TITLE

Human Energy Metabolism (HEM) can be expressed quantitatively:

Energy Intake, EI, is the amount of calories ingested (Hall, 2012). Energy Stored, ES “reflects net changes in the body mass of carbohydrate, protein and fat” (Hall, 2012). Energy Expendture, EE can be subdivided into three parts

Resting Energy Expenditure (REE) is the rate of energy at rest, influenced by body size and composition. Thermic Effect of Food (TEF) represents “digestion and processing of ingested food” (Hall, 2012). Activity Energy Expenditure (AEE), is ‘Energy Expenditure Rate during activity’ (Hall, 2012). Both equations can be combined:

For body weight maintenance EI should be equal to EE. “Any imbalance between the intake and utilization of these macronutrients will lead to an alteration in body composition” (Hall, 2012). Quantitatively we can interpret ES to represent this alteration. We obtain ES > 0 when EI > EE, and ES < 0 when EI < EE. Positive balance for prolonged period of time causes measurable weight gain (Galgani and Revussin, 2008). In this investigation we are going to consider whether positive energy balance results in higher Body Mass Index (BMI), Waist to Hip Ratio (WHR) and/or Body Fat percentage (BF%) in males and/or females. In this experiment TEF was excluded due to limitations in availability of equipment required. As discussed by Reed and Hill (1996) ventilated-hood indirect calorimetry system is needed to calculate the accurate Resting Metabolic Rate in first place, so that the rest of the procedures are valid. For collecting other data cheap, quick, easy and non-invasive methods were used.

Methods

1. Calculation of Energy Intake

Each of the 50 participants involved (48 females and 12 males) kept a food diary for a 48-hour period (Figure 1.1). The average of the total energy content (kcal) form two days was calculated.

1. Energy Expenditure

Each participant kept an activity diary for a 48 hour period (Figure 1.2). The average from two days was calculated. Height of each individual was measured using the stadiometer. Each participant stand bare feet in a natural position and the height was noted. Resting Energy Expenditure (REE) was measured using a spirometer for five minutes placing a mouthpiece removed from a Milton fluid in the mouth and clipping the nose. Each subject was breathing from spirometer for 5 minutes. Each individual was told to relax breath in from the spirometer at the start and exhale into the spirometer at the end of time. Oxygen volume inhaled was subtracted from the initial volume of oxygen present in the spirometer. Then each litre of oxygen inhaled was converted into kcal of energy knowing that each litre produces 4.8 kcal of energy. Therefore by knowing the average number of calories used per minute, results were scaled into the 24 hour period of time to obtain REE. This allowed to calculate the Total Energy Expenditure (TEE) by multiplying REE with daily activity factor.

1. Energy Stored

Weight and BF% were measured using a laboratory scale (Tanita) incorporated with Bioelectric Impedance Analysis. One kilogram was subtracted from the weight for additional clothing. From the data gathered, Body Mass Index (BMI) was calculated (Figure 1.3). Then WHR was measured by noting the narrowest point on the torso and the greatest circumference at the buttocks using a tape-measure. Those two values were then divided respectively.

Results

Table 1 shows an example observation:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sex | WHR | Height [m] | Weight [kg] | Energy Intake [kcal/day] | Energy Output [kcal/day] | Body Fat % | BMI |
| Female | 0.8 | 1.55 | 57 | 2073 | 2073 | 24.9 | 23.7 |

Table 1

The sample is composed of 50 observations, all of which can be viewed in the appendix D.

Energy Balance (EB) is calculated by subtracting energy output from energy intake for each observation.

Energy Balance is treated as the **independent variable**, because it is a direct cause of body composition change. WHR, BMI and BF% are direct (BF%) and indirect (WHR, BMI) measures of body composition change, and therefore are expected to be influenced by Energy Balance and are treated as **dependent variables**.

Female and male observations are analysed separately, as it is known that the mechanism of fat storage in the adipose tissue is strongly sex-dependent [FIX CITATION: cite nature paper].

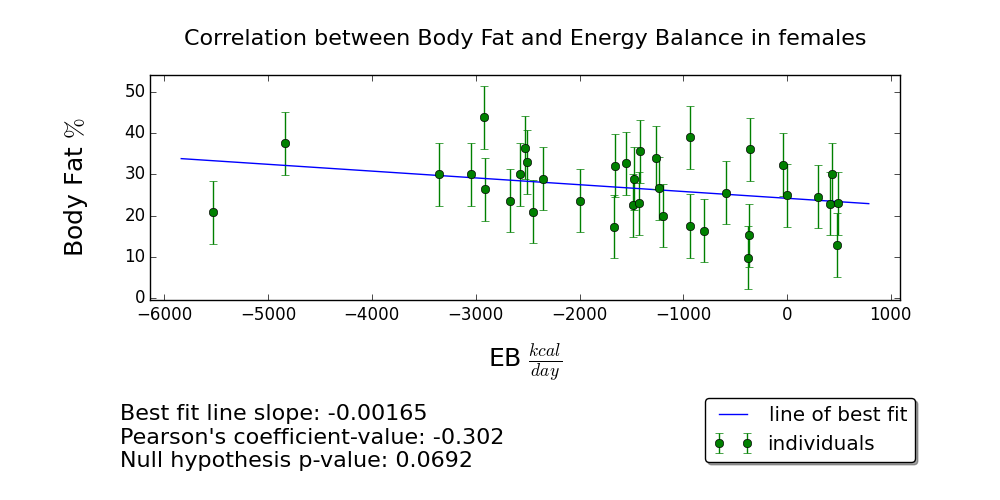
The following three assumptions are made about the distribution of independent and dependent variables:

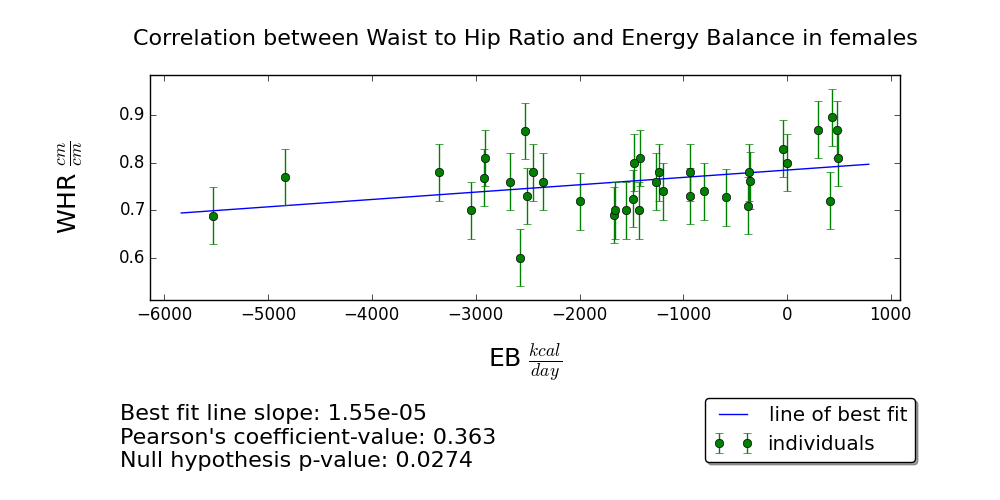
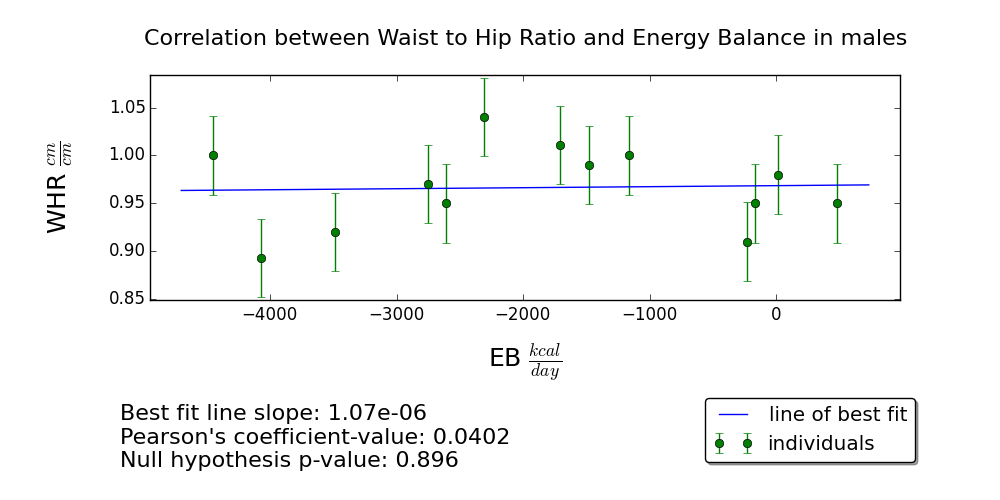
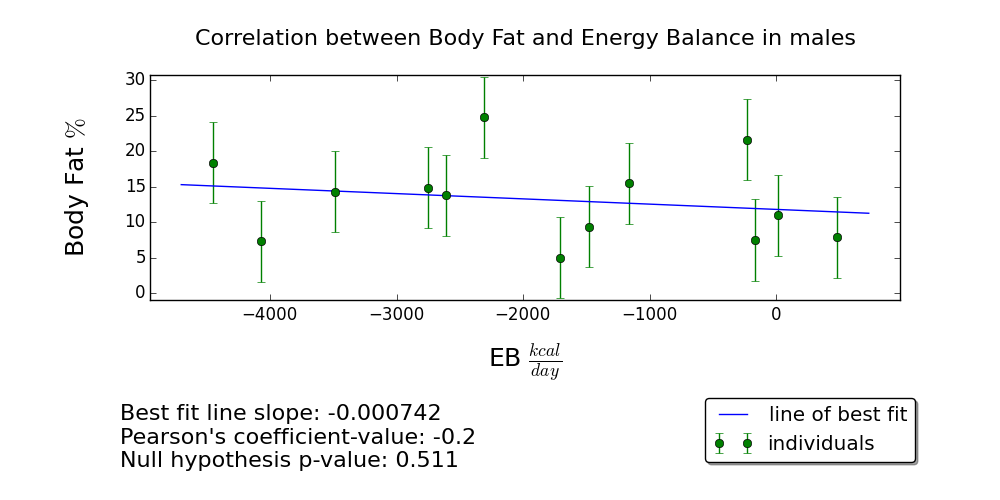
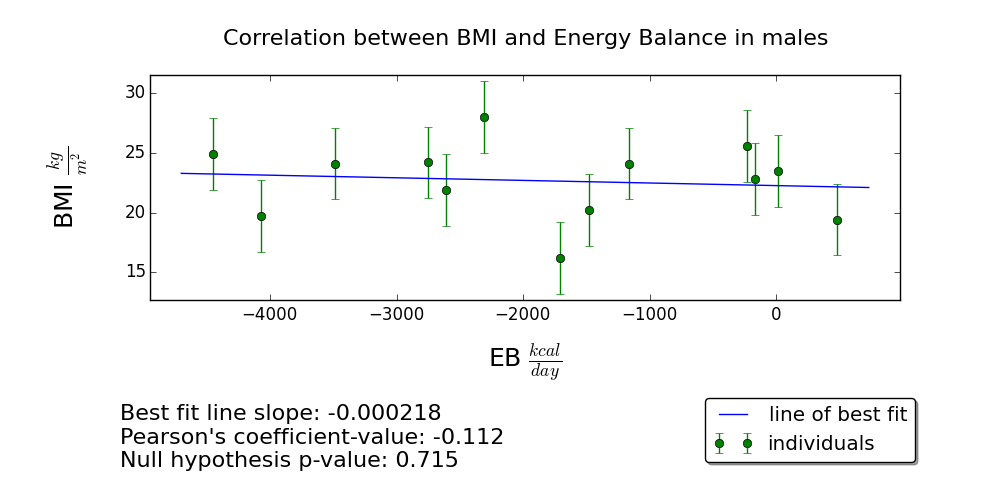
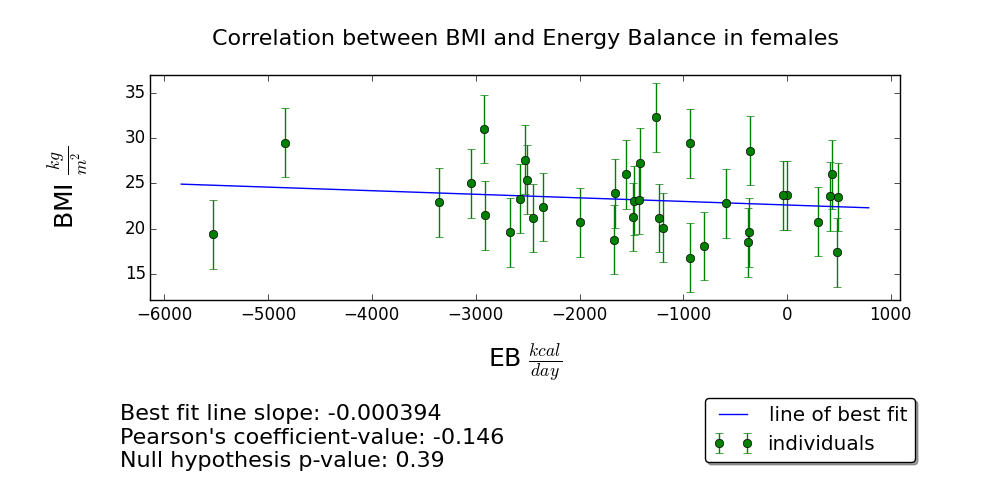
1. The independent variable and the dependent variables are both normally distributed.
2. Observations are independent between units of observation.
3. There is a linear relationship between EB and each of BMI, WHR and BF%

The validity of each of these assumptions is discussed in the appendix A – Data Assumptions.

Only through making these assumptions it becomes valid to employ linear regression to investigate the correlation between each dependent variable and EB (FIX CITATION: https://onlinecourses.science.psu.edu/stat501/node/253). Linear regression is therefore used to produce the best fit line. The slope of the line, its Pearson’s correlation coefficient and the p-value of the corresponding null hypothesis are reported. A detailed explanation of each of these values is given in appendix B – Correlation Measures. The null hypotheses are that there is no correlation between a dependent variable and the independent variable, for females or males. E.g. BMI (WHR, BF%) is not correlated to EB in females (males).

A total of 6 graphs is obtained (Figures 1 - 6). Table 2 summarises obtained statistical results.





Conclusions:

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Limitations:

There are certain procedures which may have lead to errors. To make the experiment statistically more valid, higher number of participants should have been used as well as equal number of males and females. A 48 hour period might not be an accurate source of the exact diet and activity of a person. Additionaly, data provided might not have been honest due to the fact that subjects knew in what way their data was being analysed. One of the ways to improve accuracy could be to ask subjects to keep food and activity diaries for a month without any additional information provided about the experiment. One of the biggest errors was the measure of REE, because it was done in a laboratory and for a short period of time. To improve this, each individual could rest for 30 minutes before the test was done, should consume the last meal 2 hours before the test, do the test in a quiet room and should not move their arms and legs during. Body fat percentage and weight of each participant was measured in clothes, which influenced values relying on those. To improve the accuracy for both of those all participants should be naked and on an empty stomach in the morning in case of water and food influence. Equal number of males is needed to increase accuracy for male results (mention graphs) REPETITION?

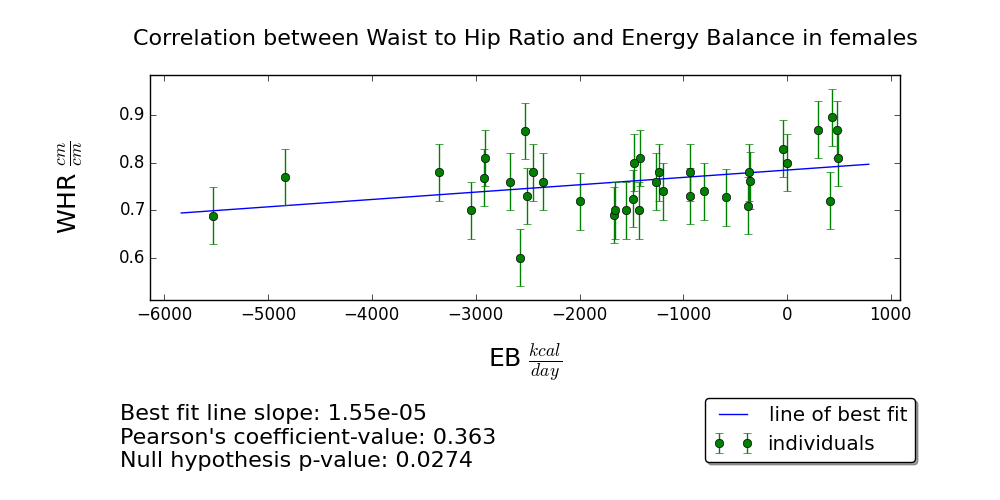
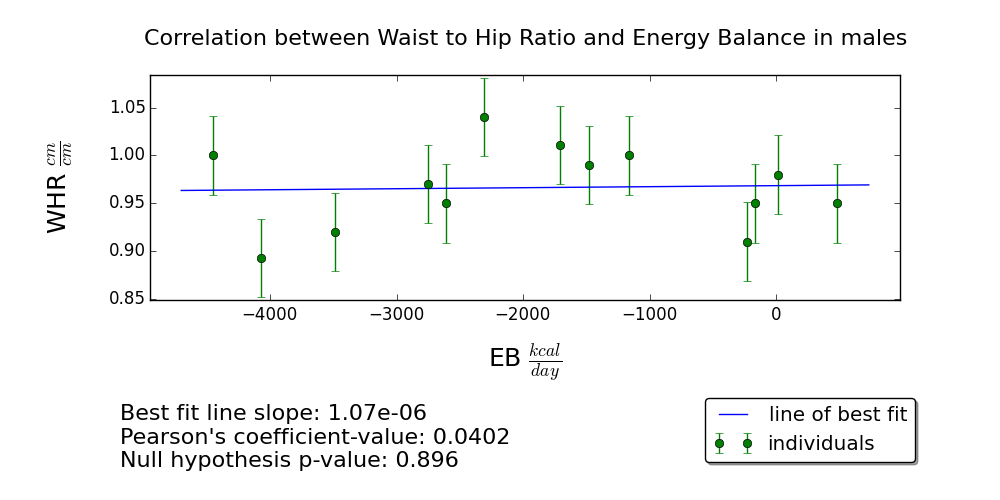
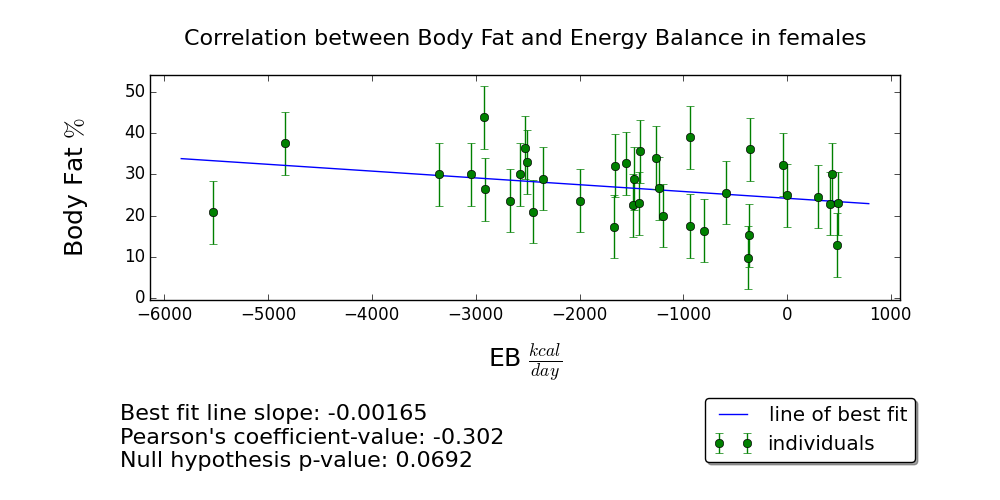
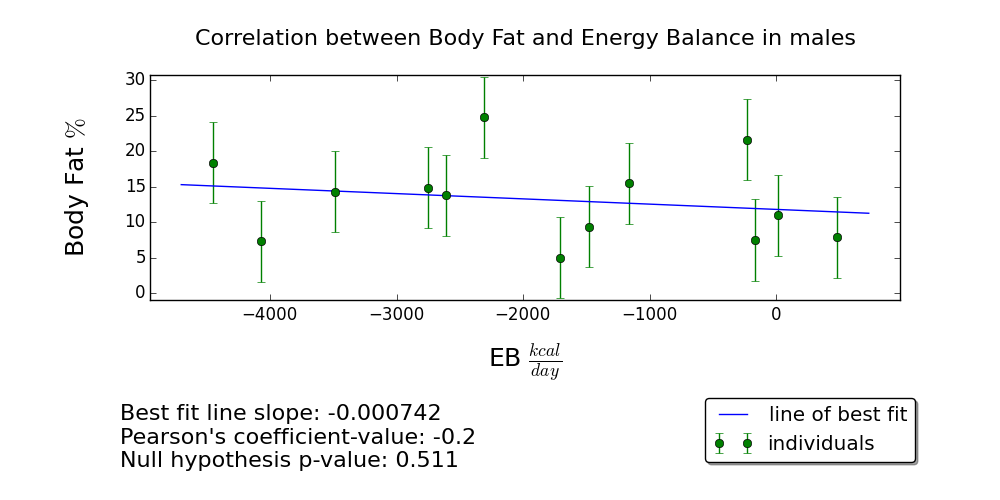
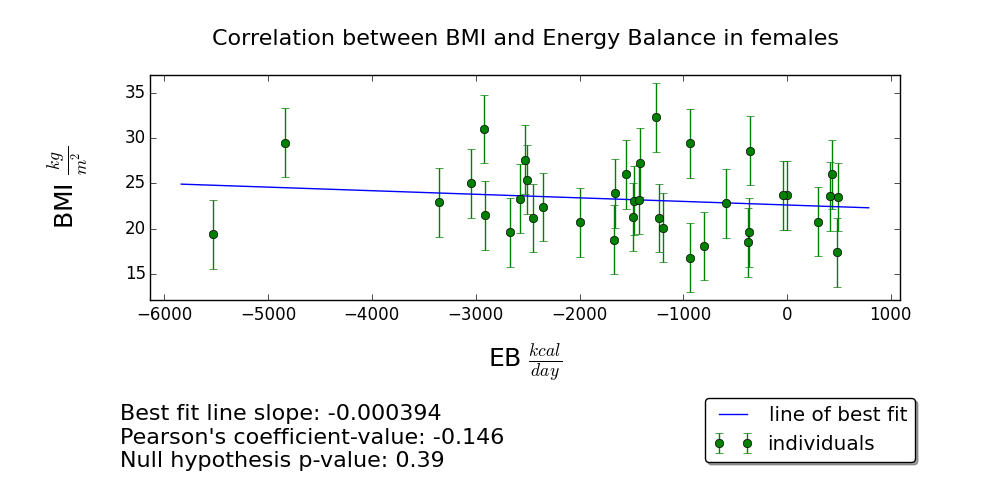
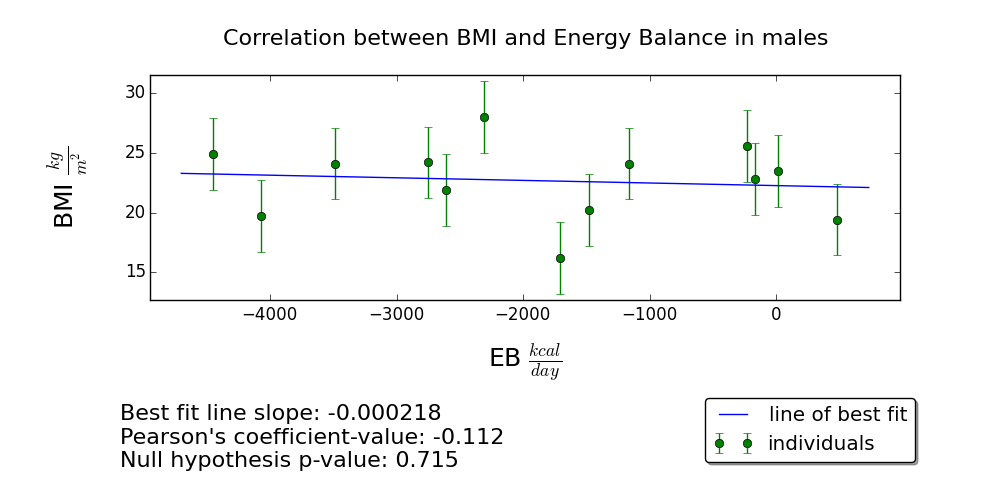
Appendix A – Data Assumptions

Assumption 1 is based on the fact that phenotypic characteristics, which are influenced by multiple genes and many environmental factors, like amount of adipose tissue [FIX CITATION: cite nature paper] are normally distributed, which is a corollary of the Central Limit Theorem.

Assumption 2 states that a weight (BMI, Energy Balance, etc.) of one student in the class does not influence the weight (BMI, Energy Balance, etc.) of any another student. This is reasonable as the study participants originate from unrelated backgrounds with various eating and exercise habits.

Assumption 3 is based on the HEM equation and the fact that there is a linear correspondence between a unit of mass of adipose tissue and the amount of energy stored.

Appendix B – Correlation Measures



Pearson’s coefficient and p-value for the corresponding null hypothesis are computed using the scipy.stats.pearsonr function in statistical library scipy.

From the manual of this function:

“The Pearson correlation coefficient measures the linear relationship between two datasets. Strictly speaking, Pearson’s correlation requires that each dataset be normally distributed. Like other correlation coefficients, this one varies between -1 and +1 with 0 implying no correlation. Correlations of -1 or +1 imply an exact linear relationship. Positive correlations imply that as x increases, so does y. Negative correlations imply that as x increases, y decreases.

The p-value roughly indicates the probability of an uncorrelated system producing datasets that have a Pearson correlation at least as extreme as the one computed from these datasets. The p-values are not entirely reliable but are probably reasonable for datasets larger than 500 or so.”

[http://docs.scipy.org/doc/scipy-0.14.0/reference/generated/scipy.stats.pearsonr.html]

Any null hypothesis is rejected, if p < 0.05.

Appendix C – Particpant Form

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Food/drink consumed | Portion small/medium/large | Amount (g) | Energy Content (kcal/100) | Total Energy Content (kcal) |
| Breakfast |  |  |  |  |  |
| Lunch |  |  |  |  |  |
| Tea |  |  |  |  |  |
| Supper |  |  |  |  |  |
| Extra Snacks |  |  |  |  |  |
| TOTAL FOR 24 HOURS (kcal) | | | | | |

Figure 1.1 Food Diary for a 24 hour period

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Hours | Time of day | Activity | Duration (hours) | Activity factor | Duration  X  Activity factor |
| 1 |  |  |  |  |  |
| 2 |  |  |  |  |  |
| 3 |  |  |  |  |  |
| 4 |  |  |  |  |  |
| 5 |  |  |  |  |  |
| 6 |  |  |  |  |  |
| 7 |  |  |  |  |  |
| 8 |  |  |  |  |  |
| 9 |  |  |  |  |  |
| 10 |  |  |  |  |  |
| 11 |  |  |  |  |  |
| 12 |  |  |  |  |  |
| 13 |  |  |  |  |  |
| 14 |  |  |  |  |  |
| 15 |  |  |  |  |  |
| 16 |  |  |  |  |  |
| 17 |  |  |  |  |  |
| 18 |  |  |  |  |  |
| 19 |  |  |  |  |  |
| 20 |  |  |  |  |  |
| 21 |  |  |  |  |  |
| 22 |  |  |  |  |  |
| 23 |  |  |  |  |  |
| 24 |  |  |  |  |  |
| TOTAL | | | | |  |
| AVERAGE DAILY ACTIVITY FACTOR (total/24) | | | | |  |

Figure 1.3 Body Mass Index equation.

Appendix D – Raw Data

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Sex | WHR | Height [m] | Weight [kg] | Energy Intake [kcal/day] | Energy Output [kcal/day] | Body Fat % | BMI |
| female | 0.8 | 1.55 | 57 | 2073 | 2073 | 24.9 | 23.7 |
| female | 0.6 | 1.67 | 65 | 1432 | 4006 | 30 | 23.3 |
| female | 0.724 | 1.76 | 66 | 2032 | 3516 | 22.5 | 21.3 |
| female | 0.73 | 1.71 | 49 | 2103 | 3041 | 17.5 | 16.8 |
| female | 0.77 | 1.54 | 70 | 1905 | 6746 | 37.6 | 29.5 |
| female | 0.81 | 1.57 | 58 | 1916 | 1431 | 23 | 23.5 |
| female | 0.719 | 1.69 | 59 | 1599 | 3592 | 23.6 | 20.7 |
| female | 0.727 | 1.61 | 59 | 1401 | 1988 | 25.6 | 22.8 |
| female | 0.78 | 1.72 | 87 | 1514 | 2447 | 39 | 29.4 |
| female | 0.73 | 1.66 | 70 | 1947 | 4451 | 33 | 25.4 |
| female | 0.81 | 1.67 | 60 | 1794 | 4703 | 26.4 | 21.5 |
| female | 0.87 | 1.57 | 43 | 1052 | 576.5 | 12.9 | 17.4 |
| female | 0.69 | 1.63 | 50 | 1251 | 2916 | 17.3 | 18.8 |
| female | 0.78 | 1.75 | 70 | 1743 | 5101 | 30 | 22.9 |
| female | 0.83 | 1.72 | 70 | 1752 | 1792 | 32.4 | 23.7 |
| female | 0.76 | 1.45 | 68 | 1680 | 2942 | 34 | 32.3 |
| female | 0.689 | 1.59 | 49 | 1274 | 6811 | 20.8 | 19.4 |
| female | 0.867 | 1.58 | 69 | 941 | 3467 | 36.5 | 27.6 |
| female | 0.7 | 1.65 | 68 | 1988 | 5032 | 30 | 25 |
| female | 0.87 | 1.74 | 63 | 1177 | 881 | 24.6 | 20.8 |
| female | 0.769 | 1.77 | 97 | 1406 | 4330 | 43.86 | 31 |
| female | 0.81 | 1.6 | 70 | 1691 | 3110 | 35.6 | 27.3 |
| female | 0.71 | 1.61 | 48 | 1170 | 1548 | 9.8 | 18.5 |
| female | 0.78 | 1.71 | 62 | 2448 | 4900 | 21 | 21.2 |
| female | 0.8 | 1.64 | 62 | 1203 | 2678 | 29 | 23.1 |
| female | 0.7 | 1.71 | 70 | 643 | 2299 | 32.1 | 23.9 |
| female | 0.7 | 1.64 | 70 | 1213 | 2765 | 32.7 | 26 |
| female | 0.76 | 1.65 | 61 | 1672 | 4022 | 29 | 22.4 |
| female | 0.76 | 1.69 | 56 | 1465 | 4135 | 23.6 | 19.6 |
| female | 0.78 | 1.61 | 55 | 1086 | 2322 | 26.7 | 21.2 |
| female | 0.74 | 1.61 | 52 | 1695 | 2896 | 20 | 20.1 |
| female | 0.78 | 1.58 | 49 | 584.1 | 950.4 | 15.3 | 19.6 |
| female | 0.74 | 1.61 | 47 | 1098 | 1901 | 16.4 | 18.1 |
| female | 0.76194 | 1.63 | 76 | 890 | 1244 | 36.1 | 28.6 |
| female | 0.896 | 1.48 | 57 | 1494 | 1058 | 30 | 26 |
| female | 0.72 | 1.58 | 59 | 2112 | 1699 | 22.9 | 23.6 |
| female | 0.7 | 1.58 | 58 | 890 | 2322 | 23 | 23.2 |
| male | 0.98 | 1.75 | 72 | 1755 | 1741 | 11 | 23.5 |
| male | 0.893 | 1.86 | 68 | 3118 | 7185 | 7.3 | 19.7 |
| male | 1 | 1.73 | 72 | 2857 | 4022 | 15.5 | 24.1 |
| male | 0.95 | 1.76 | 60 | 2612 | 2128 | 7.9 | 19.4 |
| male | 0.92 | 1.81 | 79 | 2294 | 5782 | 14.3 | 24.1 |
| male | 0.95 | 1.85 | 75 | 4247 | 6857 | 13.8 | 21.9 |
| male | 1.011 | 1.79 | 52 | 1906 | 3611 | 5 | 16.2 |
| male | 0.91 | 1.81 | 84 | 4107 | 4335 | 21.6 | 25.6 |
| male | 0.97 | 1.65 | 66 | 2063 | 4816 | 14.9 | 24.2 |
| male | 1.04 | 1.68 | 79 | 2936 | 5241 | 24.8 | 28 |
| male | 0.99 | 1.75 | 62 | 1436 | 2918 | 9.36 | 20.2 |
| male | 0.95 | 1.69 | 65 | 6032 | 6203 | 7.5 | 22.8 |
| male | 1 | 1.77 | 78 | 1649 | 6103 | 18.4 | 24.9 |

References

1. Hall, K. D., Heymsfield, S. B., Kemnitz, J. W., Klein S., Schoeller, D. A. & Speakman, J. R. (2012) Energy balance and its components: implications for body weight regulation. The American Journal of Clinical Nutrition. 95(4). p. 989-994.
2. Galgani, J. & Ravussin, E. (2008) Energy metabolism, fuel selection and body weight regulation. International Journal of Obesity. 32. p. S109–S119.
3. Reed, G. W. & Hill J. O. (1996) Measuring the thermic effect of food. American Journal of Clinical Nutrition 63(2). p. 164-9.