# Weight Gain During Finals Season: Case Study of Diet Habits and Physical Activity on Body Mass

**17 December 2022**

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**Source code:**
https://github.com/ljm297/IMM-Final-Project

## Abstract

One of the most stressful weeks of a college/university semester is finals week. During this time, due to chronic stress, students will often overeat and gain weight. This paper intends to focus on the change in body mass of a specific group (NYU female students) during the final week (with chronic stressor present).

## 1. Introduction

We all struggle with stress once in a while, especially college students during the final week. Tests, projects, and worries about grades cause college students to perform abnormally at the end of each semester and suffer from the inability to concentrate on work or sleep well. Of these, overeating is one of the most common manifestations. According to statistics, due to chronic stress 64 percent of college students at the top 100 universities in the United States will experience weight instability at the end of the semester. On the other end, a shorter duration of highly increased stress levels, known as acute stress, tends to make people lose their appetite as the brain directs resources away from normal body functions, such as eating, to the organ systems needed to survive an immediate challenge, college students are more likely to deal with chronic stress, where adrenaline's effects on appetite wear off and cortisol starts to urge the body to replenish energy stores, which leads to weight gain. At such times, foods high in fat and calories are more tempting because of the secretion of cortisol. Therefore, this paper mainly focuses on the change in body weight induced by the increase in daily energy intake, and a higher energy expenditure requirement will be suggested at the end to maintain weight stability. In addition, the paper narrowed the time span of months to years analyzed in the original paper, and only looked at weight changes over a short period of one to two weeks.

All of the mathematical calculations or modeling done in this paper are intended to enable end-of-semester college students, including all readers who are or will be experiencing chronic stress, to better understand the effects of stress on weight change and to overcome the side effects associated with it.

### 1.1 Overview of Related Previous Work

In Chow and his team's paper "The dynamics of human body weight change", The law of energy conservation is referred to the General Model of Macronutrient and Energy Flux Balance:

$$\Delta U = \Delta Q - \Delta W \tag{1}$$

The three terms represent the change in energy stored inside the body, change in energy intake, and change in energy expenditure separately, which is the basic principle for the rest of his analysis. They begin with the expression of $\rho_M$, the energy density, and its 3 constituents, $\rho_F$, $\rho_G$, $\rho_p$, respectively, contributing to the dynamics of $\rho_M$. Next, they build reduced models based on the fact that L = M - F. In this step, Chow classifies protein and glycogen with the associated intracellular water as lean mass and remains fat mass unchanged. He discussed how the three-compartment flux balance model can be replaced by a two compartment macronutrient partition model, which is further simplified by assuming that trajectories in the L–F phase plane follow prescribed paths. Finally, Chow elicits a further simplification to a one-dimensional model by finding a functional relationship between F and L so that one variable can be eliminated in favor of the other. Linearizing the dynamical equation for M around the initial mass $M_0$ gives:

$$\rho_M dM/dt \ = \ \mu - \varepsilon(M - M_0) \tag{2}$$

Variables here are defined in the same way as they are in Chow's paper.

## 1.2 Model Parameters and Assumptions

The model is based on an NYU female student, whose age $A_0$ is 18, initial body mass $M_0 = 60$kg, and we assume the final weeks last for 14 days. Now, we consider substituting these real-world examples into the formula to figure out the exact values of the parameters we require.

In Chow's paper, the energy expenditure is a function of fat mass $F(M)$ and lean mass $L(M)$. Furthermore, in the one-dimensional model, Chow establishes a relation between $F$ and $L$ from data collected across a large number of subjects:

$$F \ = \ \phi(L) \equiv Dexp(L/10.4)) \tag{3}$$

$$L \ = \phi^{-1}(F) \equiv 10.4log(F/D) \tag{4}$$

where $D$ is a free parameter.

Accordingly, Thomas, who proposed a similar classification method, categorized lean mass as fat free mass in his paper ($FFM$). Here we have the same functional relationship between $F$ and $L$ for women:

$$FFM(t) \ = \ 10.4ln(F(t)) \ + \ 14.2 \tag{5}$$

$FFM$ represents fat-free mass which equals to the lean body mass $L$ defined in Chow's equation above.

Equating (4) and (5), we get the free parameter $D \approx 0.255282$. Substituting $F,\ L$ in $M_0 \ = \ F_0 + L_0 = 60$, yields the student's initial fat mass $F_0 \approx 16.5891$, initial lean mass $L_0 \approx 43.4109$. Given the initial conditions and the equations listed in Chow's paper, we get:

$$\alpha = \frac{\rho_F}{\rho_L}\frac{F}{10.4} \approx 8.2904$$

$$p \ = \ 1/(1 \ + \ \alpha) \ \approx 0.1076$$

$$\rho_M = (\rho_F * \rho_L) \ / \ (\rho_L + (\rho_F - \rho_L) \ * \ p) \approx 27.2076$$

where $\rho_L = \rho_P / (1 + h_P) = 7.6$ MJ/kg, $\rho_F = 39.5$ MJ/kg, $\alpha(F, L)$ is a continuous function that depends on the mechanisms of body weight change, $p$ refers to $p$-ratio that defines the fraction assigned to lean body tissue. This is used in Energy Partition Model, and $\rho_M$ is the overall energy density.

The data provides convenience for the subsequent quantitative analysis and conclusion. Next, we manage to analyze the weight changes of female college students at the end of the semester in terms of energy intake and energy expenditure with the help of the previous methodologies.

### 1.2.1 Energy Intake

Carbohydrates, protein, fats, and alcohol — dietary macro components — are the sources of energy in the diet. Under normal circumstances, more than 95% of this food energy is digested and absorbed from the gastrointestinal tract to provide the body's energy needs. Studies of normal and overweight subjects have not shown any significant differences in the proportion of food energy absorbed. According to the paper "Impact of stress on metabolism and energy balance" by Cristina Rabasa, and Suzanne L Dickson, the most common stress that humans experience in life, unlike the traumatic stress of "restraint" or "forced swim" encountered by rodents in Rabasa's experiments, is less intense and usually milder and more chronic. These chronic stressors are the main objective of most human studies, in which experts found that "eating palatable high fat or sugar food can relieve negative emotions linked to stress and reduce the HPA axis response", which is later called the "Comfort Food" hypothesis by Mary F. Dallman.

In this model, the "Comfort Food" hypothesis is applied to explain the increase in the energy intake of the NYU female student. The initial daily energy intake is set to $I_0 = 2000$ kcal, and due to the stress of upcoming finals, the student will have an increase in her daily energy intake of $\Delta I = 800$ kcal (about 5 vanilla ice cream) as the "comfort food", which will result in a total intake $I_1 = 2800$ kcal during the final weeks. Here, we assume that food intake is the only way to gain energy.

### 1.2.2 Energy Expenditure

Living can be regarded as a combustion process. The metabolism of an organism requires energy production by the combustion of fuel in the form of carbohydrates, proteins, fat, or alcohol. In this process, oxygen is consumed and carbon dioxide is produced. Measuring energy expenditure means measuring heat production or heat loss. Since there isn't an explicitly defined function for the total energy expenditure in Chow's paper, the model will be defined using Thomas' definition of the total energy expenditure $E$:

$$E = DIT + PA + RMR + NEAT$$

The four quantities are dietary induced thermogenesis (DIT), volitional physical activity (exercise) (PA), basal metabolic rate (RMR), and non-exercise activity thermogenesis (NEAT). Their corresponding percentages in $E$, as Thomas suggests, are as following:

Table 1

| RMR | NEAT | PA | DIT |
|---|---|---|---|
| 40~60% | 10~25% | 20~40% | 4~15% |
| * percentage of quantity in total expenditure | | | |

The calculations of the four quantities in this model are the same as Thomas' model:

$DIT = \beta I$ where β is a constant multiplier

$PA = mM$ where $m$ is the proportionality constant in kcals/kg/day, and

$RMR = (1 - \alpha)(a_i M^{p_i} - y_i(A_0 + t/365))$
α is the percent of metabolic adaptation, $\alpha \in [0, 1]$.
$a_i$, $y_i$, $p_i$ are constants related to gender.
$A_0$ is the initial age, and $t$ is the time in days.

$\Delta NEAT = r\Delta E$ ; $NEAT = \frac{r}{1-r}(DIT + PA + RMR) + C$
$r$ represents the proportionality constant corresponding to the change in NEAT and the change in total expenditure E.

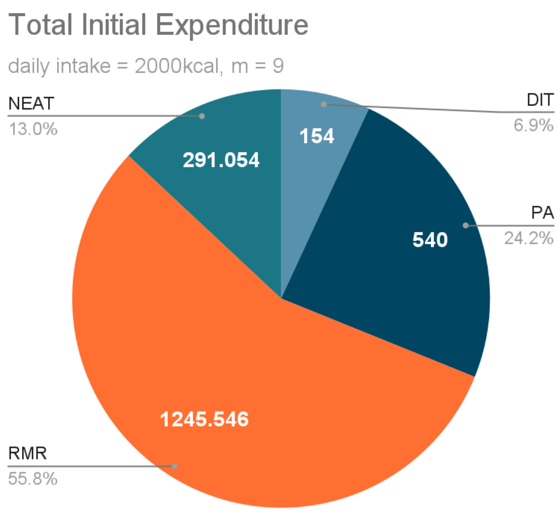
The model takes $\alpha = 0.1$, $A_0 = 18$, $t = 14$, $C =- 2500$ as an example of a possible combination of the constants, this combination gives a valid percentage in E for each of these four quantities. Based on the data from the overfed experiment in Levine's paper, "Role of Nonexercise Activity Thermogenesis in Resistance to Fat Gain in Humans", we can use the mean change in NEAT and in total expenditure E to derive a reasonable value of $r = 0.59$

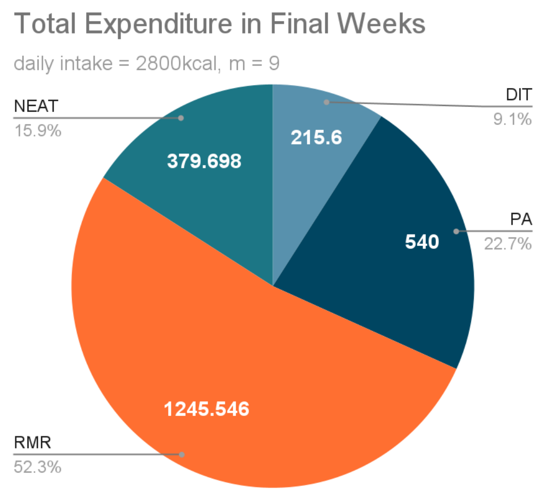
## 2. Results and Figures

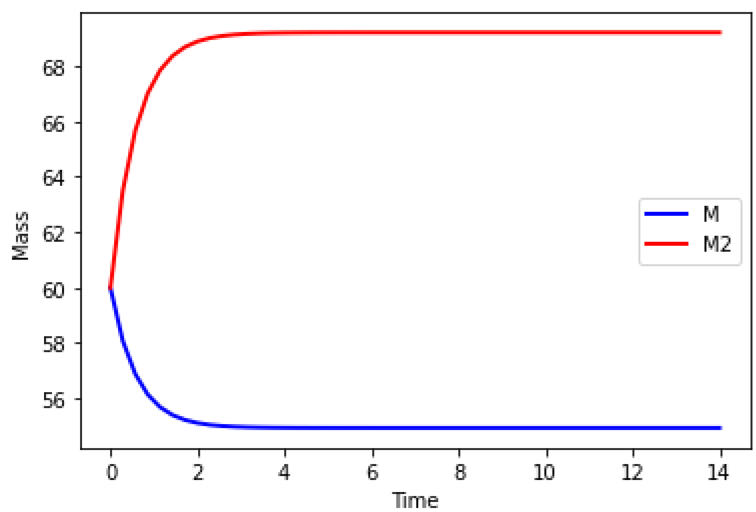
We compared two different energy expenditure outcomes for female college students with an 800-kcal difference in food intake for two different amounts of volitional physical activity every day. Since Thomas suggests that in the Chow-Hall model, "we assume that kcals used for non-weight bearing activity is negligible", here we will also assume the weight-bearing exercise is the only component of the physical activity energy expenditure. Therefore, the way we evaluate the model on different amounts of physical activity is by directly adjusting the proportionality constant $m$ in Thomas' equation for $PA$.

### 2.1 Less Daily Volitional Physical Activity ($m = 9$)

The results show that all else being equal, adding an additional 800 kcal intake resulted in a significant increase in dietary-induced thermogenesis and nonexercise activity thermogenesis. At the same time, the other two variables were unaffected. The overall energy expenditure increased by 6.7%.



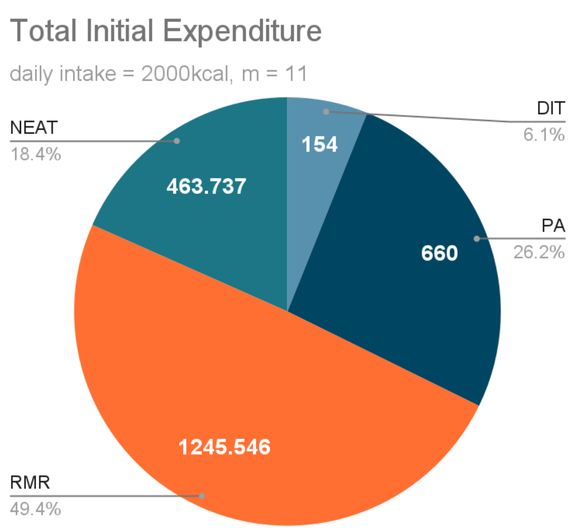



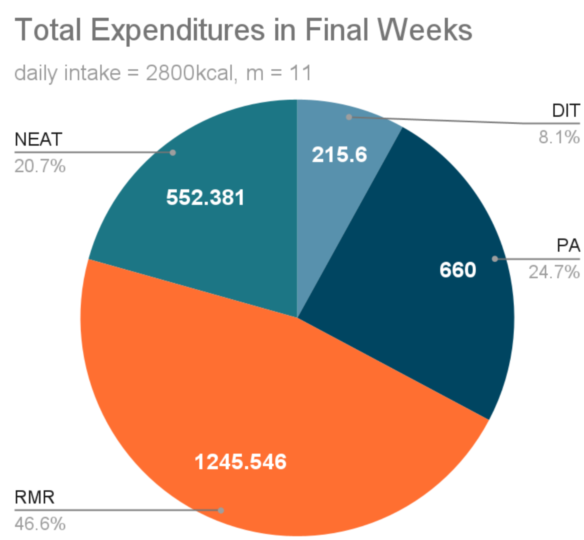



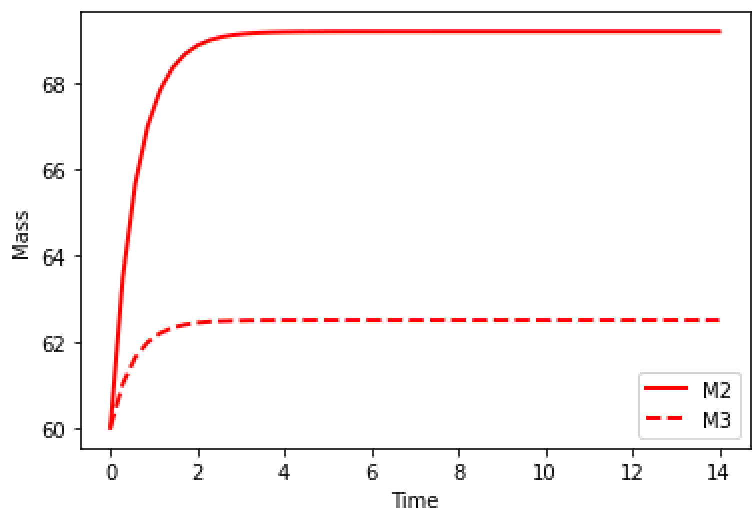

M: m = 9, I = 2000kcal
M2: m = 9, I = 2800kcal

### 2.2 More Daily Volitional Physical Activity ($m = 11$)

We observe that increasing daily physical exercise is an efficient way to prevent gaining weight when the food intake is suddenly increased. Increasing by $(11 - 9) \times 60 = 120kcal$ in daily volitional physical activity, which equals to about 30 minutes of fast-walking, this 18-year-old female student maintains her body mass under 63 kg instead of the original 69 kg after two weeks of stress-eating.




M2: m = 9, I = 2800kcal
M3: m = 11, I = 2800kcal

### 2.3 Recommended Amount of Physical Activity

Based on the previous results, we conclude that with proper amount of extra physical exercise, it is fully possible for this student to maintain her original body weight without forfeiting her comfort food. In this specific case, the recommended $m$ is about 11.88, which means a daily physical activity energy expenditure of 712.8 kcal. This recommended amount of exercise is plausible since with a body mass of 60 kg and a metabolic adaptation $\alpha$ of 0.1, the student only needs to run at a moderate speed for about 70 minutes, or do a fast-cycling for about 55 minutes.

## 3. Conclusion

The final week usually brings college students chronic stress, which has a large chance of impacting their original dieting habits. This paper does a case study of a 18-year-old female college student where we use the Chow-Hall model in conjunction with Thomas' mathematical expression for energy expenditure to determine the change in the student's body mass. After the numerical simulation, an increase of 172.8 kcal in weight-bearing physical activity can prevent the female student from gaining 9 kg during the 14 days of final week. Facing one of the most common coping mechanisms for chronicle stress: comfort food, students can still maintain their initial body weight with an extra amount of daily physical activity.

## 4. References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