About the model

A dynamic mathematical energy balance model that predicts weight change *(1)* was developed that originates from the energy balance equation based on the first law of thermodynamics *(2)* which states that the rate of energy stored/lost, ES, is equal to the difference of rate of energy intake, EI, and the rate of energy expended, EE,

$$ES = EI - EE$$

The model considered the rate of energy stored/lost as the rate of change of fat free mass (FFM) energy and fat mass energy (FM). The energy densities of FFM and FM, derived from chemical tissue analysis, is estimated as 1020 kcal/kg and 9500 kcal/kg respectively *(3,4)* Hence:

$$ES = 1020\frac{dFFM}{dt} + 9500\frac{dFM}{dt}$$

EE was modeled as the sum of resting metabolic rate (RMR), voluntary physical activity (PA), dietary induced thermogenesis (DIT), and spontaneous physical activity (SPA)

$$EE = RMR + PA + DIT + SPA$$

The non-linear function of weight, gender, and age proposed by Livingston and Kohlstadt *(5)* was applied for the RMR term (**Table 1**):

$$RMR = c_i W^{p_i} - y_i A$$

where c_i, p_i, y_i are constants depending on gender: $i = F, M$. The Livingston-Kohlstadt model was developed using cross-sectional RMR subject data (N>600) and validated on over 700 subject data points ($R^2 > 0.71$).

PA is modeled by a term that is directly proportional to weight:

$$PA = mW$$

and DIT is modeled as a direct proportion of energy intake *(6)* :

$$DIT = 0.075EI$$

SPA was related to total energy expenditures using both overfeeding and underfeeding experimental conclusions. Specifically, it was observed that

$$\Delta SPA = \left(\frac{2}{3}\right)\Delta EE$$

during weight loss *(7-9)* and

$$\Delta SPA = 0.56\Delta EE$$

during weight gain *(10).*

Integration yields:

$$SPA = sEE + C = s(DIT + PA + SPA + RMR) + C$$

where C is the constant of integration and s is 2/3 for weight loss and 0.56 for weight gain.

Isolating SPA results in:

$$SPA = \frac{s}{1-s}(DIT + PA + RMR) + C$$

Recognizing that SPA should never be negative we define SPA as the piecewise function:

$$SPA = \begin{cases} \frac{s}{1-s}(DIT + PA + RMR) + C \text{ if } \frac{s}{1-s}(DIT + PA + RMR) + C > 0 \\ 0 \text{ otherwise} \end{cases}$$

FFM-FM equations relies on the Forbes Model

$$FFM = 10.4 \ln\left(\frac{FM}{\text{Constant}}\right)$$

FFM is related to FM through the Forbes Model (12,13).

$$1020\frac{dFFM}{dt} + 9500\frac{dFM}{dt} = EI - EE$$

$$EE = (1-a)(c_i W^{p_i} - y_i A + mW + SPA + 0.75EI$$

where SPA is the piecewise defined function above.

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