

# **Sticking to your Diet A Mathematical Approach**

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## **Overview**

- **Purpose**
- **Applications and Tools**
- **Background**
- **Methods**

## Weight Loss in Structured Programs

Study and treatment protocol	Weight (kg)			Time to maximum	Rate of weight loss <sup>2</sup>	Predicted rate of weight loss <sup>2</sup>	Energy prescription
	Baseline	Maximum change	(%)				
	kg	kg	%	wk	kg/wk	kg/wk	
Tate et al (8)							
Internet education	78.8	-1.7	2.2	12	0.08	≈0.5-1	1200-1500 kcal/d
Internet behavior therapy	77.4	-4.1	5.3	12	0.34	≈0.5-1	1200-1500 kcal/d
<b>Maximum %WL is 7.7% in 18-40 wks (5-10 mos) Placebo arm of a drug study achieved ~4.3 % WL in 36 weeks (9 mos)</b>							
Low-fat diet	131.8	-1.9	1.4	24	0.08	≈0.3-0.5	30 g/d; 500 kcal/d deficit
Després et al (12)							
Placebo group in drug study	97	-4.3	4.4	24-36	0.12-0.18	≈0.4-0.6	600 kcal/d deficit
(includes run-in)							
Wadden et al (13)							
Lifestyle modification group in drug study	105.1	-8.1	7.7	18-40	0.10-0.45	≈0.5-1	1200-1500 kcal/d
Heshka et al (6)							
Self-help program	94.2	-1.9	2.0	26	0.07	NA	LCD instructions
Commercial weight-loss program	93.1	-5.9	6.3	26	0.23		LCD designed for 0.9 kg/wk weight loss
Dansinger et al (14)							
Atkins Diet	100	-3.6	3.6	8	0.45	NA	Specific advice provided for the 4 popular diets
Zone Diet	99	-3.8	3.8	8	0.48		
Weight Watchers	97	-3.5	3.6	8-26	0.13-0.44		
Ornish Diet	103	-3.6	3.5	8-26	0.14-0.45		
Pi-Sunyer et al (15)							
Placebo group in drug study	105	4.5	4.3	36	0.07	≈0.4-0.6	600 kcal/d deficit
(includes run-in)							

Heymsfield et al. *Am J Clin Nutr* 2007;85:346-54.

## Purpose

### What facilitates WL success?

#### •Success:

Frequent in-person contact with patients  
A specific dietary prescription  
Individualized feedback on dietary intake and body weight

#### •Limitation

Financial  
Geographical barriers  
Does not provide timely treatment advice to patients, which affects weight control.

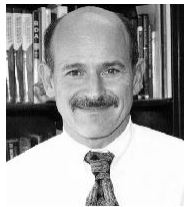
Behavior change and learning theory  
continuous treatment = superior behavior change

Schultz, W., Behavioral theories and the neurophysiology of reward.  
*Annu Rev Psychol*, 2006. 57: p. 87-115.

## Overview

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- Future Directions

## Applications and Tools Main Collaborators



**Steven B. Heymsfield**  
Executive Director PBRC



**Leanne Redman**  
Human Physiology  
PBRC



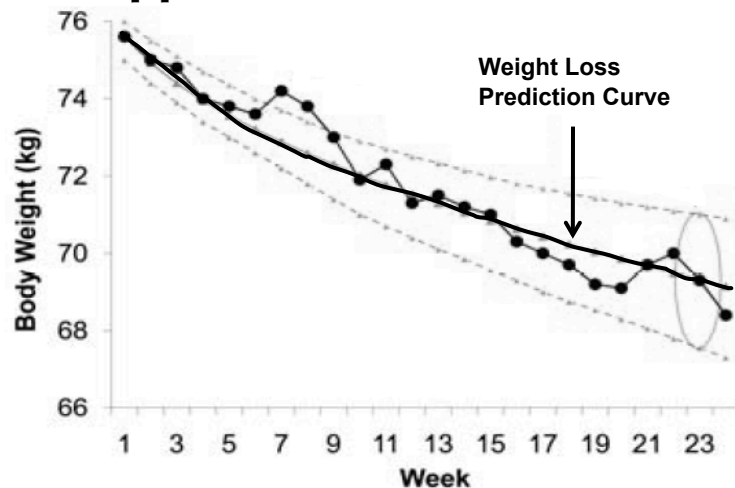
**Corby K. Martin**  
Director Ingestive Behavior  
Laboratory PBRC

## Applications and Tools

- Remote intervention for diet that provided individualized weight loss counseling via a Smartphone.
- The average 12-week weight loss was 9.4% with more than 80% of participants losing more than 5% of initial body weight.
- The corresponding weight loss in controls was only 0.5% and none lost more than 5% of initial body weight.

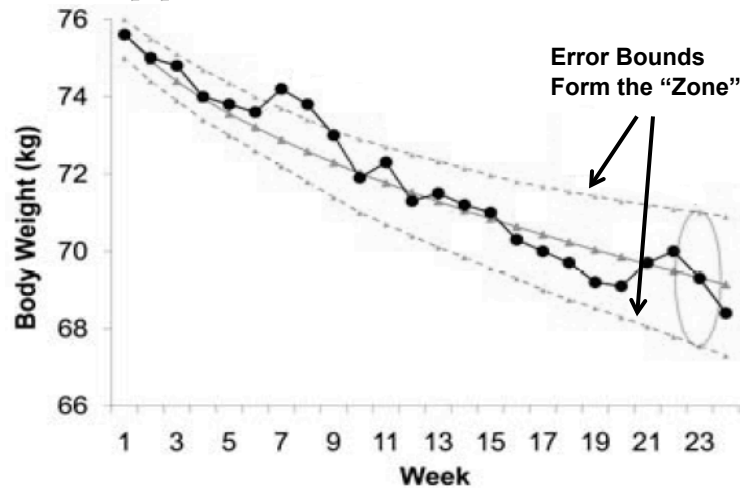
Martin, C.K., et al., Efficacy of an e-Health intervention at promoting weight loss through remote delivery of services: Preliminary results from a randomized controlled trial, in 11th International Congress on Obesity. 2010, Wiley-Blackwell: Stockholm, Sweden. p. 240.

## Differential Equation Energy Balance Model Application



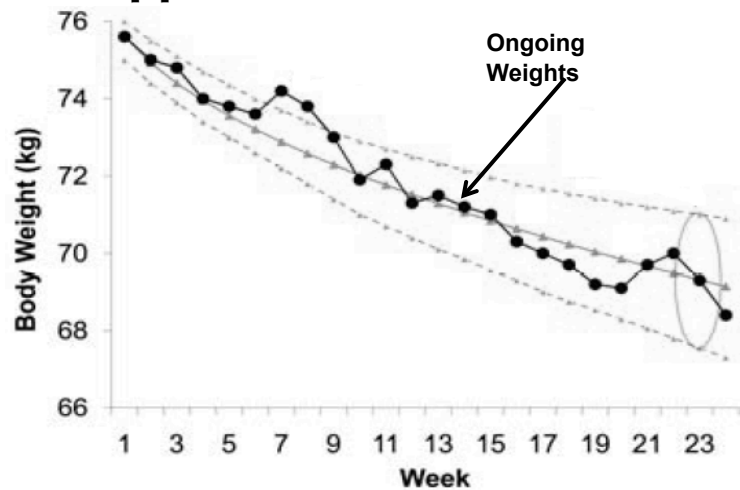
D.M. Thomas, et. al A simple model predicting individual weight change in humans, J. Biol. Dyn. 2010 (in press).

## Differential Equation Energy Balance Model Application



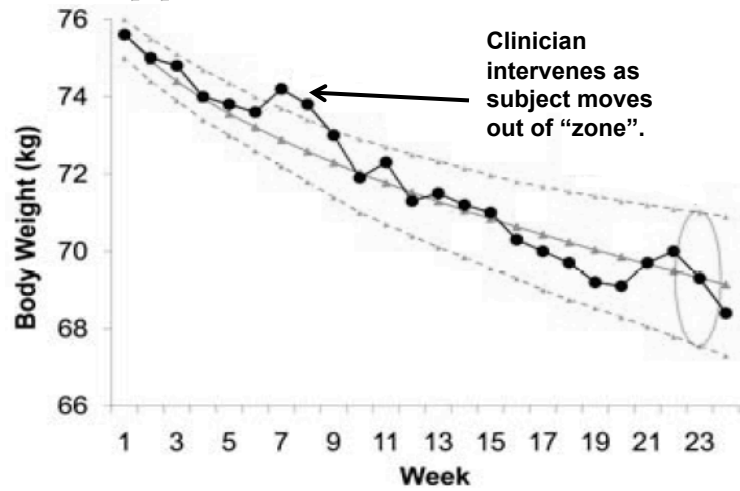
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## Differential Equation Energy Balance Model Application



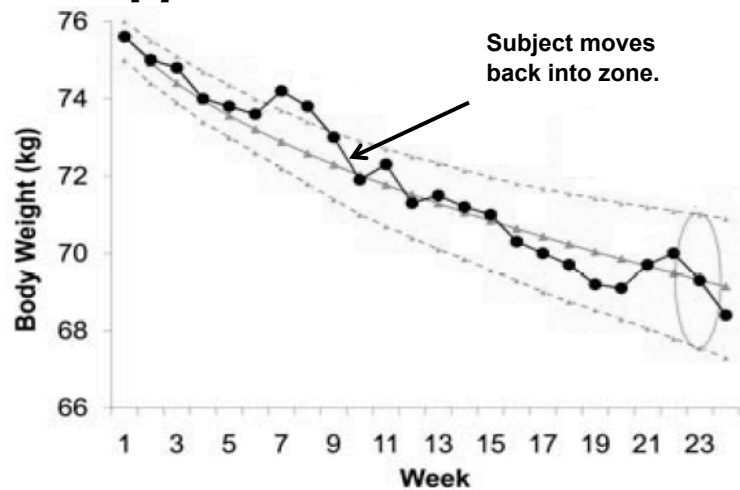
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## Differential Equation Energy Balance Model Application

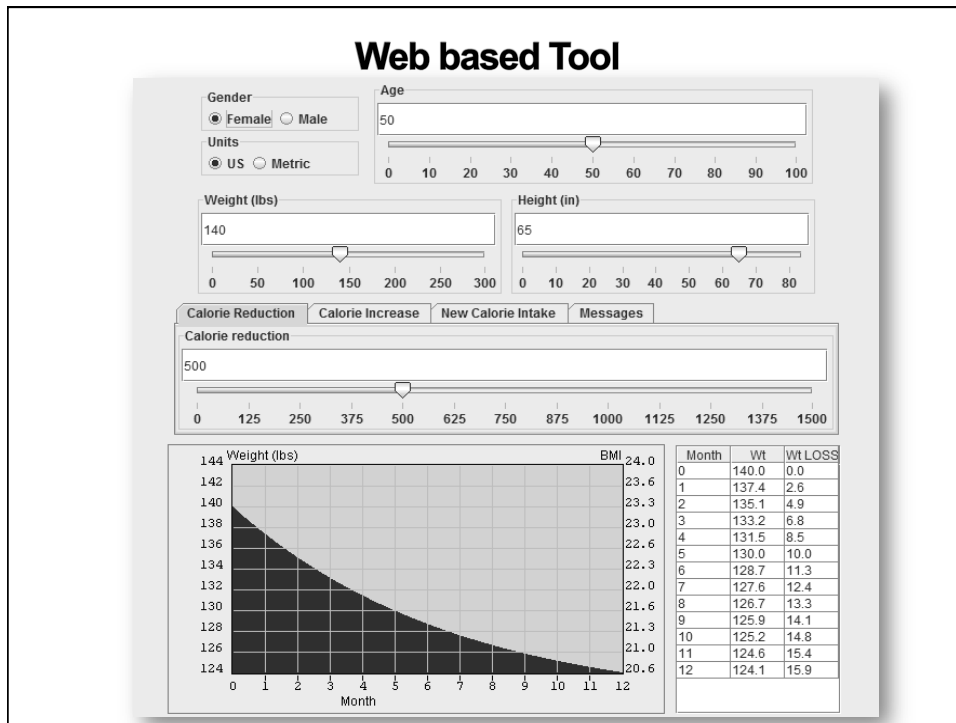


D.M. Thomas, et. al A simple model predicting individual weight change in humans, J. Biol. Dyn. 2010 (in press).

## Differential Equation Energy Balance Model Application



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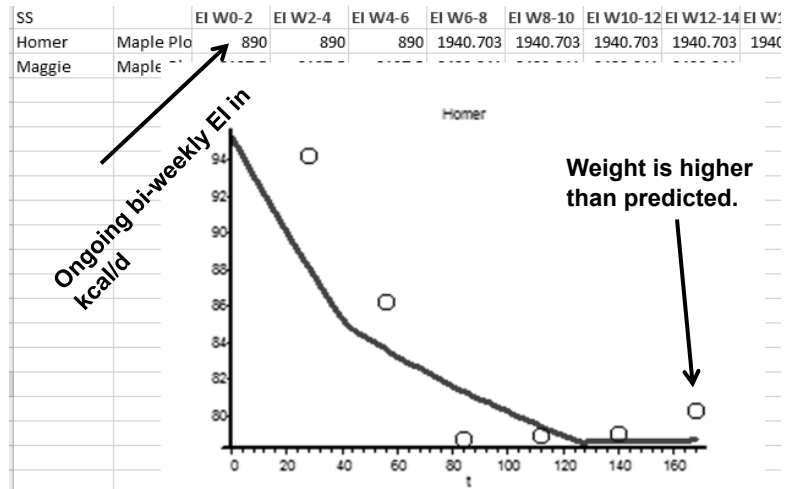
### Excel Interface for Multiple Subjects

Enter baseline data for as many subjects as you want into  
First Sheet

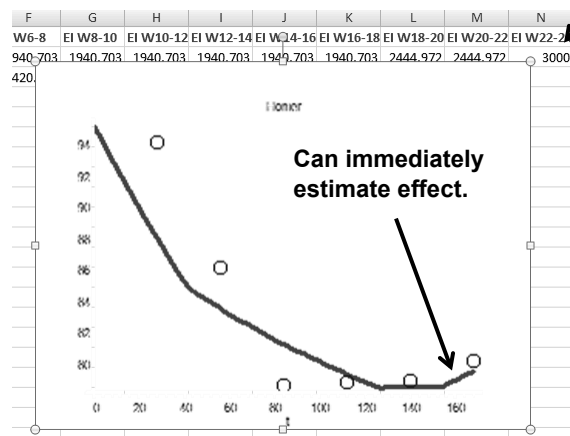
Subject Number	Age	H	Total Mass kg	Study Length in Days	Gender	Target Intake	Weight M1	Weight M2	Weight M3
Homer Simpson	50	182.09	200	168	M	890	222	230	240
Marge Simpson	42	172.11	90	168	F	2137.5	86.8	84.2	78.8
Bart Simpson	10	160.61	40	168	M	890	40	40	40
Lisa Simpson	8	173.11	30	168	F	2081.25	30	30	30
Maggie Simpson	1	172.60	10	168	F	2817	10	10	10

**Age(Years)**  
**Height (cm)**  
**Weight (kg)**  
**Study Length (days)**  
**Target Intake (kcal/d)**  
**Ongoing monthly weights (kg) for comparison to predictions**

## Observe the effects of Varying ongoing EI



Changed EI in last two weeks of study from 2444.922 kcal/d to 3000 kcal/d



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## Dynamic Models

Dynamic models of weight change

- Predict weight change
- Originate from the first law of thermodynamics  
$$ES=EI-EE$$
- Apply cross sectional data

## Methods: Energy Balance Equation

$$\begin{array}{c} \text{Rate of Energy Stored (kcal/d)} \\ \hline ES \\ \hline \end{array} = \begin{array}{c} \text{Rate of Energy Ingested (kcal/d)} \\ \hline EI \\ \hline \end{array} - \begin{array}{c} \text{Rate of Energy Expended (kcal/d)} \\ \hline EE \\ \hline \end{array}$$

## The Heymsfield Model ES

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

Energy Density FFM (kcal/kg) →  $1020 \frac{dFFM}{dt}$   
 FFM is a function of FM based on A, H, G  
 $9500 \frac{dFM}{dt}$  → Energy Density FM (kcal/kg)  
 Change in FM (kcal/d) →  $\frac{dFM}{dt}$

Thomas D, Das S, Levine J, Martin C, Mayer, L, Strauss, B. et.al. New fat free mass - fat mass model for use in physiological energy balance equations. *Nutr. Metab.* 2010; 7: 1-11.

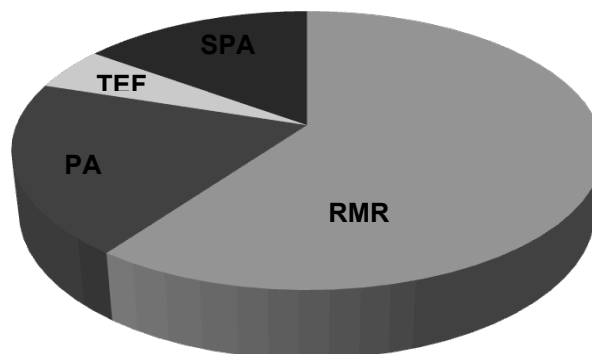
## EI “Adherence Data”

$$\underbrace{EI}_{\substack{\text{Energy intake over time interval} \\ \text{between DXA/DLW measurements}}} \approx \overbrace{1020 \frac{\Delta FFM}{\Delta t} + 9500 \frac{\Delta FM}{\Delta t}}^{\text{Estimated from DXA measurements}} + \underbrace{EE}_{\text{Estimated from DLW measurements}}$$

de Jonge L et al. Validation study of energy expenditure and intake during calorie restriction using doubly labeled water and changes in body composition. *Am J Clin Nutr.* 2007 Jan;85(1):73-9.

D. M. Thomas, et al, A computational model to determine energy intake during weight loss. *Am. J. Clin. Nutr.*, doi:10.3945/ajcn.2010.29687 (2010).

## Energy Expenditures (EE)



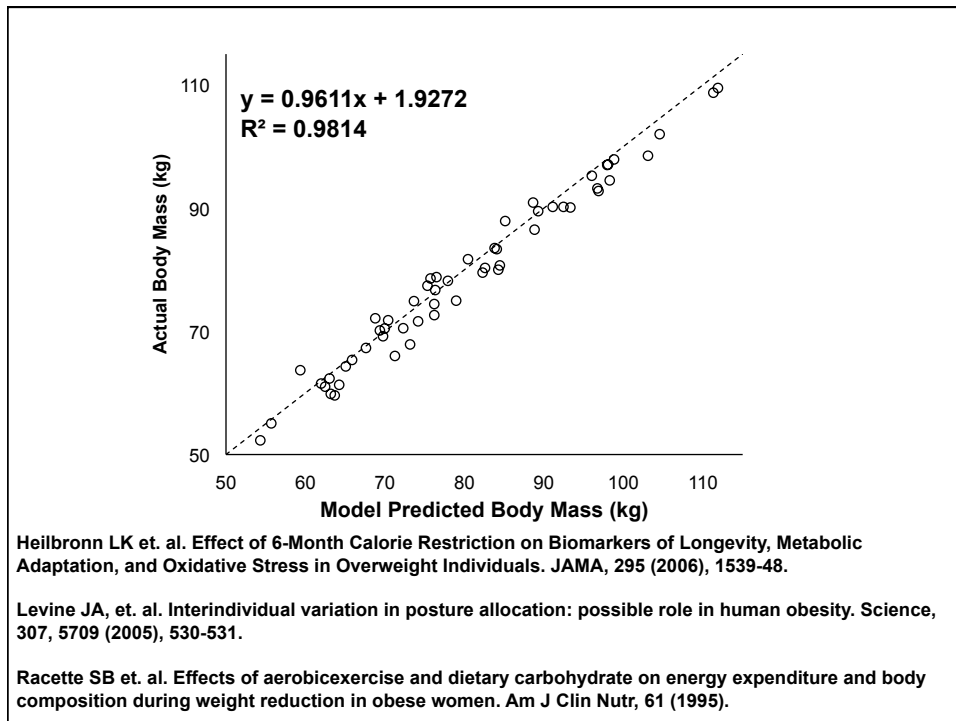
## Existing Model Underdeveloped for increased/decreased PA

Implicitly differentiated FFM-FM function (N>10,000)      PA is a function of W=FFM+FM.      SPA reflects dynamic changes that differ from PA.      Model development (N>600) Model validation (N > 700).

$$1020 \frac{dFFM}{dt} + 9500 \frac{dFM}{dt} = EI - \left[ \overbrace{0.075EI + mW}^{DIT} + \overbrace{\frac{s}{1-s} (0.075EI + mW)}^{PA} + \overbrace{(1-\alpha) \left( c_1 W^{p_1} - y_1 \left( A_0 + \frac{t}{365} \right) + C \right)}^{SPA} + \overbrace{(1-\alpha) \left( c_1 W^{p_1} - y_1 \left( A_0 + \frac{t}{365} \right) \right)}^{EMR} \right]$$

$\xrightarrow{ES}$        $\xrightarrow{EE}$   
 DXA/DLW measured EI during model validation.

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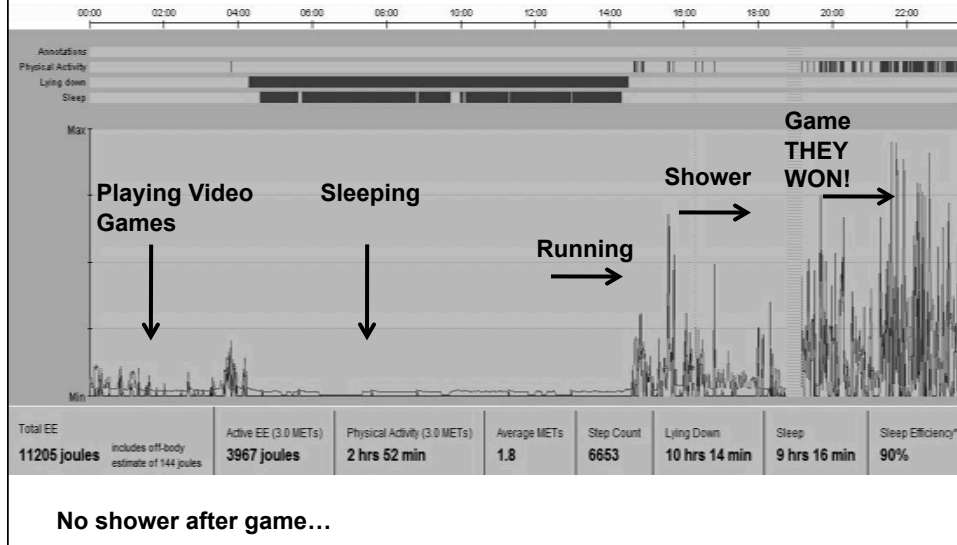
## How does changed PA impacts body composition?



### 3 Measurements at St. Luke's Roosevelt



## Example of armband data



### Thank you to my Collaborators

Anja Bosy-Westphal, Christian-Albrechts, U  
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 Boyd Strauss Monash U  
 Klaas Westerterp, Maastricht U  
  
 Theodore Zderic, PBRC

**Kubek, Lieback, Hero, and Fox Named to All Star Team**

2011-03-31



**Thank YOU!!**