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Abstract

The role of dietary carbohydrates, dietary fat, and body fat in the regulation of sleep and tiredness was determined by studying sleep and tiredness in nineteen female subjects of different body compositions. It was hypothesized that dietary fat and body fat interact to cause an increase in sleep and tiredness. Subjects were healthy college students between the ages of 18 and 25 years old. This study was dual-phased. Phase I involved a 21 day record of normal hours slept per day and self-reported tiredness. In Phase II, the subjects consumed both a high-fat and high-carbohydrate diet for five days (for a total of 10 days).

Phase I found no correlation between body fat percentage and sleep during the control (mixed carbohydrates, fat, and protein) diet. An insignificant negative correlation was found between body fat percentage and tiredness ratings, but this was likely due to psychological factors or chance.

The results from Phase II suggest that both dietary fat and carbohydrates consistently decrease sleep and increase tiredness in high-fat individuals. The primary effect of dietary fat and carbohydrates appears to be a decrease in the hours of sleep. The effect on tiredness may be a secondary response to sleep deprivation, or may be independently effected by diet. The data cannot support or contradict that tiredness differences exist for high body fat subjects who obtain similar hours of sleep during different meal composition diets, because sleep varied for each diet.

The results suggest that dietary fat interacts with body fat to increase tiredness, while at the same time decreasing sleep. Surprisingly, carbohydrates also appear to interact with body fat to decrease sleep and increase tiredness. Dietary fat, however, increased tiredness to a much larger extent than dietary carbohydrates. High body fat subjects invariably obtained less sleep and higher tiredness ratings on high-fat low-carbohydrate and high-carbohydrate low-fat diets, but lower body fat individuals were not consistently effected to a great extent. In comparison to carbohydrates, dietary fat had a greater sleep depriving effect and tiredness was dramatically increased in high body fat subjects. The conclusion of this study is that high body fat individuals can decrease their tiredness and increase sleep by avoiding high-fat and high-carbohydrate diets.

Introduction

The exact physiological and biological interactions that occur to induce sleep are unknown. It has been shown, however, that obese patients are more tired and fatigued than normal individuals (11). This can affect the ability of these individuals to be productive members of society. Therefore, to help these individuals, the mechanism that elicits this tiredness effect should be discerned. For the biological mechanism of fat induced tiredness to be understood, the kind of fat (dietary or body) responsible for this effect should be determined.

Thus far, research has shown a correlation between sleep and both dietary and body fat (13, 11). Recent evidence shows that obese individuals experience more sleepiness (tiredness) than normal weight individuals (11). Studies have been inconsistent regarding dietary fat and its effect on tiredness. Some studies show an association between dietary fat and tiredness (13, 12, 4, 5, 2). Other studies, however, conclude that there is no correlation between dietary fat and tiredness (14, 8). Body fat differs greatly from dietary fat. The mechanism in which body fat induces sleep and tiredness, therefore, may be much different from the way dietary fat elicits sleep and tiredness. However, few studies comparing these two types of fat (dietary and body) have been conducted. It is possible, then, that obese people experience more tiredness because they eat a lot of fat. Therefore, the effect could be caused by dietary fat and not body fat.

Even if diet is controlled in body fat studies, the chronic effect of a high-fat diet may not be eliminated by the control diet. For example, dietary fat has been shown to increase levels of hormones such as cholecystokinin (13). The increased levels of this and other dietary induced hormones, therefore, may be the cause of tiredness (not body fat). If one only studies body fat, however, the investigator may be observing the chronic effects of a high fat diet. This intervening variable could be eliminated in a study by measuring hormone levels to ensure they are not elevated due to a chronically high-fat diet. This is not possible since all the hormones responsible for inducing sleep from dietary fat are not known (16). Therefore, the best way to differentiate between the effects of dietary fat and body fat is to research both in the same study. Both phases of the study were done on the same subjects, so differentiation between the dietary and body fat variables could be accomplished.

The purpose of this study was to determine and compare the effects of meal composition and body fat on sleep and tiredness. Determining the difference between the role of dietary and body fat in the regulation of sleep and tiredness was only the first step in determining dietary effects on sleeping patterns. The effect of carbohydrates was also addressed in this study, due to the fact that carbohydrates were shown to effect tiredness in past studies (2, 4,5, 12, 13). Some studies indicate that carbohydrates appear to increase tiredness (4, 10), but research suggests that the effect is less intense than that of fat (13,14). Carbohydrates, however, have also been shown to have a negligible effect on sleepiness (8, 5, 9). The effect of a high-fat low-carbohydrate diet on sleep and tiredness could be due to, or at least influenced, by the lack of carbohydrates. Therefore, determining the effect of carbohydrates on sleeping patterns is necessary to accurately determine the effect of meal composition on sleep and sleepiness.

It was hypothesized that high body fat individuals would tend to sleep more than normal body fat subjects and significantly more than low body fat subjects over the three week control period (phase I). It was also hypothesized that: body fat and dietary fat would interact, sleep and tiredness would increase, and subjects with a high body fat composition would be severely effected by the high-fat diet. Normal body fat individuals and low body fat individuals were expected to be moderately effected by the dietary fat.

Carbohydrates were expected to have a negligible effect on all subjects. It was anticipated that obese individuals could increase their vivacity and stamina through dietary regulation.

Methods

For the purpose of this study, numerous terms were defined:

• *Normal body fat subjects* were defined as 18-25% body fat

• *High body fat subjects* were defined as women over 25% body fat (obese)

• *Low body fat Subjects* were defined as women less than 18% body fat.

• *High fat-low carbohydrate (HFLC) diet* was defined in this study as allowing the subjects to eat only certain foods and instructing them to avoid certain other foods high in carbohydrates (i.e. explaining what is in food so they can avoid carbohydrates and eat fat).

• *Low fat-high carbohydrate (LFHC) diet* was defined as allowing the subjects to eat only certain foods high in carbohydrates and/or protein. Fat in food will be explained and they must avoid fatty foods.

• *Control diet* was defined as the subjects normal diet and generally consisted of moderate fat and carbohydrate intakes.

• *Tiredness* was defined as the desire for sleep and is synonymous with sleepiness in this study.

• *Bioelectrical impedance* is a method used to measure body fat percentage using electricity. The percentage of fat is based on the resistance of the body to a small electrical current.

Sample and Setting

This study consisted of a sample of 19 females: 6 high-fat, 7 normal-fat, and 6 low-fat subjects between the ages of 18 and 25. All the subjects were healthy with no chronic diseases. Subjects were appropriately informed and consent to participate was obtained. The research was conducted at the University of North Florida in the College of Health's nutrition laboratory. Subjects were paid for their participation.

Phase I

Body fat percentage was measured using bioelectrical impedance. Subjects were then placed into the appropriate category in accordance with their body fat percentage. For three weeks, subjects recorded the total amount of sleep obtained each day and the time of day the sleep was obtained. They ranked their "perceived" tiredness on a Likert scale ranging from 0-10. On this scale, 10 is the most tired/fatigued one can image being and 0 is not tired/fatigued at all. This self-rated tiredness was recorded as soon as the subject woke and every subsequent five hours until the subject was again asleep. As a control measure, subjects recorded the approximate time they ate breakfast, lunch, and dinner on each day. A daily diet was also recorded for eight days of this three week period (phase I).

The average sleep and tiredness ratings were calculated for each individual and each group. The standard deviation for each group was also calculated. The individual averages were plotted against body fat percentage and linear regression was conducted to receive an r-squared value.

Phase II

Phase II consisted of ten subjects from Phase I. Each subject was placed on a high-fat, low-carbohydrate diet for five days (Monday-Friday) and a low-fat, high-carbohydrate diet for five days (Monday-Friday). During this time, they recorded their sleep and "perceived" tiredness as described in Phase I. The subjects were given detailed lists of foods to eat and avoid. The subjects could eat as much of the allowed foods as they desired. Each subject also recorded what he or she ate each day during these diet periods to assure compliance.

The average hours of sleep and average tiredness rating was calculated for the five days of each diet. The average hours of sleep and average tiredness ratings for each individual's control diet period (21 days) was then graphed with the individual's values during both diets. The average tiredness rating, average hours of sleep, and the standard deviation for each diet was also calculated. The average hours of sleep and tiredness ratings were then compared for each 5-day diet period.

Results

Phase I

Table 1. Comparison of Average Sleep and Tiredness over a Three Week Period for Three Body Fat Percent Groups.

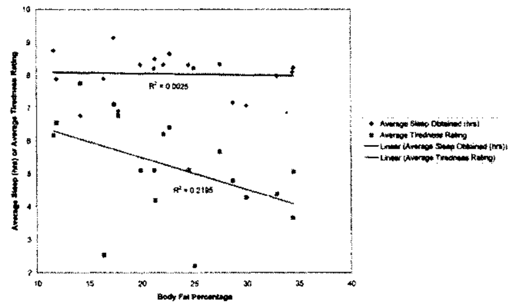
Group	Average hours sleep	Average tiredness ratings
Low body fat	7.89 (±0.95)*	6.15 (±1.85)
Normal body fat	8.36 (±0.16)	4.91 (±1.4)
High body fat	7.82 (±0.55)	4.64 (±0.69)

* Standard deviation

In Table 1, the average hours of sleep and tiredness rating for each of the three body composition groups was determined for the twenty-one day control period. The data shows that the average amount of sleep reported was greatest for the normal body fat subjects, while low body fat subjects reported the second highest average hours of sleep and high body fat subjects received the least amount of sleep. The average tiredness ratings were highest for the low body fat subjects. Normal body fat subjects reported the second highest average tiredness ratings and high body fat subjects reported the lowest average ratings. The standard deviation for each value was also calculated and noted in parentheses.

Figure 1 shows the correlation between body fat percentage and both sleep and tiredness during the 21 day control period of Phase I. The plot of average hours sleep with body fat percentage has a best-fit line that is almost completely level ($r^2 = 0.0025$). The graph of average tiredness rating with body fat percentage has a downward sloping best-fit line ($r^2 = 0.2195$).

Figure 1. Correlation of Body Fat Percentage with Average Sleep and Average Tiredness Rating During 21 Day Control Period.



Phase II

Table 2: Average Hours of Sleep Obtained during 21 Day Control Diet and 5 Day HCLF and HFLC Diets.*

Sleep: control	Sleep: HCL	Sleep: HFLC	Body fat %
7.89	8.00	7.81	16.4
9.14	9.40	8.60	17.4
6.91	7.87	8.65	17.8
8.49	8.08	9.20	21.3
8.32	8.27	6.71	22.1
8.65	8.40	8.40	22.7
7.17	6.06	5.63	28.7
7.98	7.25	6.88	32.9
8.23	7.63	7.05	34.5

* Subject 10 was omitted due to non-compliance

Table 2 shows the average sleep obtained during the 21 day control period, the five day HCLF diet, and the five day HFLC diet of Phase II. The results suggest that the HFLC diet produced both increases and decreases in the low body fat and normal body fat composition groups, as compared to the control period. The high body fat subjects, however, all exhibited a decrease in the average hours of sleep obtained on the HFLC diet, in comparison to the control period. The high body fat subjects also all decreased in the average hours of sleep obtained on the HCLF diet, in comparison to the control diet. The low body fat individuals increased their average hours of sleep during the HCLF diet and the normal fat individuals all decreased their hours of sleep on the HCLF diet.

Table 3. Average Tiredness Ratings Obtained during 21 Day Control Diet and 5 Day HCLF and HFLC Diets.

Tirednes: control	Tiredness: HCL	Tiredness: HFLC	Body fat %
2.54	1.48	2.44	16.4
7.12	7.49	4.24	17.4
6.77	3.03	6.92	17.8
4.19	3.72	4.21	21.3
6.21	6.19	6.56	22.1
6.41	3.96	3.76	22.7
4.79	5.03	6.18	28.7
4.38	4.65	5.68	32.9
5.06	5.90	7.12	34.5

* Subject 10 was omitted due to non-compliance

Table 3 compares the average tiredness ratings recorded during the control period, five day HFLC diet, and five day HCLF diet of Phase II. Compared to the control diet, the HFLC diet had five subjects recorded higher tiredness ratings and four subjects recorded lower ratings. Compared to the control diet, the HCLF diet had four subjects record higher tiredness ratings and five subjects record lower ratings. Comparison of the HFLC and HCLF diet tiredness ratings in table 3 shows that seven out of nine subjects gave higher ratings on the HFLC diet. Tiredness ratings for all high body fat individuals were greater during the high-carbohydrate diet and much greater during the high-fat diet, as compared to the control diet period.

Table 4. Average Hours of Sleep and Average Tiredness Ratings During HFLC and HCLF Diets.

Body fat %	Sleep (hrs): high fat	Sleep (hrs): high carb	Tiredness: high fat	Tiredeness: high carb
16.4	7.81	8.00	2.44	1.48
17.4	8.60	9.40	4.24	7.49
17.8	8.65	7.87	6.92	3.03
21.3	9.20	8.08	4.21	3.72
22.1	6.71	8.27	6.56	6.19
22.7	8.40	8.40	3.76	3.96
28.7	5.63	6.06	6.18	5.03
32.9	6.88	7.25	5.68	4.65
34.5	7.05	7.63	7.12	5.90
Phase III Average	7.65 (□ 1.16)	7.88 (□ 0.91)	5.23 (□ 1.63)	4.61 (□ 1.81)

* Standard deviation

Table 4 presents average hours of sleep and average tiredness ratings during the five day HCLF and five day HFLC diets of Phase II. Comparison of sleep during the HFLC and HCLF periods indicates that one diet did not consistently produce higher or lower sleep values. However, six out of nine subjects on the HFLC diet did obtain less sleep than when they were on the HCLF diet. Comparison of tiredness during the HFLC and HCLF diet periods indicates that one diet did not consistently produce higher or lower tiredness values. However, seven out of nine subjects on the HFLC diet indicated higher tiredness ratings. Sleep tended to decrease and tiredness tended to increase in those individuals on the HFLC diet.

Figure 2 shows the correlation between body fat percentage and both sleep and tiredness for the HFLC diet of Phase II. The best fit line for sleep has a downward slope ($r^2 = 0.4010$). The best fit line for tiredness has an upward slope ($r^2 = 0.2947$).

Figure 2. Correlation of Average Tiredness Rating and Average Hours of Sleep with Body Fat Percentage for Phase II HFLC Diet.

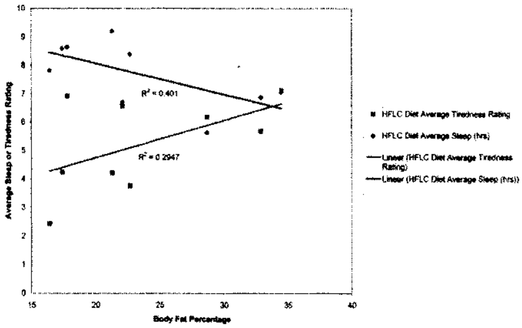


Figure 3 shows the correlation between body fat percentage and both sleep and tiredness for the HCLF diet of Phase II. The best fit line for sleep presents a downward slope (r2 = 0.3680). The best fit line for tiredness presents an upward slope (r2 = 0.0991).

Figure 3. Correlation of Average Hours of Sleep and Tiredness Ratings with Body Fat Percentage for Phase II HCLF Diet.

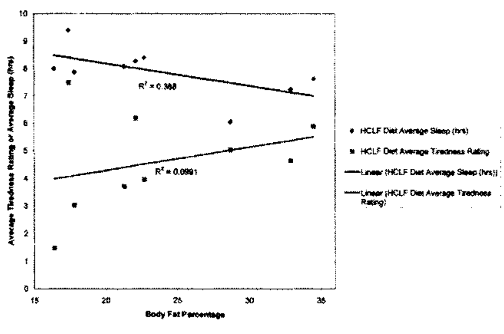


Figure 4 compares the effect of control, HCLF, and HFLC diets on the average hours of sleep obtained in Phase II. The plots for each period overlap and no plot is consistently above or below the other for subjects oh high body fat composition. The HFLC diet graph is also consistently below the HCLF diet graph for the subjects of high body fat composition.

Figure 4. Effect of Control, HCLF, and HFLC Diets on Average Hours of Sleep Obtained per Day in Phase II

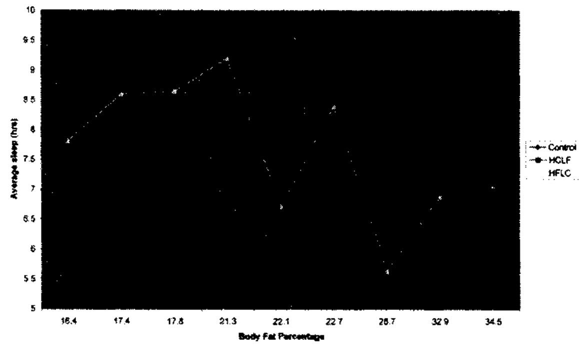
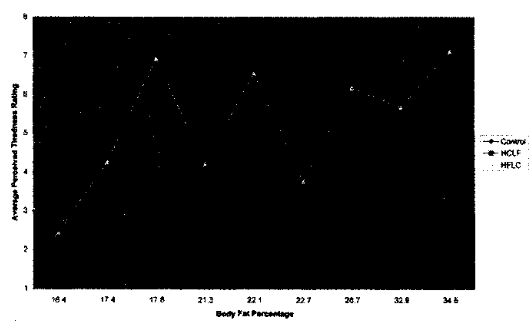


Figure 5 compares the effect of control, HCLF, and HFLC diets on the average tiredness ratings obtained in Phase II. The plots overlap and no plot is consistently above or below the others. However, in subjects of high body fat composition, the HFLC and HCLF diet plots are consistently above the control plot. The HFLC diet plot is also consistently far above the high-carbohydrate diet graph for the high body fat subjects.

Figure 5. Effect of Control, HCLF, and HFLC Diets on Average Tiredness Ratings Obtained in Phase II.



Discussion and Conclusion

Phase I:

Phase I results suggests that there is no correlation between body fat and sleeping patterns during the 21 day control diet period. As shown in Table 1, the average values for sleep and tiredness for each group do not vary significantly based on their standard deviations. If sleep or tiredness was related to body fat percentage on the control diet, as hypothesized, there would have been a consistent increase in sleep and tiredness as body fat increased. This was not the case, as those with the highest body fat percentage actually averaged the least amount of sleep. Body fat does not appear to be related to body fat percentage.

Figure I also shows that body fat and the average hours of sleep obtained are unrelated as the best-fit line is almost a level line. Its r^2 value of 0.0025 shows that average sleep appears to be constant and independent of body fat percentage. The downward sloping best-fit line of Figure I also exhibits an overall insignificant negative correlation between body fat percentage and self-reported tiredness. The r^2 value of 0.2195 indicates a very weak correlation. With only an insignificant negative correlation between body fat percentage and tiredness ratings, this finding is of no importance.

The tiredness was self-reported and was intended only to be used to compare tiredness changes within a specific subject. Subjective tiredness ratings are not accurate predictors of tiredness between individuals, but rather are best used to determine changes over time in the same individual (7). The fact that there was a small negative correlation between body fat % and sleepiness, is likely due to psychological or other non- physiological processes. The sample size was also relatively small and the self reported tiredness ratings vary in perception between individuals. For example, one subject might rate a specific feeling of tiredness as a four on a tiredness scale, while another subject could rate the same feeling as an eight. This subjective variability further questions the validity of the average tiredness ratings. Only a very strong correlation would suggest any relationship with the subjectivity, variability, and small sample size in this study.

Phase II:

The results of Phase II are presented in tables 2-4 and Figures 4-7. The lack of a consistent increase or decrease in the average hours slept in low and normal body fat individuals due to dietary change, shown in Table 2 and Figure 4, indicates that dietary intake has a trivial effect on these individuals. The sleep decrease in the high body fat subjects during the HFLC and HCLF diets, however, suggests that sleep in these subjects is depressed by these diets. The difference in sleep depression between the HFLC diet and HCLF diet was minimal, but there was a major difference between these two diets and the control diet. The change in the graphs of Figure 4 to a consistent format in high body fat subjects, indicates that diet has a greater impact on individuals of high body fat composition.

Figure 2 shows that there is a strong negative correlation between body fat percentage and sleep during the HFLC diet. The correlation is not as strong for the HCLF diet, as indicated by the smaller r^2 value of the best fit line in Figure 3, but a correlation is still suggested. The data suggests that body fat interacts with the dietary fat and carbohydrates to decrease sleep. Dietary fat, however, appears to have a greater effect on sleep than carbohydrates.

Tiredness increased on both HFLC and HCLF diets as body fat percentage increased. The inconsistent tiredness results of Table 3 and Figure 5 suggest that low and normal body fat subjects were not influenced by dietary factors to a great extent. Data in Figure 5 suggest, however, that high body fat subjects had consistent increases in tiredness ratings on the HFLC and HCLF diets, as compared to the control diets.

It was hypothesized that dietary fat would interact with body fat to cause an increase in sleep and tiredness in high body fat subjects. However, the findings of this study suggest that sleep, or the ability to sleep, is actually decreased by a HFLC diet. The tiredness ratings increased for high body fat subjects on HFLC diets, but this could simply be a compensatory effect of sleep deprivation. The results of this experiment cannot support or contradict that tiredness differences exist for high body fat subjects who obtain similar hours of sleep during control and HFLC diets, because sleep varied for each diet. However, the data does suggest that tiredness increases on HFLC diets. The reason for this, however, is unknown.

Carbohydrates were not expected to create a major variation in sleeping patterns. The results of the study do not support this hypothesis. The data suggests that sleep is decreased and tiredness is increased in high fat individuals. The tiredness ratings did not increase very much in comparison to the sleep decrease. The results of this experiment cannot support or contradict that tiredness differences exist for high body fat subjects who obtain similar hours of sleep during control and HCLF diets, because sleep varied for each diet. Tiredness had a slight increase on the HCLF diet, but the reason whether this is simply the result of sleep deprivation cannot be concluded. Further studies in this area are needed.

The results of this study support past findings suggesting that dietary fat increases tiredness (2, 4, 5, 12, 13). The increase in tiredness due to carbohydrates is also supported by past research (9,10). On control diets, the high-fat subjects were actually less tired than the other groups.

The results of this study suggest that sleep is directly reduced and tiredness increased by a high-fat or high-carbohydrate diet. A high-fat diet appears to decrease hours of sleep more than a high-carbohydrate diet. Tiredness may be a secondary effect caused by the lack of sleep, or may be independently effected by meal composition. A conclusion could not be drawn on the cause of the tiredness.

The data suggests that the decreased hours of sleep and increased tiredness ratings are directly related to increasing body fat percentage. The results of this study suggest that high body fat individuals who want to a decrease their tiredness should eat a mixture of fat and carbohydrates. This is good news for obese individuals who are very tired. However, decreasing tiredness of obese individuals through dietary regulation may only work by increasing sleep. The results show little evidence that tiredness can be decreased in obese (high body fat) individuals through dietary regulation, if sleep is not altered.

Study Limitations

This study involved female college students between the ages of 18 and 25 years old. The results, therefore, may not be applicable to the general population. It has been shown that young adults, especially college students, are generally more tired than other age groups (3). This sleepiness difference is also thought to be attributed mild sleep restriction. Therefore, the sleepiness and sleep values for college students may not be effected by diet or body fat due to their already present sleep dysfunction.

Based on qualitative analysis, the timing and energy content of the meals were assumed to have a trivial impact on the result of this study. Based upon the results of past research, it was presumed that meal timing does not effect the sleep cycle to a great extent (6). However, it has also been suggested that the timing of meals does have an impact on sleeping patterns (12). Energy content was also disregarded in analysis but recent research concluded that this factor did not significantly affect sleep (1).

This study was limited due to the fact that measured body fat percentage using bioelectrical impedance may not be as accurate as measurement by underwater weighing. The bioelectrical impedance method should be sufficient in this study, however, because this experiment was not studying changes in body fat percentage.

The data logs reporting sleep, tiredness, and food intake may not have been answered honestly and people may have forgotten to record values or falsified data.

The study also assumed that the subjects followed and understood instructions regarding high-fat low-carbohydrate and high-carbohydrate low-fat diets. Unfortunately, non-compliance with dietary regimens caused several subjects' data to be thrown out. This study assumed that subjects could accurately assess their level of tiredness. This type of study required a great deal of involvement from the participants and subject cooperation was paramount to obtaining accurate results.

Appendices

Appendix A:

Table A. Participants

Group	Subject #	Body fat %
Underweight	18	11.6
Underweight	6	11.9
Underweight	19	14.1
Underweight	9	16.4
Underweight	17	17.4
Underweight	4	17.8
Normal weight	2	19.9
Normal weight	8	21.2
Normal Weight	11	21.3
Normal weight	15	22.1
Normal weight	3	22.7
Normal weight	5	24.5
Normal weight	12	25.0
Overweight	16	27.5
Overweight	1	28.7
Overweight	7	30.0
Overweight	14	32.9
Overweight	10	34.4
Overweight	13	34.5

Table B1. Three Week Average of Sleep and Tiredness Ratings for Underweight Individuals

Subject #	Avg. hrs. sleep	Avg. tiredeness rating	Body fat %
18	8.75	6.17	11.6
6	7.88	6.55	11.9
19	6.77	7.76	14.1
9	7.89	2.54	16.4
17	9.14	7.12	17.4
4	6.91	6.77	17.8
Overweight avg.	7.82	4.64	

Table B2. Three Week Average of Sleep and Tiredness Ratings for Normal Weight Individuals

Subject #	Avg. hrs. sleep	Avg. tiredeness rating	Body fat %
2	8.32	5.11	19.9
8	8.21	5.10	21.2
11	8.49	4.19	21.3
15	8.32	6.21	22.1
3	8.65	6.41	22.7
5	8.32	5.12	24.5
12	8.22	2.21	25.0
Normal avg.	8.36	4.91	

Table B3. Three Week Average of Sleep and Tiredness Ratings for Overweight Weight Individuals

Subject #	Avg. hrs. sleep	Avg. tiredeness rating	Body fat %
16	8.34	5.67	27.5
1	7.17	4.79	28.7
7	7.08	4.28	30.0
14	7.98	4.38	32.9
10	8.10	3.67	34.4
13	8.23	5.06	34.5
Overweight avg.	7.82	4.64	

Appendix B: Subject Data Log

Subject #:_______________ Date:__________ Week:__________ Day:________

Exercise: Type: 1.
2.
3.

Duration: 1.
2.
3.

Time of Sleep:

Fell asleep at: ____________A.M/P .M Woke at: ____________A.M/P .M
Fell asleep at: ____________A.M/P.M Woke at: ____________A.M/P.M
Fell asleep at: ____________A.M/P.M Woke at: ____________A.M/P.M
Fell asleep at: ____________A.M/P.M Woke at: ____________A.M/P.M

Sleepiness:
-Recorded as soon as you wake, and approximately every subsequent 5-6 hours afterwards until asleep. Try to record measurements at least one hour after eating.

Time recorded:	Degree of Sleepiness:
____________A.M/P.M	0 1 2 3 4 5 6 7 8 9 10
____________A.M/P .M	0 1 2 3 4 5 6 7 8 9 10
____________A.M/P.M	0 1 2 3 4 5 6 7 8 9 10
____________A.M/P .M	0 1 2 3 4 5 6 7 8 9 10
____________A.M/P.M	0 1 2 3 4 5 6 7 8 9 10

Time of Meals:
Breakfast: ____________A.M/P .M Lunch: ____________A.M/P .M
Dinner: ______________A.M/P .M Snack I: ____________A.M/P .M

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