National Academy of Sports Medicine

Comparing Energy Expenditure Prediction Equations

By

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Introduction

Kathy has decided that she needs to lose weight given how her current weight represents an all-time high. Frustrated and concerned, she decides it is time to diet and begin an exercise program. To help with her weight loss plan, Kathy does some online research to determine her daily calorie needs. However, after visiting a few internet sites that offer calorie calculators, she quickly discovers a lot of conflicting information and becomes very confused and frustrated.

Before reading the next section, think back to the strategies you have used in the past to help individuals quantify daily calorie needs. Do you recall which method(s) you used and have you ever questioned their accuracy? If you did calculate a caloric value, did it appear reasonable or accurate, or did it raise concerns and questions in your mind?

Total Daily Energy Expenditure

Successful weight loss often involves the mathematical calculation of energy balance (calories in versus calories out), and has long been viewed as a foundational principle in weight loss programming. In other words, if an individual consumes fewer calories (food & beverages) than he or she expends (body functions, physical activity) a reduction in weight will occur. Conversely, if an individual consumes more calories than he or she expends, a net gain in weight will occur. Therefore, tracking the number of calories consumed versus expended is very important for the goal of weight loss.

Tracking the number of calories consumed is relatively uncomplicated (although somewhat monotonous) as food labels and online resources provide calories per serving. This information can be gathered and summed to determine the 'calorie in' side of the energy equation. But how do individuals estimate the number calories they are expending (calories out) without sophisticated equipment or body sensor devices?

Total daily energy expenditure (TDEE), is defined as the amount of energy (calories) spent, on average, in a typical day. TDEE is actually the sum total of three different energy components:

- *Resting metabolic rate (RMR)*: The amount of energy expended while at rest; represents the minimal amount of energy required to sustain vital bodily functions such as organ function, blood circulation, respiration, and temperature regulation. RMR typically accounts for approximately 70% of TDEE.
- *Thermic effect of food (TEF):* The amount of energy expended above RMR as a result of the processing of food (digestion) for storage and use. TEF accounts for approximately 10% of TDEE.
- *Thermic effect of physical activity (TEPA):* The amount of energy expended above RMR and TEF associated with all forms physical activity (exercise and non-exercise activity). Physical activity accounts for approximately 20% of TDEE.

TDEE Equations

Numerous TDEE estimates exist and include commonly utilized scientific formulas; Mifflin-St. Jeor, Harris & Benedict, Owen, Katch-McArdle and Institute of Medicine (IOM). Each is different and will provide different values because they are derived from different studies. The Mifflin-St. Jeor, Harris & Benedict and IOM equations are presented in Table 1.

Table 1. Harris & Benedict, Mifflin-St. Jeor, IOM Equations	
Harris & Benedict	
Men:	RMR = 88.362 + (13.397 x kg) + (4.799 x cm) – (5.677 x age)
Women:	RMR = 447.593 + (9.247 x kg) + (3.098 x cm) – (4.33 x age)
Mifflin-St. Jeor	
Men:	RMR = (9.99 x kg) + (6.25 x cm) – (4.92 x age) + 5
Women:	RMR = (9.99 x kg) + (6.25 x cm) – (4.92 x age) – 161
Institute of Medicine (IOM)*	
Men:	662 − (9.53 x Age) + *Physical Activity Score x ([15.91 x Kg] + [539.6 x Height (m)])
Women:	353 – (6.91 x Age) + *Physical Activity Score x ([9.36 x Kg] + [726.0 x Height (m)])
**Physical Activity Scores are presented in Table 4.*	

Although generally considered valid, these formulas exhibit potentially large errors with both obese and non-obese individuals as illustrated in Table 2. The Harris & Benedict equation, originally created in 1919, and revised in 1984 (1) has long been considered the gold standard, showing accuracy up to 81% of the time in non-obese individuals. But research also demonstrates a large potential for error as it can also underestimate and overestimate obesity in that same population by 23 and 42% respectively (2). The Mifflin-St. Jeor (MSJ) equation on the other hand, created in 1990 demonstrates smaller margins of error and is now considered the most appropriate mathematical formula for the U.S. population (3). One major drawback with both of these formulas, however, is that they fail to consider the relative amounts of lean and fat mass which influence metabolism significantly. The Katch-McArdle formula is an exception, being derived from lean body mass and therefore improving accuracy of the estimate. But unfortunately, it relies upon an accurate assessment of body fat percentage, which is often difficult to obtain.

Table 2. Estimates with Harris & Benedict, Mifflin-St. Jeor Equations for RMR

Formula	Accurate Estimates	Underestimation	Overestimation
Harris and Benedict			
• **Non-Obese (using BMI Standard)**	45 – 81%	23%	42%
• **Obese**	36 – 64%	35%	43%
Mifflin-St. Jeor			
• **Non-Obese (using BMI Standard)**	82%	18%	15%
• **Obese**	70%	20%	15%

Calculating TDEE Formulas

These formulas generally involve two mathematical steps to determine total daily energy expenditure. One exception is the IOM equation that calculates TDEE in one step, referring to it as estimated energy requirement (EER).

- Step One: Estimate resting energy expenditure (REE) or resting metabolic rate (RMR).
- Step Two: After estimating REE or RMR, determine the additional calories expended through the thermic effect of food and the thermic effect of physical activity.

As an example, let's use these equations to calculate TDEE for Kathy, a relatively inactive 40-year old female who stands 5'4" (162.5 cm) and weighs 145 lbs. (65.9 Kg). She participates in approximately 30-minutes of light-to-moderate intensity activity two to three times per week, but works as a data software controller, a predominantly sedentary occupation.

Step One: Calculate REE or RMR

Harris & Benedict:

- RMR = 447.593 + (9.247 x kg) + (3.098 x cm) – (4.33 x age)
    - RMR = 447.593 + (609.38) + (503.43) – (173.2)
    - RMR = 1,387 kcal

Mifflin-St. Jeor:

- RMR = (9.99 x kg) + (6.25 x cm) – (4.92 x age) – 161
    - RMR = 658.34 + 1,015.63 – 196.8 – 161
    - RMR = 1,316 kcal

A 71 daily difference in kilocalories between the two formulas (1,387 kcal versus 1,316 kcal) may appear insignificant, but when extrapolated over a one year period it amounts to 7.4 pounds (3.4 Kg).

Step Two: Calculate Thermic Effect of Physical Activity

This step determines the additional calories expended through TEPA which includes TEF. It is calculated by either using a *Standard Activity Factor (SAF)* or a *Weighted Activity Factor (WAF)* derived from a client's activity logs.

A SAF score (Table 4) is designated by selecting a pre-determined level that best represents the client's exercise activity, but presents several concerns and limitations:

- Accuracy of self-reported levels of activity.
- Accuracy of data when under observation – Hawthorne Effect*
- Insufficient detail and failure to consider activities outside of exercise:
  - For many, exercise accounts for only a small portion of the total calories expended in the average week, yet these SAF scores are generally based off exercise. For example, woman in the U.S. consume an average of 12,397 kcal of food per week, yet three, 30-minute cardio sessions at 5 mph (8 km/h) will only expend 1,021 kcal or 8.2% of that total (Table 3) (4,5).
  - Consider two individuals; one participates in moderate-to-intense exercise three to five times per week, but spends 10-hours a day seated versus an individual who only manages two to three bouts a week of light-intensity exercise, but works as a food server, constantly moving and carrying items for six to eight hours a day, five to six days per week. According to the SAFs presented in Table 4, the light-exerciser is classified in a lower activity category, whereas in reality he or she may be more active than the first individual.

Table 3: Total Weekly Expenditure

Gender	Weekly calorie consumption	Sleep (49 – 56 hours)	Exercise (3 – 5 hours)	Difference between kcal consumption and expenditure
Men	17,528 kcal (1)	~ 3,466 – 4,683 kcal	1,500 – 3,000 kcal	9,845 – 12,562 kcal
Women	12,397 kcal (1)	~ 3,466 – 4,683 kcal	1,500 – 3,000 kcal	4,714 – 7,431 kcal

**Hawthorne Effect*

It is a phenomenon whereby subjects improve or modify a particular aspect of their behavior being measured in response to the fact that they know they are being observed (3).

Table 4: Harris & Benedict Standard Activity Factors (SAF) and IOM Physical Activity Scores (PA)		
Harris & Benedict SAF Scores		
SAF Score		**Description**
1.200		Sedentary, little or no physical activity
1.375		Light Activity or Exercise: Light-intensity exercise 1 – 3 days / week
1.550		Moderate Activity / Exercise: Moderate-intensity exercise 3 – 5 days / week
1.725		Heavy Activity / Exercise: Moderate-to-vigorous intensity exercise 6 – 7 days / week
1.900		Very Heavy Activity / Exercise: Vigorous training two times a day / or job requiring hard physical labor
IOM Scores (6)		
PA Score		**Description**
Men	**Women**	
1.00	**1.00**	Sedentary: Sitting and basic activities of daily living – ADL's (e.g., household tasks, walking to bus)
1.11	**1.12**	Low-active: ADL's plus 30-60 minutes of daily moderate activity (e.g. walking at 3 – 4 mph)
1.25	**1.27**	Active: ADLs, with more standing activities plus 60 minutes of daily moderate activity
1.48	**1.45**	Very active: ADL's, mostly with standing activities plus at least 60 minutes of daily moderate activity plus an additional 60 minutes of vigorous activity or 120 minutes of moderate activity

Do The Math		
Measurement	*Conversion*	*Example*
Weight (Kg)	*2.2lb. = 1 Kg*	*145lb. ÷2.2 = 65.9 Kg*
Height (m)	*1 inch = 2.54 cm* *100 cm = 1 m*	*5'4" = 64' x 2.54 = 162.5 cm = 1.63m*
Your Turn		
1. 187 lbs. = ______ Kg	*5. 5'10" = ______ cm*	
2. 174 lbs. = ______ Kg	*6. 5'7" = ______ cm*	
3. 92 Kg = ______ Kg	*7. 183 cm = ______ inches*	
4. 76 Kg = ______ Kg	*8. 157 cm = ______ cm*	
Answers: (1) 85 Kg (2) 79.11 Kg (3) 202.4 lbs. (4) 167.2 lbs. (5) 177.8 cm (6) 170.2 cm (7) 78" (8) 61.8"		

Using SAF scores

To complete step two for the Harris & Benedict and Mifflin-St Jeor equations, we select an SAF score of 1.375 (best matches Kathy activity levels) and multiply that number by her RMR score:

<u>Harris & Benedict</u>

- TDEE = RMR x SAF
    - TDEE = 1,387 kcal x 1.375
    - TDEE = 1,907 kcal

<u>Mifflin-St. Jeor</u>

- TDEE = RMR x SAF
    - TDEE = 1,316 kcal x 1.375
    - TDEE = 1,810 kcal

With our same example, but using the one-step IOM formula to estimate her EER:

- EER = 353 – (6.91 x Age) + Physical Activity Score x ([9.36 x Weight] + [726.0 x Height])

- EER = 354 – (6.91 x 40) + 1.12 x ([9.36 x 65.9 Kg] + [726.0 x 1.63 m])
- EER = 354 – (276.4) + 1.12 x ([616.8] + [1,183.4])
- EER = 77.6 + 1.12 (1,800.2)
- EER = 77.6 + 2,016.2
- EER = 2,094 kcal

When comparing these three results, we notice a discrepancy of 284 kcal in Kathy's TDEE. Again while 284 kcal may not appear overly significant, when extrapolated over the period a one year, it amounts to 103,660 kcal (29 ½ lbs.), the equivalent of 360 hours of walking at 3 mph for the average woman.

Using WAF scores

An alternative, but more time-consuming strategy is to calculate a weighted average factor from an individual's activity logs. While this offers a more realistic view of one's daily activity, it does require more detailed and tedious activity recording. Traditionally, individuals maintain 24-hour activity logs for a minimum of three days. Values are assigned for each activity then summed together according to the total time spent performing each activity (Table 5). The information presented below provides step-by-step instructions for calculating an individual's WAF score. Table 6 provides a sample activity log. However, this method is also subject to the error as individuals generally over-report their activity levels.

Table 5. Weighted Activity Factor (WAF) for Different Activities	
Score	**Activity**
0.8	**Sleeping**
1.0	**Supine or Reclining:** Lying down totally relaxed, not sleeping
1.2	**Very Light:** Sitting and seated activities; standing
1.3	**Light:** Most light standing activities - dressing, bathing, cooking, teaching, lab/shop work, regular pace walking
1.4 -1.6	**Moderate:** Brisk walking, jogging, cleaning, gardening type job, light-to-moderate exercise
1.7 -1.8	**Moderately Heavy:** Moderate-to-vigorous exercise, heavy manual labor (e.g., digging, tree felling, climbing)
1.9 - 2.0	**Heavy:** Fitness-oriented cycling or similar vigorous exercise
2.1 - 2.2	**Sports:** Vigorous sports competition (football, racquetball, tennis, etc.)
2.3 - 2.4	**All-Out Training:** Extremely high intensity weight training with little rest between sets or exercises
2.5	**Extended Maximum Effort:** Extremely high intensity and high duration sports competition (triathlon, cross country skiing, marathon)

Instructions to calculate WAF score:

1. Provide activity logs to record activity time and classification (Table 6).
2. Instruct individuals to log activities by general classifications outlined in Table 5.
3. Assign numerical activity factor values to each activity or grouping of similar activities (e.g., seated, standing).
4. Multiple the time allocation for each activity or group of activities by the corresponding activity score to determine a sub-total.
5. Tally the sub-totals to calculate a total daily value.
6. Divide this value by 24 (hours) to determine a WAF score.

Table 6. Sample 24-hour Activity Log

Time of Day	Activity	Score	Sub-Total (score x time)
00:00 – 06:30 am	Sleep	Sleeping: 0.8	6½ hours x 0.8 = 5.20
06:30 – 07:30 am	Prepare for Work	Light: 1.3	1 hour x 1.3 = 1.30
07:30 – 08:30 am	Commute (drive)	Very Light: 1.2	1 hour x 1.2 = 1.20
08:30 – 12:00 pm	Seated – computer	Very Light: 1.2	3½ hours x 1.2 = 4.20
12:00 – 01:00 pm	Lunch - seated	Very Light: 1.2	1 hour x 1.2 = 1.20
01:00 – 05:00 pm	Seated – computer	Very Light: 1.2	4 hours x 1.2 = 4.80
05:00 – 06:00 pm	Commute (drive)	Very Light: 1.2	1 hour x 1.2 = 1.20
06:00 – 07:00 pm	Gym	Moderate: 1.5	1 hour x 1.5 = 1.50
07:00 – 07:30 pm	Commute (drive)	Very Light: 1.2	½ hour x 1.2 = 0.60
07:30 – 08:30 pm	Bathing, cooking	Light: 1.3	1 hour x 1.3 = 1.30
08:30 – 11:30 pm	Dinner, TV , reading	Very Light: 1.2	3 hours x 1.2 = 3.60
11:30 – 12:00 am	Prepare for bed	Light: 1.3	½ hour x 1.3 = 0.65
Total 24-hour Score			**26.75**
WAF Score = Total ÷ 24 hours			**= 1.11**

To complete step two for the H&B and MSJ, use the WAF score of 1.11 and multiply that by the RMR score:

<u>Harris & Benedict</u>

- TDEE = RMR x SAF
    - TDEE = 1,387 kcal x 1.11
    - TDEE = 1,540 kcal

<u>Mifflin-St. Jeor</u>

- TDEE = RMR x SAF
    - TDEE = 1,316 kcal x 1.11
    - TDEE = 1,461 kcal

These numbers are significantly lower than those calculated using the SAF scores, but considering how WAF offers a better representation of daily activities, using a WAF score may be a better option.

Theory to Practice

Peter is a 46-year old business executive seeking to lose weight. Using the following information, estimate his TDEE using the MSJ equation and SAF score.

- *Age: 46*
- *Height: 6'2"*
- *Weight: 240 lbs.*
- *Activity level: IT sales consultant who works from home, but travels frequently (by car and plane) to meet with customers. Given his travel schedule, he manages 2 to 3 workouts per week on average, where he participates in circuits at a light-to-moderate intensity.*

Answers

Height: 6'2' = 74 inches = 74 x 2.54 = 188cm

Weight: 240 lbs.÷ 2.2 = 109.1 Kg

RMR: = (9.99 x 109.1) + (6.25 x 188) – (4.92 x 46) + 5 = 2044 kcal

SAF Score: 1.375

TDEE: 2044 x 1.375 = 2,810 kcal

Summary

It is important to note, all prediction equations are somewhat flawed as these methods are estimations. However, these equations can give health and fitness professionals and their clients a basic starting point when determining calorie needs. Of the prediction equations mentioned, the Mifflin St. Jeor does appear to be the most accurate. Understanding how to use these formulas correctly can help take some of the guesswork out of energy equation. In light of these errors presented, it is important to remember that these formulas provide estimations, thus understand they will not offer an accurate solution to calories in versus calories out. Therefore use these numbers accordingly, but also seek alternative, simpler solutions – some examples are presented in the next article.

References

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