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Metabolic factor: A new clinical tool in obesity diagnosis and weight management

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ABSTRACT
Obtaining resting metabolic rates (RMR) via indirect calorimetry is a critical component of weight management that is used to calculate a new concept, metabolic factor. This calculation allows for the standardized expression of RMR to make it possible to compare metabolism between people and over time. This study found an inverse relationship between weight and metabolic factor, statistically significant, $r = -.63$, $p < 0.001$, effect size = .46, suggesting that people who weigh more tend to have lower metabolic factors. Furthermore, statistically significant differences were found in the metabolic factors between people who were normal weight, overweight, and obese, $p < 0.001$. There was also an inverse relationship between metabolic factor and age, $r = -0.21$, $p < .05$, effect size = .03, suggesting that age has a small but significant effect of metabolic factor This variable has the potential to play a key role in treatment planning as it can be used to set realistic weight goals, determine caloric needs for a given weight, and to make decisions as to surgical intervention. More importantly, metabolic factor can be a key instrument in clinical work used to educate people regarding unique differences in metabolism to lower prejudice against the obese and to reduce the devastating shame that often accompanies weight issues.

KEY WORDS: ***Metabolic factor; Obesity; Resting metabolic rate***

INTRODUCTION
Knowledge of an individual's resting metabolic rate (RMR) can be the foundation of weight management services. There has been a general assumption that one size fits all when it comes to weight loss, which has led to prejudice and inappropriate treatment[1]. Given the metabolic variation that does occur, any approach should be tailored to each individual's unique body metabolism. Most weight management approaches consider calories in and calories out since a chronic imbalance in this area leads to weight gain. RMR is believed to comprise 50%-80% of energy expenditure in adults and varies between people[2]. The remainder of energy expenditure comes from physical activity and thermogenesis, yet this key measure of metabolism is rarely used in treatment decisions.

According to Nieman et al[3], basal metabolic rate (BMR) is the rate of energy expended for an individual at rest and is measured immediately after at least 8 hours of sleep and at least 12 hours of fasting. The authors also commented that most investigators use the term RMR when energy expenditure measurements use altered conditions required for measuring BMR. The process of acquiring RMR information actually began in 1780[4]. By the late 1800s, direct calorimetry was the procedure that was in use[5]. Haugen et al[6] defined direct calorimetry as "the measurement of the heat produced by metabolic processes to quantify total energy expenditure". Because this kind of measurement required a thermally sealed chamber, it was time-consuming and expensive, which meant it was restricted to research and not practical for clinicians. Therefore, an effort was made beginning in the early 1900s to develop simple formulas clinicians could use to estimate RMR. Even as recently as the 1990s, the Harris and Benedict equation, developed in 1919, remained one of the most widely used prediction formulas[7]. The formulas varied, but considered factors such as body weight, height, sex, or age. Unfortunately, the equations had shortcomings related to the reference study populations, methodological drawbacks, and the individual variability of RMR[8]. Prediction equations remained in use for so long, despite their considerable flaws and error, because of their simplicity, low cost, and no other alternative given the impractical nature of direct calorimetry.

Dissatisfaction with predictive equations helped create a demand for more easily measured and accurate RMR. Indirect calorimetry was discovered to be a more practical method for clinical settings. Haugen et al[6] described indirect calorimetry as the process of quantifying RMR by measuring the volumes of oxygen inhaled and carbon dioxide produced. Within the past 10 years, technology has advanced to the point that indirect calorimetry has become possible via a handheld device, armband, or desktop machine. Indirect calorimetry became cheaply and readily available for the measurement of energy expenditure. Regarding the widespread use of indirect calorimetry, Rosado et al[9] proclaimed that indirect calorimetry remains a gold standard in measuring energy expenditure in clinical settings. It offers a scientifically based approach to customize a patient's energy needs and nutrient delivery to maximize the benefits of nutrition therapy. With recent advances in technology, indirect calorimeters are easier to operate, more portable, and affordable.

Due to the metabolic differences between people, RMR must be standardized in some fashion in order to allow for useful comparisons. In other words, just because two individuals have the same RMR does not allow for many conclusions to be drawn regarding the efficiency of their bodies in processing energy. Research from Miller and Blythe[10] led to the promising use of the ratio between RMR and fat-free mass (FFM). In a meta-analysis, Astrup et al[11] found that people who had formerly been obese had a 3-5% lower ratio than individuals who had never been obese.

However, several authors have commented on the problems with a ratio of RMR to FFM. Elia[12] described errors in obtaining FFM measurements from different people using different techniques in a variety of settings. Ravussin and Bogardus[13] provided an explanation of the error that arises when the y-intercept of the two variables does not equal 0, which is the case with RMR and FFM. As a result, no common baseline for statistical comparisons can be made. Another issue is that the ratio is based on the assumption that RMR is proportional to FFM on a constant basis, which may not be accurate[14]. Therefore, the accuracy of the ratio is dependent on an assumed linear relationship between RMR and FFM. The ratio of RMR to FFM might be appropriate for people of normal and overweight, but it appears to lose accuracy when the target population is obese. The relationship is curvilinear in nature, which makes any direct comparison difficult.

The concept of metabolic factor could represent an improvement in the standardized expression of RMR and allow for comparisons between people. In 1985, Stephen Phillips coined the term to signify the ratio of RMR to overall weight (personal communication, October 1, 2013). For example, a person with an RMR of 2,000 who weighs 200 pounds would have a metabolic factor of 10 (2,000/200) This simple calculation could provide a standardized way to statistically compare people and groups, but also provide a number the average patient and health care practitioner could easily understand.

A review of RMR literature identified a number of studies that provided sufficient information to calculate metabolic factor. There were two studies that provided information for BMI ranges. A total of 130 subjects were studied by Frankenfield et al[7]. Their data produced an overall Metabolic Factor of 8.6. Non-obese participants had average metabolic factors of 9.8 while obese people had 7.5. Within the obese, those with a BMI greater than 40 had metabolic factors of 6.9. People with a lower BMI, between 30 and 40, had slightly higher Metabolic Factors of 8.3. Another study used information taken from a German database of 2,105 people[8]. Their overall sample had a Metabolic Factor of 9.3. Individuals with a BMI less than 18 had metabolic factors of 11.2 while it was 10.4 for BMI 18-25, 9.1 for BMI 25-30, and 8.1 when BMI was over 30.

Table 1 shows the results for seven studies that reported specific BMI's for the overall samples[15-21]. The clear trend for this data is an inverse relationship between BMI and metabolic factor.

The aim of this pilot study was to introduce the concept of metabolic factor and to look at the relationships in a prospective fashion. The study intended to compare the metabolic factors of people of normal weight, those who are overweight, and the obese to ascertain whether or not there were differences.

Table 1: Metabolic Factors for studies that reported specific BMI

Study	BMI mean	BMI SD	Metabolic Factor
Foster et al[15]	38.9	7.4	7.6
Bertoli et al[16]	30.0	5.0	8.4
Slinde et al[17]	30.0	2.8	8.0
Seidell et al[18]	25.1	2.8	9.0
Malavolti et al[19]	24.0	3.0	10.8
St. Onge et al[20]	23.9	4.0	9.2
Katzmarzyk et al[21]	23.9	3.4	9.9

MATERIALS AND METHODS

Participants

The research protocol was approved by Touro College's School of Health Science IRB and informed consent obtained from each subject prior to inclusion in the study. The 121 participants were comprised of 81 females and 40 males with an average age of 43.6 (age range of 18-68). The sample was primarily Caucasian (92.6%), followed by Asian-American (3.3%), African-American (3.3%) and Hispanic (0.8%). Participants were recruited from two locations. The first location was from a rural town in Iowa. Recruitment methods were personal solicitation and an invitation to participate sent via a chamber of commerce email to local residents. In addition, a retrospective records review was conducted to retrieve data from bariatric surgery pre-operative evaluations performed by the lead author. Due to the effect of the large amount of data used from these candidates, the average BMI for the entire sample was 36.3 with a standard deviation of 12.9 and range of 19-90. The second location for participants was a metropolitan corporate office of an engineering firm in Kansas City. Employees were invited by the firm's

Director of Employee Development and Wellbeing to participate in the study as one component of the company's overall wellness program, which also includes the domains of physical, financial, career, social, and community wellbeing.

Measurements

RMR was measured by indirect calorimetry (ReeVue indirect calorimeter, Korr Medical Technologies, Salt Lake City, UT) with participants in a supine position. While the environmental conditions were comfortable and all participants were tested in the same position, participants were not routinely screened for fasting, nicotine, caffeine, medication use, and physical activity as recommended by Compher et al[22]. Weight was measured by a digital scale and height was self-reported.

RESULTS

The sample was divided into standard weight status categories of normal weight (18.5 to 24.9), overweight (25.0 to 29.9), and obese (30 or higher) according to their BMI calculations. The mean weight in pounds (with standard deviations in parentheses) for the normal group was 143.7 (19.3) while the overweight group was 178.8 (23.5) and the obese group was 285.0 (72.4). The overall average weight was 229.7 (82.8). Logically, these differences were statistically significant, p<0.001.

Comparing the metabolic factors of the three groups was the primary aim of this study. The results can be seen in **Table 2**. The normal weight group had a mean of 12.8 (1.9), the overweight group's mean was 10.6 (1.5), and the obese mean was 8.3 (1.5). The differences between the three groups was statistically significant, p<0.001. The correlation between weight and metabolic factor was also statistically significant, r = -.63, p<0.001. The effect size based on adjusted R Square was .46. The overall sample had a metabolic factor mean of 9.7 (2.4).

The mean ages for the three groups were 38.3 (11.6), 44.3 (15.7), and 45.3 (11.9), respectively, which were not found to be statistically significant. The correlation between metabolic factor and age was not strong, but nonetheless statistically significant, r = -0.21, p < 0.05. The effect size based on adjusted R Square was .03. Age was not significantly related to weight (r = .12) or BMI (r = .11). Similarly, there was not a statistically significant difference with height. The normal weight group had a height of 66.1 inches (3.2), the overweight sample was 68.0 (3.9), and the obese group was 66.4 (3.7).

Table 2: Metabolic factor means and SD for the three weight groups

Group	BMI mean	BMI SD	Metabolic Factor mean	Metabolic Factor SD
Normal weight	22.9	1.5	12.8	1.9
Overweight	27.1	1.5	10.6	1.5
Obese	45.5	10.3	8.3	1.5
All	36.3	12.9	9.7	2.4

DISCUSSION

The negative correlation between metabolic factor and weight (r = -0.63, p<0.001) demonstrates not only an inverse relationship but also a statistically strong one. The metabolic factor could account for up to 40% of the variance with weight. While behaviors can clearly exacerbate obesity, this research suggests that one's unique metabolism is a factor that may predispose people to a weight classification. If metabolic factor is stable across the lifespan and across weight fluctuations, it would become an even more meaningful piece of information for people to know about themselves to manage their health properly.

As clinicians and researchers, we need to examine how metabolic factor can be used both as an instrument of treatment planning and education for patients and other clinicians. The knowledge of metabolic factor may indeed prove useful in setting weight goals because patients will be able to calculate reasonable caloric requirements that are tailored to their own bodies' metabolisms. The shame of obesity and repeated weight loss failure could be mitigated for those with low metabolism. As weight loss occurs, clients' caloric needs can be re-calculated for the new weight without using additional indirect calorimetry. For example, an individual with an RMR of 2,000 who weighs 200 pounds will have a metabolic factor of 10.0. If the person loses 50 pounds and gets down to 150 pounds, the new RMR would be 1,500 (150 x 10.0).

The metabolic factor could also prove clinically useful in making decisions as to surgical interventions for obesity. People with low, as opposed to high, metabolic factors will find natural weight loss more challenging. Since their caloric intake may not be very high, a restrictive procedure that simply reduces the amount they can consume might not be effective in achieving and maintaining weight loss. Instead, given the efficiency of digesting food among people with low metabolic factors, procedures that produce malabsorption might be more appropriate. Individuals with higher metabolic factors might be able to lose weight naturally and should focus initially on behavioral aspects of weight management prior to surgery.

A potential problem with metabolic factor is similar to the problem with the ratio of RMR to FFM in that a linear relationship is assumed. As Horgan and Stubbs[23] explained, when people gain weight, they gain both FFM and fat. At the level of morbid obesity, people are gaining more fat than FFM. Since FFM is the largest contributor to RMR and adipose tissue is less metabolically active, a person's RMR increases at a slower rate in morbid obesity than at lower weights, thus violating the assumption of a linear relationship. While the relationship might be linear at normal weight and overweight, it appears to curve in obesity. Despite some possible error when it comes to metabolic factor in the obese, Metabolic Factor is easier to calculate than FFM and clinically useful because it can communicate how one's metabolism compares to others.

This study had several limitations with the sampling. The sample was largely homogenous in regards to race. In addition, children and the elderly were excluded. Another limitation involved the testing of indirect calorimetry as recommended protocol was not followed in regards to food intake, nicotine use, caffeine consumption, and medication.

The primary area of future research is replicating these findings since metabolic factor is being introduced for the first time. A comparison seems warranted between the metabolic factors from this study, as shown in **Table 2**, and the metabolic factors calculated from the seven studies from **Table 1**. However, some of the comparisons are problematic due to differences in the makeup of the samples as well as variability of their BMI. For example, three of the studies that included participants from the entire range of BMI had average BMI that ranged from normal to obese[16,18,21]. No comparison is possible in another case because that study only involved people with BMI between 18 and 35, for which there was no corresponding group in this study[20].

When comparisons between this study and previous studies from **Table 1** are appropriate, there are disparate results. In several cases, the metabolic factors obtained in this study are higher than expected given the results elsewhere[16-

[18,21]. However, the metabolic factor from Foster et al[15], who only examined obese individuals, were relatively similar to what was obtained from the obese group in this study. Although Malavolti et al[19] indicated their sample was made up of individuals from a normal weight group, their average BMI of 24.0 (3.0) suggests they also had overweight participants. A comparison to the normal and overweight groups from the present study would lead to an expectation of metabolic factors between 10.6 and 12.8, which encapsulates their 10.8 finding.

Another area of future research is changes to metabolic factor after large weight gains or losses. It should be investigated in order to establish the stability of metabolic factor within a person and demonstrate that it is not simply a function of one's current weight. Another area is the applicability of the concept across ethnic groups, at the extremes of ages, and at the extremes of weight. It has been believed that metabolism slows with age, but this study found that the slowing might be much less than expected. Longitudinal research is needed to understand this more thoroughly. This research is needed given the importance and relevance of metabolic factor in weight problems as suggested by the present study. Metabolic factor may prove to be both a key instrument for clinical work and an instrument for public education to lower the prejudice against the obese.

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