry among apparently healthy obese and non-obese young Jordanians.

The findings of the this study demonstrate that among the four tested RMR prediction equations, only Harris–Benedict equation was comparable with that measured in obese and non-obese Jordanian young females. Harris–Benedict equation remains one of the most widely used equations by clinicians in the United States, and elsewhere [27]; nonetheless, it was originally validated almost a century ago using only 239 predominantly normal weight white participants; 136 males aged 27 ± 9 years and 103 females aged 31 ± 14 years [7]. For instance, it was demonstrated that Harris–Benedict equation overestimated the RMR among male and female obese and non-obese Canadian females [4,9]. Although the findings of the current study are consistent with the findings of another report [28], which indicated that the original Harris–Benedict equation is a valid tool for predicting RMR in Belgian women at wide range of body mass index (BMI 18.5–50 kg/m²), the equation remains questionable and requires further validation with regard to different races, ethnicities and weight status [2,26].

Generally, our findings show that there was a significant ($p \leq 0.05$) underestimation in the predicted RMR as compared to measured RMR with major variation between young males and females regardless of weight status for predicted RMR using FAO/

WHO/UNU, Mifflin, Owen, and Harris–Benedict (in male participants only) equations. We found that while FAO/WHO/UNU equation was inaccurate in predicting RMR in normal weight participants and overweight males, the predicted RMR using Mifflin equation was inaccurate in obese females and all male groups. Mifflin equation was originally derived from 498 normal bodyweight, overweight, obese and severely obese individuals; of them 251 males aged 19–78 years old (mean age 44.5 ± 14 years) [6]. It was reported that Mifflin equation provides a valid estimation of the actual RMR in the largest proportion of non-obese and obese individuals when compared to measured RMR value using indirect calorimetry, suggesting that this equation could be used as the standard equation for calculating RMR in obese and non-obese adults. However, only 130 adults were included in the study exhibiting a wide range of BMI (18.8 – 96.8 kg/m²) [9]. The FAO/WHO/UNU equation was developed based on a meta-analysis of approximately 100 studies, which included data from 7173 apparently healthy individuals (3–60 years) [5,10]. It remains valid to suggest that the accuracy of both FAO/WHO/UNU and Mifflin equations remains inconsistent. Additionally, Owen equation failed to show an agreement in RMR prediction among all the studied participants when compared to RMR measured using indirect calorimetry. It is worth noting that Owen equation was based on a small sample size (60 males, 44 females) with wide range of age (males; 18–82 years, and females; 18–65 years) [8].

The findings of this study demonstrate that the measured RMR was significantly higher than that predicted by the four tested RMR prediction equations with major variation between male and female participants and various weight groups. The inconsistency and variation of RMR values using the prediction equations in various populations could be attributed to race [14,29], fasting blood glucose [30], physical activity [15] and biological variables or discrepancies in the methods [4]. In a systematic review of predictive RMR equations among healthy non-obese and obese individual of various age groups and ethnicities, Frankenfield and colleagues [26] reported that such current predictive equations have limitations due to the gap of the knowledge related to the accuracy of equations for use in specific sex, age and ethnic groups. They also recommended practitioners to use clinical judgment to discern the best method in energy requirement determination. Findings of previous reports attributed several possible reasons for the observed deviations in RMR prediction equations to specific characteristics of the studied samples such as the presence of mental illness [31], anorexia nervosa [32], type two diabetes mellitus [2] and dysmetabolism [33]. However, since participants of this study were healthy, it would be reasonable to expect more consistency between the predicted and measured RMR.

Recent findings has reported that the predicted RMR equations overestimate the RMR values [34]. However, since that was not the case of the current study, we suggest that along with ethnicity, the fat mass and fat free mass (kg and percentage) might be associated with the variation between measured and predicted RMR for either males and females across weight categories [4,34,35]. Moreover, given that most of the tested equations underestimated RMR values in the current sample, it would be reasonable not to expect the high prevalence of overweight and obesity in Jordan is linked to, or partially associated with the inaccurate estimation of RMR. Future research using a larger sample size focusing on developing new equations, or calibrating the existing ones possibly through adding additional components such as fat mass, and fat free mass would be significant for researchers and healthcare workers.

The strength of this study lies as it is the first study that provides data on predicted and measured RMR in healthy young adults in

Jordan as well as the Middle East. The main limitations of this study were that it was conducted on a narrow age group, therefore, it cannot be generalized to the whole Jordanian population. Also, BMI was used to classify the weight status of the participants, as such we were not able to determine the level of adiposity or leanness [36].

5. Conclusion

Of the examined RMR equations, Harris–Benedict equation was the only valid equation to predict RMR as compared to that measured by indirect calorimetry among young Jordanian females regardless of weight status. Apart from that these equations did not perform well at the group level. This study highlights the need for further population based studies to understand the factors that could affect the accuracy of predicted RMR which may help to validate existing or developing new and improved equations.

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