Building a system dynamics model of body weight regulation and obesity

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Outline

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- Problem Description and Research Objectives
- Data
- Weight cycling, or “yo-yo dieting”, as a common feature
Introduction

- **Obesity is a problem.**
  - Factors influencing obesity and the regulation of body weight have been under intensive investigation.
  - Growing interest has culminated in the growth of simulation models:
    - as a tool to investigate this complex system
    - as a means for evaluating hypotheses concerning the underlying pathology

- **Obesity is a “dynamically complex” problem.**
  - A dynamic problem is one that necessitates continuous monitoring and action ("management"). “Chronic” problems.
  - Internal structure is the main cause of dynamic behavior
    - The enemy is us!
Introduction

- Body weight regulation constitutes a suitable area for simulation modeling:
  - Feedback complexity
  - Different levels of factors involved (genetic, dietary, ..)

- Time delays, interplay of factors make it difficult to make quantitative predictions of dynamic patterns

System dynamics is appropriate for quantitative analysis of chronic problems
Methodology- System Dynamics

- A simulation-based procedure for complex dynamic systems
- Main focus: Internal feedback structure, identifying internal relations causing system behavior
- “Predicting” the “dynamic pattern”, instead of predicting system variables point-by-point
- System represented by stock, flow and auxiliary variables
- Corresponds to a set of difference/differential equation
Methodology-
Steps of System Dynamics methodology

- Problem identification *(a dynamic feedback problem is selected)*
- Model conceptualization *(causal loop diagramming)*
- Model construction *(mathematical, numeric)*
- Simulation & verification testing
- Validation *(is my model appropriate for real life?)*
- Analysis and results
- Implementation
Problem Description and Research Objectives

- Most adults maintain a stable body weight and composition, in spite of substantial deviations in their daily food intakes, physical activity levels, resulting energy balances. (Flatt, 1995)
  - Energy In and Energy Out tend to remain adjusted, and protein, carbohydrate, fat balances are achieved
  - As long as this is not the case, body composition keeps changing

Deviations from energy balance trigger body's homeostatic mechanisms:
- 1-Regulating food intake
- 2-Altering rate of energy expenditure
- 3-Altering the composition of fuel mix used for energy generation
Some of core physiological mechanisms

Energy Intake-Expenditure

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Energy Intake-Expenditure

Carbohydrate-fat interactions and obesity examined by a two-compartment computer model

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Computational model of in vivo human energy metabolism during semistarvation and refeeding

- A general simulation model for body weight change based on the Minnesota Starvation Experiment (1940).
- Model consists of 3 macronutrient compartments (stocks): fat, glycogen and protein, and fluxes (flows) between them.
- Energy intake of fat, carbohydrate and protein are external inputs.

Hall Model- Stock-Flow diagram

Hall Model- Stock-Flow diagram

Why to model food intake regulation?

- Diet induced changes in “energy expenditure” help to slightly attenuate the gap between energy intake & expenditure, but does not have power to offset energy imbalances. (Flatt, 1978)

- Regulation of “energy intake” appears to be a more important phenomenon to help achieving a steady-state body weight.

- Less well explored by previous models, also less is known

- We aim to explore interactions between food intake regulation and body composition.
Different “levels”

“Human energy and weight regulation is a complex of nested feedback processes at multiple levels”.

1- Physiological aspects

2- Aspects between the physiology and the behaviour – Combination of voluntary and involuntary effects

3- Environmental, cognitive aspects
Research Questions

- How does food intake- diet composition effect the effort of losing weight?

- How does our body composition change when we lose and gain weight, and what are the implications of this for further attempts of weight loss?

- Can we simulate this model to examine a common feature: “weight cycling”? 
Data: Long-term assessment of energy balance and its relation to body composition*

- **Investigators:** Dr. Scott Lear, Dr. Diane Finegood*
- **Purpose:** To identify the amount of food we eat daily and the amount of physical activity relate to changes in body composition, how day-to-day changes in energy balance affects our weight.
- **Research Design:** This study recruits 20 participants for a period of 3 months.
  - Daily assessment of dietary intake and physical activity
  - Weekly assessment of anthropometry, body composition, resting energy expenditure and provide a fasting blood sample.
Weight cycling, or “yo-yo dieting”

- Unintended consequences of dieting: Detrimental effects on body composition? Both supportive and counter-arguments can be found

We believe that drivers for “natural” weight cycles and today’s “yo-yo dieting” and consequent body weight trajectories are different in nature.

- First dynamic behavior is mainly driven by an “externally” imposed function.
- We cannot observe a similar external data source for the latter.

Fig. Seasonal fluctuations in body weight in rural Gambian women. 
Plot derived from over 20,000 measurements in women of child-bearing age. (Prentice et. al, 1992)
When does weight cycling become more interesting for us?

- We see a pattern in the real data, but cannot observe any externally imposed functions to explain this cyclic behavior.
- No simple, straight answers, no straight-line-thinking!

Endogenous (structural) explanation for weight cycles

- Without having external data force, peoples weights are oscillating, i.e. problem “structural”.
- “Structure”: Complex interactions between our physiology, psychology, behavior & social factors
- Problem is quantitative and dynamic: well suited to computer simulation.

- Iteratively develop models of varying size & scope along with the development of hypotheses & supporting evidence.
A model for the dynamics of human weight cycling

A model for the dynamics of human weight cycling

Summary

- Previous models on body weight regulation are explored in detail, reproduced and simulated when possible.

- The application of system dynamics is appropriate because of the central role homeostatic (feedback) processes play in human energy regulation.

- Regulation of food intake behavior appears to be an important phenomenon to help achieving a steady-state body weight, needs to be further explored.

- Investigating the weight cycling phenomenon would be a good application of SD modeling.
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Questions/ Comments?
(My) Questions

- One shortcoming of the second part of my proposal:
  - It may be hard to find empirical data in these areas, so that we can test our theories (i.e. models).

Do you know any good datasets to study..

- How dieting affects body composition, and vice versa?
- Weight cycling/ yo-yo dieting, its effect on further attempts of losing weight?

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