PREDICTING WEIGHT-LOSS USING DIFFERENTIAL EQUATIONS (PRELUDE)

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INTRODUCTION

Weight-loss is induced by an imbalance between energy intake (EI) and energy expenditure (EE).

The 3500 kcal rule[1] is a weight-loss prescription that approximates a 3500 kcal energy deficit to 1 lb of weight-loss[2]. EI and EE are considered independent variables and weight is assumed to decrease at a fixed rate driven purely by behaviour.

Such **static modelling** grossly overpredicts weight-loss by disregarding changes in EE induced by underfeeding[3].

1. Firstly, ***obligatory decline*** in EE due to the loss of metabolically active tissue[4] i.e., skeletal muscle
2. Physiological mechanisms alter EE to maintain weight at a genetically determined set-point, a process referred to as ***adaptive thermogenesis***[5]

Mathematical modelling may more accurately predict weight-loss by simulating perturbations in EE and energy partitioning in response to underfeeding.

While primarily used in research, accuracy at individual-level is limited due to large variability in physical activity, uncertainty in estimating energy requirements and difficulty ascertaining true dietary intake in free-living individuals.

OBJECTIVES

1. Assess the accuracy of static modelling i.e., the 3500 kcal rule in predicting weight-loss
2. Quantify obligatory and adaptive perturbation in EE associated with severe energy restriction
3. Propose an alternative method of weight-loss prediction requiring simply inputs of weight and calorie intake that can be used in a clinical environment

METHODS

Identifying target group

Individuals enrolled on the **LighterLife UK Ltd Very Low Calorie Diet (VLCD)** weight-loss plan consuming four food-packs per day providing 600 – 800 kcal for 6 – 12 weeks. Individuals were weighed weekly at group meetings and participated in a behaviour-change programme delivered by trained weight management counsellors.

Predicting weight-loss by mathematical modelling

Our model uses an energy conversion of 7700 kcal per kg weight to convert energy deficit to weight-loss.

Assumption: **Weight kg/day =** $\frac{1}{7700}(EI - EE)$

Energy expenditure (EE) is subdivided into:

1. Resting energy expenditure **(REE)**: modelled using a predictor equation[6] based on FFM

REE = 22.76 ***(FFM)*** + 483.94

FFM is predicted using gender- and weight-specific estimates. FFM is assumed to decrease exponentially**,** stabilizing after 10% weight-loss (10% points higher)

2. Physical activity energy expenditure **(PAEE):** modelled using physical activity level index,[7] assuming a fixed value to 1.4 (sedentary-light physical activity)

TEE *(kcal/day) = 1.4(REE)*

3. Diet-induced thermogenesis **(DIT):** modelled as a product of energy intake, assuming a fixed value of 5% of energy intake per day[8]

DIT *(kcal/day) = 0.5(EI)*

Adaptive thermogenesis (AT): No AT assumed at baseline. AT is assumed to increase exponentially, stabilizing after 10% weight-loss at a value of ~15% of TEE.

Summary of Assembed Equation:

$$\frac{d}{dt}w(t) = \boldsymbol{EI} - \underbrace{[\text{REE} + \text{PAEE} + \text{DIT} - \text{AT}]}_{\boldsymbol{EE}}$$

RESULTS

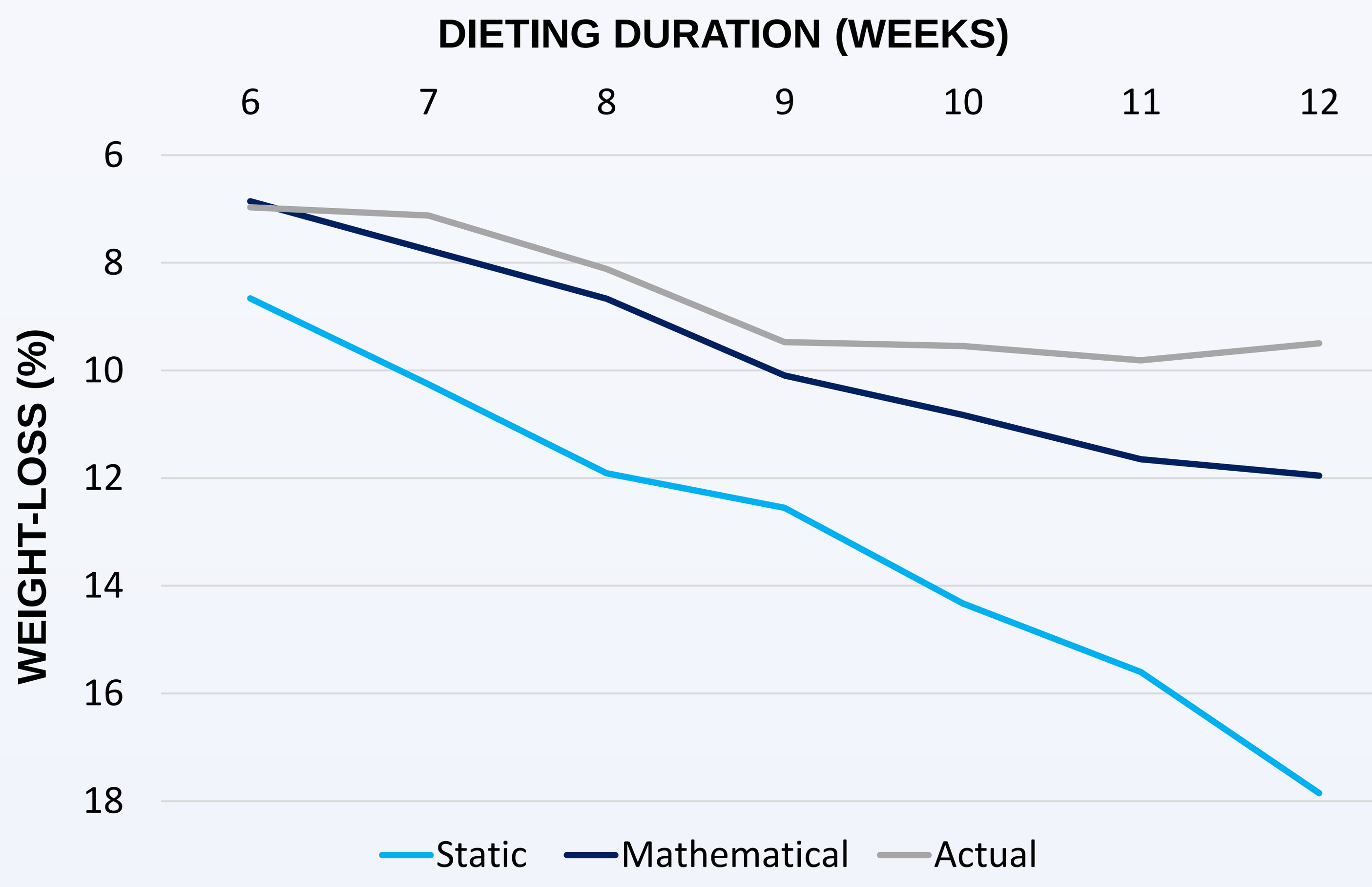

Figure 1: Actual weight-loss *vs.* static and mathematical modelling

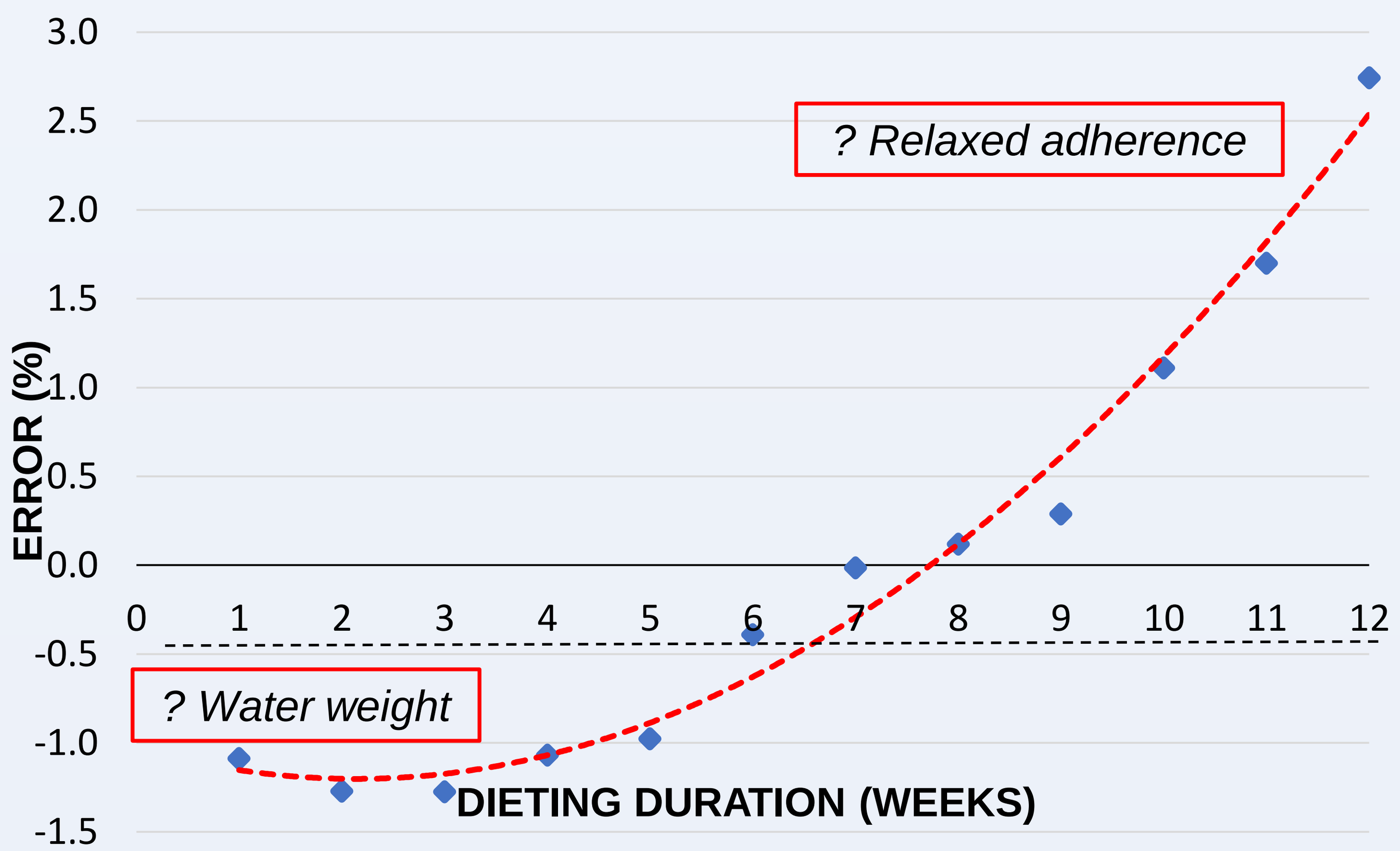

Figure 2 : Summary of weighted mean error (%) using our model

DISCUSSION

Target group (n = 983)

- 983 overweight / obese females
- Mean starting weight of 93 kg (BMI = 35 kg/m^2)
- Mean overall weight-loss of 8.5±4.5 % **(Figure 1)**

Static modelling overestimated weight-loss by ~50%, predicting an overall weight-loss of 12.5±3.6 % **(Figure 1)**

Mathematical modelling predicted a more accurate overall weight-loss of 9.3±2.2% **(Figure 1)**

- Week 1 – 8: model underestimated weight-loss
- Week 9 – 12: model overestimated weight-loss
- Weight-loss within 0.5 kg predicted from week 6 – 9
- Weighted mean error across all dieting duration was calculated at **–0.6**±3.45 % **(Figure 2)**

CONCLUSIONS

1. Static modelling sets unrealistic expectations of achievable weight-loss in clinical weight management
2. Mathematical modelling has a valuable role in setting weight-loss prescriptions and assessing dietary compliance
3. Reliance on simple baseline inputs of weight and calorie intake makes our model applicable in a clinical setting
4. Further refinement needed for reliable prediction in longer dieting durations

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