THE EFFECT OF AN AEROBIC TRAINING PROGRAM WITH TWO DIFFERENT TRAINING INTENSITIES ON THE ENERGY INTAKE, DIETARY COMPOSITION AND BODY COMPOSITION OF FEMALE SUBJECTS

by

Brenda M. Mueller

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APPROVED:

Janet Walberg-Rankin

Don Sebolt

Anne Alexander

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(ABSTRACT)

Female subjects aged 18 to 40 began a running program with the goal of running a marathon. The subjects were randomly divided into two training groups. One group always trained at or below their lactate threshold, while the other group trained above their lactate threshold on alternate days. The subjects completed their weekly mileage in four to six days. Seven-day dietary records were kept at the onset of the study and at three month intervals throughout the study. Body weight and body fat data was also obtained at approximately the same intervals. Twenty-four women had dietary data at the onset of the study, with twenty-one remaining at six months. By this time the women were running twenty-four miles per week. Dietary records were analyzed using the Nutripractor nutritional analysis computer program for energy, macronutrients, and selected micronutrients. No significant differences were found in energy intake, macronutrients, or body composition between groups or over time. Surprisingly, subjects maintained their body weight and body fat despite a large increase in activity level, with no significant changes in caloric intake. The women, in general, consumed diets which did not meet the Recommended Daily Allowances (RDA) for calcium, magnesium, zinc, and iron across all three time periods. A trend analysis procedure showed significant quadratic trends in vitamin D intake, sodium intake, grams of fat consumed, and magnesium intake, and a significant linear trend downward in cholesterol intake. Individual responses were, however, highly variable. These results indicate that exercise training at either of the two intensities did not affect caloric intake, macronutrient mix, or body composition in this subject population.

Index terms: training program; lactate threshold; dietary records.

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Chapter I

INTRODUCTION

Many individuals begin exercise training to improve their physical fitness and to favorably alter their body weight and body composition. It would seem that these individuals would naturally increase their caloric intake to prevent a state of negative energy balance. However, research indicates that there is not a clear relationship between aerobic exercise and its effect on body weight, body composition and energy intake. Responses seem to be highly variable, and may depend on an individual's sex and body weight status and the duration and intensity of the exercise.

Studies done in rats (Mayer et al., 1954, Katch et al., 1979) indicate that exercise intensity affects food consumption. Rats exercising at very high exercise intensities had a decreased food consumption as compared to rats exercising at low intensities, despite equal caloric costs. Thompson et al.(1988) suggests a similar relationship may exist in humans. Although the researchers did not find a significant decline in food consumption with high intensity exercise, they did note a decreased hunger rating in the subjects which suggests that appetite suppression may still occur. Other human studies have shown appetite suppression with high intensity exercise (Kissileff et al., 1990).

Sex and body weight may also be important factors in determining how an individual will respond to an increase in physical activity. Staten (1991) and Janssen et al. (1989) found that lean male subjects increased their energy intake in response to exercise while exercise did not have any effect on the energy intake of lean female subjects. In contrast to these results, McGowan et al. (1986) found no changes in energy intake in lean male subjects with increased physical activity. Woo and Pi-Sunyer (1985) found that lean women increased their intake in response to exercise training.

Conflicting results also have been noted in obese individuals. Kissileff et al. (1990) found that obese female subjects who were 130 to 150 per cent of ideal body weight did not show any changes in food intake after an acute bout of exercise. Woo et al. (1982) found that obese women with a mean per cent of ideal body weight of 187% increased their caloric intake in response to an exercise program, although the increase was not statistically significant. Keim et al. (1989) did not find that the energy intake of overweight women was consistently affected by exercise and postulated that behavioral and psychological factors, rather than physiological factors, affect the energy intake of overweight women.

These data indicate that energy intake in both lean and overweight males and females is not consistently affected by increased physical activity. The mechanisms by which energy intake is affected are not clear, but energy expenditure is not the only factor which must be considered.

Studies investigating the effect of aerobic exercise training on body weight and body composition have also shown mixed results. Hagan et al. (1986) found that overweight men and women, who ranged 120 to 140 per cent of ideal body weight, maintained their body weight and body fat despite twelve weeks of moderate intensity aerobic exercise. Nieman et al. (1990) also showed stable body weight and per cent body fat in overweight women with a mean per cent body fat of 36.5 per cent during a fifteen week walking program. Researchers have suggested that some individuals may become metabolically more efficient at using energy, enabling them to maintain their weight despite an increased energy expenditure. In contrast, Martin and Kauwell (1990) showed significant decreases in the body weights of overweight women with a minimal amount of aerobic exercise.

The research in the area of exercise and its effect on energy intake, body weight and body composition is far from conclusive. It is difficult to make comparisons between many of the studies in this area due to the short-term nature of most of the studies. The lack of consistent findings indicate that research is needed to further investigate the energy balance concept, and more attention should be focused on finding long-term effects. The purpose of this study is to investigate the effect of an aerobic training program, with two training intensities, on the dietary intake and body composition of female subjects over the period of six months.

Research Problem

The problem addressed in this investigation was identifying the effects of two aerobic training programs of different training intensities on the energy intake, dietary composition, body weight, and per cent body fat of previously only moderately active female subjects.

Research Hypothesis

The following null hypothesis was tested:

There was no difference in energy intake, dietary composition, or body composition in women who train above or below their lactate threshold over a six month period of exercise training.

Significance of Study

Many individuals engage in physical activity so that they may improve their fitness level and maintain or improve their body weight and per cent body fat. It is possible that changing energy expenditure will affect dietary quantity or quality. Several studies have failed to show that training alters dietary intake or body composition especially in certain population groups, for example overweight individuals and females. The present study was undertaken to investigate the spontaneous changes in body weight and body composition of female subjects beginning a training program, and to investigate any dietary changes which may have occurred during this time period. Exercise intensity may also play a role in these responses.

Delimitations

The following delimitations were imposed by the investigator due to the nature of the study:

1. The sample size was limited to 24.

2. The selection of subjects was limited to untrained women aged 18 to 40, without any known health problems, and with a per cent body fat less than 40%.

3. Dietary assessment was accomplished using repeated seven-day diaries at baseline, three months, and six months.

4. Body weight and body fat analysis was limited to one measurement at approximately the same intervals as the dietary records.

5. The exercise mode was limited to running at two different training intensities, one at the lactate threshold and the other at 50 per cent of the difference between lactate threshold and maximal oxygen consumption.

6. The dependent measures were limited to dietary composition and body composition.

Limitations

The following limitation of the study is recognized:

The subjects did not receive feedback on their diets, which may have affected the subjects compliance in accurately recording their dietary intake.

Definitions and Symbols

The following definitions will be used:

1. Training program - a six month running program with the initial weekly mileage of 6.25 miles which was increased by 1.25 miles every other week, with an eventual weekly mileage of 24 miles by five months. This was held constant during the last month.

2. Lactate threshold - blood samples were taken at rest and at the end of each stage of a maximal graded exercise test using an indwelling catheter. Blood lactate concentrations were determined from the blood samples using a lactate analyzer. Lactate threshold was defined as the highest running velocity obtained for which there was no elevation on blood lactate levels above baseline values.

3. Dietary records - self-reported food diaries which were kept for seven consecutive days.

Basic Assumptions

The following assumptions were made:

1. It was assumed that the random assignment of the subjects to the two groups with differing intensities prevented biased results, despite non-random sampling.

2. It was assumed that all subjects accurately recorded their food intake in the dietary records.

3. It was assumed that all subjects did not intentionally modify their diet so as to alter their body weight or body composition.

4. It was assumed that all subjects complied fully with the training regimen.

5. It was assumed that all data provided by the other investigators (University of Virginia) including body weight, body fat, and lactate threshold was accurate.

Summary

The major objective of this study was to determine the effect of an exercise training program on the energy intake and diet composition of female subjects over the period of six months and to determine if changes in body fat and body weight occurred. Two training intensities were used to determine if exercise intensity has any effect on dietary intake or body composition, as has sometimes been shown. The concept of energy balance is well accepted, however, recent studies have shown that increasing energy expenditure may have a variety of effects on energy intake and diet composition. This study was undertaken to further clarify these effects, and to determine if exercise intensity is a factor.

Chapter II

LITERATURE REVIEW

Exercise training is a means by which many individuals can improve their physical fitness and favorably alter their body weight and body composition. Frequently, individuals will also modify their dietary habits which may further precipitate these changes. It is often agreed that most lean individuals will automatically increase their caloric intake as a result of an increased energy expenditure to prevent a negative energy balance. However, recent evidence indicates that this relationship is much less clear, especially in obese individuals. Even without dietary changes, exercise training typically still results in decreases in body weight and per cent body fat. The review of literature in this area will be divided into five sections: 1) the effect of aerobic exercise on energy intake; 2) the effect of aerobic exercise on body weight and body composition; 3) the dietary patterns of physically active individuals; 4) the effect of aerobic exercise on diet composition; and 5) the validity of dietary records.

The Effect of Aerobic Exercise on Energy Intake

As an individual begins to exercise, they must increase their energy intake to maintain their weight, thereby preventing negative energy balance. This relationship is not always straightforward, as many factors must be considered. The intensity and duration of the exercise and the initial body weight status of the individual may be important factors in the effects of exercise on energy intake.

Intensity

Animal studies seem to support the idea of a relationship between exercise and the regulation of energy intake. Data by Mayer et al. (1954) showed a varied food intake response to exercise intensity and the amount of work done in rats. Rats that were made to be very inactive did not show a close relationship between intake and expenditure, whereas rats classified as "active" showed a close relationship between intake and expenditure. Rats involved in an extremely high level of activity did not match their intake to expenditure. As they fatigued with a large caloric deficit they did not take in adequate calories to remain in energy balance.

Katch et al. (1979) showed similar results in a study on the effects of exercise intensity on food consumption in male rats. Twenty four rats were made to exercise on a treadmill at two different intensities but with an equal caloric cost. The rats were divided into control and exercise groups with the exercise group divided further in half for the order of a low and high intensity exercise groups. During the low intensity exercise the rats had a respiratory exchange ratio of about 0.84 and with the high intensity exercise a ratio of 0.95; the high intensity exercise consisted of running three times faster than the low intensity exercise. To equalize the caloric cost of the two conditions the duration of the high intensity exercise was reduced. Food intake was monitored by allowing the rats only to eat in an eating chamber. The rats were exercised only during the second and fourth weeks of a five week study period to allow for adequate rest. Both exercise groups ate significantly less than the control period, with the high intensity group eating less than the low intensity group. However, this difference was not statistically significant. It is interesting to note that food consumption was inhibited in the high intensity group for twenty four hours after the exercise bout. When the data was expressed in terms of food consumption per gram of body weight, the high intensity group did consume significantly less food per gram body weight as compared to the low intensity group.

This data suggests that exercise intensity and not just total energy expenditure may be a factor affecting food intake. Some explanations for this may include increased lactic acid levels (Baile et al., 1970), increased catecholamine production (Crews et al., 1969), or increased core temperatures (Brobeck, 1948), all of which may occur with high intensity exercise.

Thompson et al. (1988) suggests that exercise intensity may have similar effects on the food intake of humans. Sixteen non-obese male subjects aged 19 to 29 years were randomly assigned to one of three orders of three experimental sessions. One session consisted of low intensity exercise on a cycle ergometer at 35% of maximal oxygen uptake, one consisted of high intensity exercise at 68% of maximal oxygen uptake, and one control condition which consisted of no activity. Subjects fasted for twelve hours overnight before each session. A test meal was given to each subject one hour after the experimental sessions and they were instructed to eat as much as they desired within a twenty minute period. The amount of food consumed was covertly measured. Hunger ratings were also made following each condition.

Total caloric intake did not vary significantly across the three conditions. However, hunger ratings were suppressed following the high intensity exercise as compared to the low intensity exercise and the control period. This suggests that exercise intensity may affect an individuals appetite, but that appetite suppression may only occur for a short period of time after high intensity exercise.

These results may have shown significance had the test meal been provided immediately following the exercise bout. There may have also been a greater suppression response if the high intensity bout had been more intense than 68% of maximal oxygen uptake.

Data by Kissileff et al. (1990) suggests that a similar response to strenuous exercise may be seen in humans. This short term study was conducted to examine the acute effects of exercise on the food intake of obese (130-150% of ideal body weight) and non-obese (85-115% of ideal body weight) women. Nine obese and nine non-obese women aged 18 to 35 years participated in three experimental sessions on three nonconsecutive days. The subjects reported to the testing center after an overnight fast and consumed a standard breakfast of less than 300 calories. They returned to the center two hours later for their session. One session consisted of stationary cycling for 40 minutes at 30 Watts, one consisted of more strenuous cycling at 90 Watts for 40 minutes, and one consisted of sitting quietly in the laboratory for 40 minutes. Fifteen minutes after the session the subjects were given a yogurt shake and instructed to eat as much as they desired. Intake was measured as the amount of the shake consumed.

Intake was 46 grams higher after moderate exercise as compared to intake after the resting session in the non-obese subjects. As with the previously mentioned study involving rats, intake was significantly reduced after the strenuous exercise in the non-obese subjects by 87 grams as compared to moderate exercise. This inhibitory effect on intake was not seen in the obese subjects, who did not show significant changes in intake during any of the sessions. The obese subjects did, however, show a decrease in intake after both exercise sessions as compared to rest.

The results indicate that strenuous exercise may have an inhibitory effect on intake in non-obese women as compared to moderate exercise. It would be interesting to know if the subjects compensated for this acute inhibitory effect later in the day, for example one or two hours after exercise rather than fifteen minutes. The lack of significant findings in the obese subjects may indicate that obese subjects are less responsive to changes in energy expenditure, at least in a short term setting.

These studies indicate that exercise intensity may be an important factor to consider when examining the effect of exercise on food intake. While the exact mechanism by which high intensity exercise may inhibit food intake is not known, several possibilities have been suggested. High intensity exercise may result in increased lactic acid production, increased catecholamine production, increased core temperatures, or may even be due to cognitive factors such as external discomfort or distraction (Thompson et al., 1988). Although the mechanism is not known, it does not seem to be dependent upon total caloric expenditure. Appetite suppression does not seem to be dependent upon sex, but data by Kissileff et al. (1990) indicates that body weight status may be an important factor.

Body Weight

It seems that lean individuals are able to regulate their intake with increased physical activity to prevent a state of negative energy balance. However, recent evidence suggests that this relationship is not always true. Staten (1991) examined the effect of acute exercise on the energy intakes of twenty lean male and female subjects. Maintenance caloric requirements for each subject was estimated using a diet history, weight, height, and activity level. All women were started on the diet within three days of the onset of their menstrual period to account for variations in food intake which sometimes may occur. The subjects obtained all food items from a metabolic kitchen, with two meals eaten on the unit each day. Items not eaten were returned to the unit for weighing. The subjects were allowed to freely select the type and amount of food desired. Food intake was monitored with the subjects knowledge but they were unaware of the exact purpose of the study. Subjects were weighed daily but were not told their weight so that they would not alter their intake. The diet consisted mostly of a liquid supplement but also included items for which the caloric composition was well known, such as chicken breast, eggs, saltine crackers, margarine, celery, etc. Subjects were given two to five days to adjust to the diet, and were then randomly assigned to begin either an exercise or sedentary period, with all subjects participating in both. The exercise period consisted of five days of supervised exercise, one hour per day at about 68% of their maximal oxygen uptake on a treadmill. This resulted in a mean caloric expenditure of 669 calories per day for the men and 441 calories per day for the women. Subjects lived their usual lifestyles during the control period.

There was a significant increase in food intake in the male subjects but no significant effect on intake in the female subjects during the exercise period. No significant changes in body weight were noted, although this may have been due to the relatively short length of the study. Additionally, no prolonged effect of an exercise bout on the metabolic rate was noted. This data indicates that not all lean individuals will compensate for an increased energy expenditure through an increased intake, especially women.

Janssen et al. (1989) showed similar results in a study following the dietary intakes of nine female and eighteen male lean novice athletes as they began an eighteen month training period before a marathon. The study was divided into three training periods; the initial twenty five weeks, the middle twenty weeks, and the final thirty five weeks of training. The runners were training at a distance of approximately 250 kilometers per three weeks at the conclusion of the last period. The individuals were all given one lecture on basic nutrition prior to beginning training. Food intake data was collected using seven day food records prior to beginning training, at one year of training, and two weeks before the marathon.

The male subjects showed a significant increase in energy intake by about 20% over the course of the training period, while the female subjects showed no change in energy intake. This data, as with the previously mentioned study, indicates that not all lean individuals will increase their intake in response to an increased energy expenditure, and gender may be an important factor to consider.

In contrast to the aforementioned studies, McGowan et al. (1986) did not find that lean male joggers changed their intake with an increased energy expenditure. Seven male subjects aged 22 to 27 years who were already regularly engaging in a jogging program running a minimum of 12.5 miles per week participated in three different exercise conditions. The subjects kept records of their food intake for two weeks prior to the study and during the three weeks of the study. The first experimental condition consisted of no exercise, the second consisted of the subjects usual training mileage, and the third consisted of regular mileage for two days of the week and double mileage for three days.

Caloric intake was determined by an analysis of three days of the seven day records for each week. No significant differences were found in caloric intake across the three conditions. Intake did not decrease the week that the subjects were not active, with an average intake of 2529 versus the usual 2535 calories per day. However, intake did increase from 2534 to 2695, a six per cent increase from the typical week to the high mileage week. This difference was not found to be statistically significant. Intake may have increased further had the subjects increased their usual activity level for more than three days. This data suggests that energy expenditure may not regulate caloric intake in lean male joggers, but the limitations of the study should be taken into consideration. Intake was only studied for a very short period of time during the highly active condition which was only three days in length. The small number of subjects should also be noted.

In contrast to these results, Woo and Pi-Sunyer (1985) found that lean women did increase their intake in response to increased physical activity. Five lean women aged 21 to 51 years were hospitalized on a metabolic ward for a total of 62 days. The subjects first participated in a baseline five day sedentary evaluation period, then a nineteen day experimental sedentary period, a second nineteen day period which consisted of mild treadmill exercise at 110% of sedentary expenditure, and a final nineteen day period of moderate exercise at 125% of sedentary expenditure.

Subjects were provided with meals and instructed to eat as much as they desired. All items were weighed before and after the meals with intake being covertly monitored. While the women consumed a mean of 1724 calories per day during the sedentary period, intake increased to 2015 calories per day during the mild exercise period and 2098 calories per day during the moderate exercise period. These increases were both significantly higher than sedentary values, although not significantly different from each other. These results indicate that intake and expenditure may be coupled. No inhibitory effect of exercise on food intake was noted, although this may be due to the relatively low intensity level of both exercise treatments. The individuals did take in adequate calories to remain in energy balance throughout all treatment periods.

Many studies done in obese individuals have also shown conflicting results. Kissileff et al.(1990), as previously mentioned, found that obese subjects did not show any changes in food intake after an acute bout of exercise. Woo et al. (1982) studied three women with "stable" obesity with a mean per cent of desirable body weight of 187%. The subjects were studied for 62 days while living on a metabolic ward. They began a supervised daily walking program designed to raise their daily energy expenditure to 125% of their sedentary values. Daily intake of regular foods was monitored without the subjects knowledge throughout the study. Intake increased from a mean of 1844 calories per day to 1950 calories per day over the study period, however, this change was not significant. The subjects were in negative energy balance which resulted in a significant mean weight loss of 6.75 kilograms over the study period. The investigators also found a drop in the metabolic rate of two individuals during the study. The energy cost for sleeping and for sitting decreased 7% and 4% respectively. It is possible that in a state of negative energy balance the body will become more efficient at certain activities to conserve calories, thus slowing the rate of weight loss.

The authors suggest that factors other than exercise may determine an individuals energy intake, such as the palatability and appearance of the diet. Thus, if energy intake and expenditure are not related, as indicated in this study, the subjects may have increased their intake had the experimental diet been more desirable. This may or may not be the case, as previous studies have also observed that obese individuals may not be sensitive to changes in energy balance (Kissileff et al., 1990) regardless of diet.

In agreement with these results is a study done by Keim et al. (1989) on twelve overweight women ranging 116 to 142 per cent of ideal body weight. The subjects were 21 to 36 years of age and were not regularly exercising upon entrance to the study. The subjects lived freely in the community throughout the entire study, but were required to report to the research center to consume two meals per day, pick up additional foods needed, and to participate in their exercise program. The first study period consisted of a nineteen day diet stabilization period, during which the subjects consumed a prescribed diet set to maintain their weight. Three eighteen day exercise treatment periods followed, during which the subjects consumed self-selected diets at the research facility as described above. All foods were weighed before and after consumption and food not consumed in the dining facility was recorded in a food diary. The first exercise treatment period consisted of no exercise, during which the subjects were instructed to maintain their usual daily activities. The next exercise treatment consisted of moderate duration treadmill exercise which was supervised seven days per week, set to increase total energy expenditure by 12.5% over baseline levels. The final exercise treatment consisted of the same type of exercise but set to increase daily energy expenditure by 25%. Exercise intensity was maintained at levels estimated to be 65 to 80% of maximal oxygen uptake.

Daily aerobic exercise did not significantly affect average daily energy intake over the exercise treatment periods. Average intake during the sedentary treatment period was 2186 calories per day which increased to 2299 calories per day during the moderate duration exercise and 2352 calories per day during the high duration exercise period. These increases were 5% and 8% respectively but were not statistically significant. Interestingly, body weight increased by 1.2 kilograms over the three treatment periods and this increase was statistically significant. This increase was attributed to fat free mass as a result of daily exercise, as body fat mass did not change.

The authors conclude that the energy intake of overweight women is not consistently affected by exercise, and that factors other than physiological factors such as behavioral and psychological factors may play a role in the energy intake of overweight women.

Not all researchers support these conclusions. Krotkiewski et al. (1979) studied obese women participating in an exercise program for six months. The women were not monitored with respect of their intake, and upon completion of the study had not lost any body weight or body fat as a whole. The authors attributed this to an increased food intake, although this cannot be verified as intake was not monitored. As has been previously suggested, the women may have became more metabolically fuel efficient.

Intake has even been shown to decrease in overweight women with increased physical activity. Nieman et al. (1990) studied the effects of moderate exercise training of the intakes of fifty mildly obese women, who were 10% to 40% over their ideal body weight. Subjects were randomly assigned to either an exercise or a control group. Subjects kept seven day food intake records during a baseline period, at six weeks, and at the conclusion of the study (fifteen weeks). The subjects were instructed to eat as they desired and not make conscious efforts to reduce their intake. The exercise group participated in a supervised walking program five times per week for 45 minutes for the fifteen weeks of the study. Exercise intensity was set at 60% of heart rate reserve and monitored through frequent pulse rate checks. 36 women were able to complete the study.

The exercise group experienced a 9% decrease in average caloric intake by the conclusion of the study with initial intakes of about 1840 calories per day declining to about 1680 calories per day. The control group showed a 9% increase in caloric intake over the study period, although this difference was not found to be significant. Body weight remained stable in the exercise group but increased slightly in the control group.

These data indicate that increases in energy expenditure in both lean and overweight individuals does not consistently affect energy intake. Staten (1991) found that lean male subjects increased their energy intake in response to acute bouts of exercise while female subjects showed no changes in energy intake. Janssen at al. (1989) also showed similar results in lean individuals in response to an eighteen month training period. However, McGowan et al. (1986) found that lean male joggers did not change their energy intake when their training mileage was increased and when training was momentarily discontinued. Woo and Pi-Sunyer (1985) found that lean women did increase their intake in response to increased activity. Several studies in overweight individuals have shown that they may not increase their intake in response to increased energy expenditure (Kissileff et al., 1990, Woo et al., 1982, Keim et al., 1989). The wide variety of methods used in these studies makes the data difficult to interpret, but it does seem that intake and expenditure are not tightly coupled in lean or overweight individuals. If the hypothesis that the acceptability and palatability of the diet may affect food intake is true, then many of the studies using experimental diets may have been flawed. Exercise intensity may have also been a factor in studies showing a decreased intake in response to increased expenditure if the exercise had an inhibitory effect on food intake. Although the mechanisms by which energy intake is affected are not yet clear, it does seem that factors other than energy expenditure must be considered.

The Effect of Aerobic Exercise on Body Weight and Body Composition

Increasing daily energy expenditure through exercise training should result in a decrease in body weight and body fat provided that energy intake does not increase. Surprisingly, this energy balance concept has not always been shown to be true in both lean and overweight individuals.

Janssen et al. (1989) studied body composition in lean individuals training for a marathon. Nine female subjects and eighteen male subjects began training an average of four to ive days per week for eighteen months. Measurements included body fat analysis on the sum of four skinfolds, body mass index, and body weight. Energy intake data was also collected at different times throughout the study. The runners were training at a distance of approximately 250 kilometers per three weeks at the conclusion of the study.

Only the male subjects showed a tendency to decrease their weight, body mass index, and per cent body fat, while the female subjects showed no changes. No significant differences were noted in any of the body composition variables. The female subjects also did not show any increase in energy intake despite increased training mileage. This indicates that the women were in negative energy balance, but somehow failed to lose weight. These results may support the hypothesis of an increased food efficiency in women, allowing them to maintain their body weight even when in negative energy balance.

Although it is interesting that lean individuals may somehow compensate for a negative energy balance while still maintaining their weight, studies involving overweight individuals have also shown surprising and often conflicting results.

Hagan et al. (1986) studied the effects of twelve weeks of aerobic exercise without caloric restriction on the body composition of overweight men and women. All subjects were 120 to 140% of their ideal body weight. Twelve male subjects and twelve female subjects began a walking program for 30 minutes each day, five days per week. Subjects were instructed to maintain their normal pattern of dietary consumption. Body composition was determined at the onset and conclusion of the study using hydrostatic weighing.

The men maintained a mean per cent body fat of 24.2% and the women maintained a mean per cent body fat of 33.4% throughout the study, both without significant changes. Body weights also remained stable in both groups. Analysis of three day food records indicated that there was only a slight rise in energy intake, although this data was not provided.

Nieman et al. (1990) also showed a lack of change in body weight and body fat over a fifteen week exercise program in overweight women. Eighteen women with an average initial body weight of 76.7 kilograms and body fat of 36.5% began a supervised walking program five days per week for 45 minutes each day.

There was no significant change in body weight or per cent body fat as a result of the exercise treatment. Additionally, the subjects has a significant decrease in energy intake during the study as determined by seven day food records. As with the study by Janssen et al. (1989) in lean women, this study indicates that somehow body weight may be maintained even in a state of negative energy balance. Again, this may support the hypothesis that women may become metabolically more efficient at utilizing energy.

Keim et al. (1989) conducted a study involving overweight women who participated in three eighteen-day treatment periods. Twelve women with a mean per cent body fat of 36.1% and a mean weight of 79.1 kilograms participated in one sedentary period, one period of moderate duration exercise and one period of long duration exercise. Both exercise periods involved daily supervised treadmill walking seven days per week with the moderate duration exercise lasting 31 to 49 minutes and the long duration exercise lasting 51 to 88 minutes. Body weights and total body conductivity were measured to assess fat mass, fat-free mass, and body weight. Food intake as determined by direct measurement of items consumed did not change throughout the study.

Body weight increased slightly but significantly from 77 kilograms to 78.2 kilograms as the result of exercise training. Exercise did not significantly affect fat mass, but did increase fat-free mass from 49.3 to 50.8 kilograms which resulted in the increased body weight. It should be noted that individual results were highly variable.

These results indicate that despite exercise training without a compensatory increase in caloric intake, body weight may be maintained or even increase. It is possible that the women may have decreased their usual daily energy expenditure to accommodate for calories expended through exercise, although no changes were noted.

In contrast to these results, Martin and Kauwell (1990) found significant changes in body weight with a much lower level of physical activity. This study was conducted on seventeen sedentary overweight women with a mean body weight of 70.9 kilograms. The subjects engaged in stationary cycling exercise at 70 to 85% of their predicted maximal heart rate for 30 minutes, two times per week. Body girth and skinfold measurements were made at the onset and conclusion of the study ten weeks later. No change was noted in caloric intake as determined by three-day dietary recalls.

The subjects lost a significant amount of weight over the study period with a mean loss of 1.1 kilograms. No significant changes were noted in girth measurements of skinfold values, with skinfolds determined by the sum of four areas. This may have been a limitation of the study. These results indicate that even a small amount of aerobic exercise may result in weight loss independent of dietary changes. These results are much in contrast to the previously mentioned studies by Hagan et al. (1986) and Nieman et al. (1990), despite a larger energy expenditure in these studies. However, the authors note that the women were extremely deconditioned prior to the study which may explain the positive results with a small amount of activity.

Gwinup (1987) studied the effect of various modes of aerobic exercise on weight loss without caloric restriction in women aged 20 to 40 years. The women ranged from 30 to 40% body fat and were advised to continue with their regular dietary habits throughout the study. The 45 subjects were randomly divided into one of three exercise groups, a walking group, a cycling group, and a swimming group. Each exercise group was told to gradually increase the duration of their exercise to 60 minutes per day, however, the subjects were not controlled with respect to intensity and they were not supervised, using daily logs to record their activities. Twenty-nine subjects completed the study.

The walkers, who initially had a mean body weight of 152 pounds and 32mm for triceps skinfold, reduced to a mean body weight of 135 pounds and 19mm for triceps skinfold. The cycling group began with an initial body weight of 148 pounds and a triceps skinfold of 30mm and experienced a decrease down to 129 pounds and 17mm. The swimming group began with a mean body weight of 148 pounds and a triceps skinfold of 28mm and ended with a mean body weight of 153 pounds and no change in triceps skinfold. Caloric intake was not measured although the subjects were instructed not to alter their intake.

Although these results are questionable given the lack of controls on exercise intensity, duration, and diet, a fair amount of weight loss was seen in two of the exercise groups. The use of one skinfold site to determine body fat is also questionable. Since the subjects had been previous dieters, it was mentioned that they were all discouraged with caloric restriction and would gladly attempt to lose weight with exercise alone. These findings may still indicate that weight loss is possible with daily exercise training alone.

Frey-Hewitt et al. (1990) also showed positive results in a study on the effects of exercise on weight loss in overweight men without caloric restriction. Fifty-two men ranging 120 to 160% of ideal body weight, aged 30 to 59, began a supervised walk/jog program three to five days per week. The subjects eventually reached a duration of 40 to 50 minutes per session by the sixth month of the study. Subjects were instructed to maintain a heart rate of 65 to 85 per cent of their peak heart rate as determined by a treadmill test. The subjects were instructed not to alter their intake and seven-day food records were used for verification. Body composition measurements were made at baseline and at the conclusion of the study one year later.

The exercisers lost an average of 4.1 kilograms and had a decline in per cent body fat of 3.65% over the study period, both of which were statistically significant changes. All of the weight lost was attributed to loss of body fat. No significant changes were noted in energy intake over the one year period. As with the previously mentioned study, weight loss may be possible with exercise training independent of changes in caloric intake.

The length of the study period may help to explain some of the conflicting results in these studies. While the two studies showing definite changes in the body weight of overweight individuals lasted six months to one year, the studies not finding significant changes lasted a maximum of three to four months. It may be that overweight individuals require longer exercise treatment periods before results are seen. The study length did not seem to be a factor in the study by Janssen et al. (1989) who did not see results in lean individuals after eighteen months of training.

Data showing no change in body composition with increased energy expenditure but no change in caloric intake indicates that some individuals may become more metabolically efficient in order to maintain their weight. This possibility needs further investigation as it seems it may be the only explanation for some of these results in both lean and overweight individuals.

The Dietary Patterns of Physically Active Individuals

Active individuals may exhibit different eating patterns as compared to the sedentary population due to an increased health awareness and perhaps knowledge that proper nutrition has the ability to improve performance. It is interesting to study the dietary habits of exercising individuals for many reasons. One would think that athletes would consume a diet which would replace the metabolic fuels used during exercise, which in most cases would be a high carbohydrate diet. Also, athletes may be more aware of unnecessary foods in their diet, such as "junk foods" which have little overall food value. Athletes may also be prone to using items which they think may enhance their performance, such as dietary supplements.

Armstrong et al. (1990) investigated the dietary habits of recreational exercisers with the use of a questionnaire. The subjects were adult participants in a twelve kilometer road race, 53% women and 47% men, between the ages of 19 and

80 years of age. A majority of the respondents indicated that they consume more fresh vegetables, fresh fruits, whole grain products, poultry and fish as compared to five years ago. They also indicated a decreased red meat consumption, especially in the women. This may have negative implications for women with poor iron status, which is relatively common among female runners. Seventy-five per cent of the respondents indicated that they were trying to reduce their dietary fat intake, especially the women. This may be due to an increased concern about cardiovascular disease and/or weight control. The authors conclude that exercising individuals are more likely to make dietary changes, and attention should be paid as to the appropriateness of these changes.

Nieman et al. (1989) studied the nutrient intakes of 347 male and female marathon runners using three-day food records. Total energy consumption was found to be 2526 calories for the males and 1868 calories for the females, which are below the levels recommended for individuals engaging in endurance activities at about 35 kilocalories per kilogram of body weight. The macronutrient composition of the diets were 16.6% protein, 30.9% fat, and 51.8% carbohydrate for the men and 15.8% protein, 32.0% fat, and 52.7% carbohydrate for the women runners. These are close to levels recommended for the public by the American Heart Association. Although the runners consumed more carbohydrate and less fat than the general population, carbohydrate intake was still below the recommended 60 to 65% for endurance athletes. The respondents had an increased fiber intake at 20.9 grams for the males and 17.1 grams for the females as compared to the general public, as well as lower saturated fat and cholesterol intakes at 295mg and 9.2% for the males and 224mg and 9.3% for the females. When caloric intake was expressed per kilogram of body weight, both men and women showed an increase with weekly training mileage. A similar relationship was seen with carbohydrate intake when expressed per kilogram of body weight. As with the data by Armstrong et al. (1990), more than 75% of the runners reported increased intakes of fruits, vegetables, whole grains, poultry and fish with a decrease in consumption of red meats, eggs, salt and fats as compared to their pre-running diets.

These data suggest that habitual physical activity may be associated with an improvement in eating patterns. However, it was interesting to note the surprisingly low energy intakes in these highly active people.

Pate et al. (1990) compared the dietary intakes of female distance runners to age-matched inactive women. Subjects provided a 24-hour dietary recall and an additional two-day dietary record. The runners reported a slightly higher caloric intake than the controls at 1603 calories as compared to 1538 calories, however this difference was not statistically significant. This did not change when energy intake was expressed relative to body weight. The runners did report a carbohydrate intake of 192.4 grams which was significantly higher than the control group at 165.0 grams. The runners also reported protein and fat intakes of 59.1 grams and 57.5 grams which was lower than the inactive women who reported protein and fat intakes of 64.8 grams and 66.1 grams. The runners also had a lower cholesterol and saturated fat intake at 213.6 mg and 11.3% than the control group who had a cholesterol intake of 268.1 mg and a 13.7% saturated fat intake. Fiber intake was 4.5 grams in the runners and 3.5 grams in the inactive women. Both groups reported use of dietary supplements, including multivitamins, vitamin C supplements, iron, and calcium supplements, although the runners tended to use more of these than the inactive women.

It is important to note that while the investigators found no difference in energy intake between the two groups the macronutrient composition of the diets did differ. The higher carbohydrate intake in the runners may reflect the fuel utilization of their training, and the lower fat intake may be due to a greater interest in cardiovascular health.

These studies indicate that athletic individuals tend to be more aware of general nutrition principles as shown by their tendency to consume less fat and cholesterol and more fresh fruits, vegetables, and whole grain products

(Armstrong et al., 1990, Nieman et al., 1989). Surprisingly, many of these studies also found that the athletes consumed fewer calories and carbohydrate than was recommended for individuals engaging in endurance activities (Nieman et al., 1989, Pate et al., 1990). Active individuals were even shown to be consuming as many calories as their sedentary counterparts, despite the high level of their physical activity (Pate et al., 1990).

Physical activity may promote positive dietary habits, however, special attention should also be paid to ensure that athletes are consuming a nutritionally adequate diet. Athletes should be encouraged to consume adequate calories and pay more attention to certain problem nutrients, such as iron.

The Effect of Aerobic Exercise on Diet Composition

Miller et al. (1990) studied the relationship between diet composition and exercise habits in males and females, and found that leaner individuals consumed more carbohydrates and less fat than the obese individuals. The leaner individuals also exercised more frequently. It is not known from this study whether or not these differences came about as the result of physical activity. However, it was demonstrated in the previous section that physically active individuals consumed diets with a more favorable macronutrient composition than non-active individuals.

Several studies have investigated the dietary changes which occur as the result of initiating an aerobic exercise program. Janssen et al. (1989) studied nine female and eighteen male subjects as they began training for a marathon over an eighteen month period. Seven-day food records were collected at the onset of the study, after one year, and at the conclusion of the study. Both males and females showed a significant increase in carbohydrate intake by the end of the training period. The male subjects increased from an initial carbohydrate intake of 280 grams to 346 grams before the marathon, and the female subjects increased from 239 to 283 grams. The women also showed a significant decrease in protein and fat consumption. The male subjects showed a slight decrease in fat consumption although this difference was not significant. These values were not provided in the journal. It is also important to note that while the male subjects increased their caloric intake from 131 to 171 kilojoules per kilogram per day, the females had no change in energy intake. Therefore, the macronutrient composition of the female runners diets changed as training progressed without a change in caloric intake. This may indicate that the runners began to consume more high carbohydrate foods as the result of increased carbohydrate utilization due to their training. It is also possible that the runners were trying to "carbohydrate load" prior to the marathon, as the records were taken a week before the event.

Another study investigating the effect of aerobic exercise on diet composition was conducted by Staten (1991) on twenty lean male and female subjects. Food intake was monitored during a five day period of daily treadmill exercise and again at a five day sedentary control period. Subjects obtained all food from a metabolic kitchen during both of the study periods, with the diet consisting of a liquid formula, chicken, eggs, bread, crackers, celery and other common food items for which the nutrient composition is well known. No difference was found in the macronutrient composition of the diet between exercise and control periods for men or women. However, this may have been due to the limited selection of foods available on the experimental diet and the short duration of the exercise treatment period.

Keim et al. (1990) investigated the effect of exercise on the diets of twelve women ranging 116 to 142% of ideal body weight. The women participated in three treatment periods. One eighteen day period consisted of no exercise, one of daily supervised treadmill exercise at 65 to 80% of maximal oxygen uptake for 31 to 49 minutes, and one of long duration daily exercise at the same intensity for 51 to 88 minutes. Subjects consumed only food obtained at the research center with all items being weighed before and after consumption. Carbohydrate intake tended to be higher during the exercise periods as compared to the sedentary period, with an initial intake of 259 grams increasing to 281 grams during the last exercise period. However, this was not statistically significant. Protein intake remained relatively constant at 93 versus 96 grams at the conclusion of the study. Fat intake increased slightly from 92 grams per day to 100 grams per day, but this was also not statistically significant. As with the previous study, the subjects obtained all foods from a research center with the menus being on a four-day rotation cycle. This may have limited the subjects food choices although it was stated that the menu provided a wide variety of food items. The tendency toward a higher carbohydrate intake is a positive trend, however fat intake also increased slightly with exercise. The results may indicate that obese individuals may not choose certain types of foods, for example high carbohydrate foods, in response to exercise training, and that other factors may control food intake such as the acceptability and palatability of the diet. It would be interesting to have followed the individuals for a longer period of time to see if their body weight was a factor in the types of foods they selected. For example, to find out if leaner individuals choose foods in order to replenish fuels they use with exercise as seen by Janssen et al.

(1989), and if the same would happen to obese individuals upon losing weight.

Nieman et al. (1990) also found that obese individuals will change the macronutrient composition of their diet in response to exercise training, however, it was not as expected. Thirty-six women who were 10 to 40% over their ideal body weight began a walking program five days per week for 45 minutes per day at about 62% of their maximal oxygen consumption. Subjects kept seven-day food records at the onset of the study, at six weeks, and at the conclusion of the study at fifteen weeks. No significant differences were noted in the subjects protein or fat intakes at about 16% and 34% of total calories, respectively. However, there was a significant decrease in carbohydrate consumption over time from 231 grams to 208 grams in the exercise group, which accounted for about 50% of total calories. This is surprising considering that carbohydrate intake is usually expected to increase with increased aerobic activity. Again, it may be possible that these individuals will experience a change in diet composition in response to physical activity once they lose weight.

These studies suggest that individuals may not always increase their carbohydrate intake and decrease their fat intake as the result of the initiation of an exercise program. It seems that leaner individuals may be more likely to do this in response to exercise than obese subjects. A long term study is needed to follow obese individuals until they have lost weight to see if this factor changes their dietary habits. Obese subjects do not seem to alter their dietary pattern with an increase in fuel utilization, although further research is needed to determine the if body weight is a factor in eating patterns.

The Validity of Dietary Records

Many studies involving energy intake rely on the accuracy of food diaries and diet recalls as the measure of food consumption. Occasionally energy intake data is not well correlated with body weight under stable conditions. One possible explanation for findings such as these is that intake data is inaccurate.

Lissner et al. (1989) studied the dietary intakes of 63 women aged 19 to 67 years with stable body weights. Subjects consumed all of their meals on a metabolic ward for 14 to 63 days. Energy intake was determined by weighing the subjects daily intake of the experimental diet. Physical activity levels were kept constant. Prior to beginning their stay on the metabolic unit, the subjects kept either food journals or had 24-hour recalls done to determine their "reported intake". The subjects did receive instructions by a dietitian on recording their intake and estimation of portion sizes. Energy intake was calculated with the use of food composition tables.

The reported energy intakes were about 548 calories lower than observed energy requirements, which was an error of about 23%. The largest underreporting errors were seen in subjects with the highest energy requirements. The underreporting error occurred more frequently in obese subjects as compared to nonobese subjects. The authors also note that lean body mass was a significant predictor of energy requirements whereas fat mass was not. This may explain results showing relatively low energy intakes in some obese individuals. Unfortunately, The article does not state whether or not the subjects maintained their weight throughout the study period, which would greatly affect the comparisons made between actual and reported intakes.

Mertz et al. (1991) also found that individuals tended to underreport their energy intakes. Two hundred and sixty-six male and female subjects aged 21 to 64 years were trained by dietitians to record their food intake for a minimum of seven days. The subjects then consumed a defined experimental diet for a minimum of 45 days during which time weight was kept stable. All meals were consumed on a metabolic unit with the exception of lunches during the week and weekend meals. Subjects were provided with prepared meals during these times. Food consumption was monitored by a dietitian during breakfast and dinner with lunches and weekend meals verified by interviews. Food intake data was analyzed using the Nutrient Data Bank from the United States Department of Agriculture.

Eighty-one oer cent of the participants reported their habitual energy intake as being about 700 calories below the intake determined to maintain their body weight. Eight per cent of the subjects overreported their intake by an average of about 408 calories. Eleven per cent of the subjects accurately reported their intake to within 100 calories of their actual needs. The mean difference between actual and reported intake in women was 428 calories and in men was 565 calories. The authors admit that there are several possibilities where errors could have been made including the database used for diet analysis, the instruction of the volunteers, the food records and the determination of actual needs. However, they offer their rationale as to why none of these areas are likely in error. The authors conclude that the large amount of underreporting was likely due to subconscious motivation by the belief that a low body weight is healthy. They do not believe that the majority of the population would knowingly "cheat".

The article mentioned the suggestion of adding a correction factor to diet record data, although this would only increase the amount of error in dealing with individuals who overestimate their needs and is not thought to be a reasonable solution for overcoming the problem.

As dietary records are not a perfect tool, they are still very useful for detecting large changes in eating patterns. For many studies there is no reasonable alternative to using diet records. Many studies have found the underreporting of diet records to be about 400 to 500 calories, or about 18 to 20% of total calories. Thus dietary records are likely not an accurate indicator of small changes in food consumption. However, they are still useful in detecting large changes in intake as long as the appropriate efforts are made to increase their accuracy as much as possible. This would include a thorough instruction on how to measure and record food intake data, preferably by a dietitian; records that are several days long that include at least one weekend day; review of records by a dietitian to correct inaccuracies or clarification of entries; and an accurate database for the calculation of calories and nutrients. The potential inaccuracy of diet records must also be given consideration in the interpretation of research articles.

Summary

The review of literature in the area of exercise and its effect on energy intake, body weight and composition, and dietary habits reveals that responses may be highly variable depending upon an individuals sex and initial body weight status, and the duration and intensity of the exercise. While it is often believed that an individual will increase their caloric intake in response to an increase in activity level, this has not always been shown to be true. Studies have also shown that individuals who engage in physical activity can somehow maintain their weight despite a negative energy balance. Even studies on the dietary intakes of athletes reveal a surprisingly low energy intake with a high level of activity, especially in female athletes. A possible explanation for these findings is that some individuals have a greater food efficiency, meaning that they require fewer calories per unit of metabolically active mass. Another possible explanation is that a change in 24 hour energy expenditure occurs, or that an individual will experience a decline in some portion of their daily energy expenditure, such as the metabolic cost of sleeping. It is also possible, as discussed in the last section, that the dietary records are inaccurate. The research in this area is far from conclusive with many studies showing conflicting results. More research is needed to determine the causes for this breakdown in the energy balance concept, especially in women and obese individuals.

Chapter III

JOURNAL MANUSCRIPT

The Effect of an Aerobic Training Program with Two Different Training Intensities on the Energy Intake, Dietary Composition and Body Composition of Female Subjects

Brenda M. Mueller, Janet Walberg-Rankin, Don Sebolt and Anne Alexander

Laboratory for Exercise, Sport and Work Physiology

Division of Health and Physical Education
Virginia Polytechnic Institute and
State University, Blacksburg, Virginia

Address Correspondence:
Brenda M. Mueller
507 Q Sunridge Drive
Blacksburg, VA 24060

ABSTRACT

Female subjects aged 18 to 40 began a running program with the goal of running a marathon. The subjects were randomly divided into two training groups. One group always trained at or below their lactate threshold, while the other group trained above their lactate threshold on alternate days. The subjects completed their weekly mileage in four to six days. Seven-day dietary records were kept at the onset of the study and at three month intervals throughout the study. Body weight and body fat data was also obtained at approximately the same intervals. Twenty-four women had dietary data at the onset of the study, with twenty-one remaining at six months. By this time the women were running twenty-four miles per week. Dietary records were analyzed using the Nutripractor nutritional analysis computer program for energy, macronutrients, and selected micronutrients. No significant differences were found in energy intake, macronutrients, or body composition between groups or over time. Surprisingly, subjects maintained their body weight and body fat despite a large increase in activity level, with no significant change in caloric intake. The women, in general, consumed diets which did not meet the Recommended Daily Allowances (RDA) for calcium, magnesium, zinc, and iron across all three time periods. A trend analysis procedure showed significant quadratic trends in vitamin D intake, sodium intake, grams of fat consumed, and magnesium intake and a significant linear trend downward in cholesterol intake. Individual responses were, however, highly variable. These results indicate that exercise training at either of the two intensities did not affect caloric intake, macronutrient mix, or body composition in this subject population.

Index terms: training program; lactate threshold; dietary records.

Introduction

To prevent a state of negative energy balance, caloric intake should increase with an increase in activity level. However, research has shown that increased activity does not consistently affect energy intake and body composition (11, 13, 28). Individual responses seem to be highly variable, and factors such as sex, body weight status, and the duration and intensity of the exercise seem to be important (11, 13, 14, 28, 33).

Studies in rats (12, 19) indicate that exercise intensity may affect food consumption. A similar relationship may exist in humans (14, 29).

Gender may also be a factor in determining responses to increased activity. Some studies have found that lean male subjects increase their energy intake in response to exercise while the intake of lean female subjects remains unchanged with exercise (11, 28). Conflicting results were seen in studies by McGowan et al. (20) and Woo and Pi-Sunyer (34).

Body weight status may play a role in the dietary intake response to exercise training. Studies have shown that obese women may not have significant changes in their food intake with exercise (14, 33). Nieman et al. (23) found that overweight women decreased their food intake with the initiation of a walking program, but found that body weight remained unchanged. In contrast, significant changes in body weight have been shown with relatively low levels of physical activity in overweight women in another study (18).

Dietary composition is another factor which has been suggested to change with the adoption of an exercise program. Armstrong et al. (1) found that recreational exercisers reported consuming more fresh fruits and vegetables, whole grain products, poultry, and fish, while consuming less red meats and eggs. This suggests that they tried to consume diets higher in carbohydrates and lower in fats and cholesterol. Pate et al. (24) found that women runners reported consuming increased levels of carbohydrates and less fats, as compared to inactive women. The active women also consumed more fiber and less cholesterol and saturated fats. These studies indicate that active individuals may consume healthier diets than the sedentary population.

Research in the area of exercise and its effect on dietary intake and body composition is far from conclusive. It is difficult to make comparisons between many of the studies in this area due to the short-term nature of most of the studies. In addition, most of the studies were cross-sectional in design. This study attempted to focus on long-term changes in energy intake, diet composition and body composition in a longitudinal study of exercise training.

Methods

This study used data previously collected as part of a larger study conducted at the University of Virginia. Untrained women, aged 18 to 40, were recruited for participation in the study. The women were screened to remove anyone with metabolic or renal disease, eating disorders, or prior orthopedic injuries. All subjects were eumenorrheic at the onset of the study. No one was accepted if they did more than recreational exercise, defined as less than the equivalent of ten miles per week of running. Subjects with a per cent body fat greater than 40% were excluded from the study. All subjects had to agree to refrain from "fad" diets during the course of the study. Twenty-four women began the study, with twenty-one remaining at six months.

The subjects were all admitted to the University of Virginia Clinical Research Center prior to the onset of the study during the early follicular phase of their menstrual cycle (two to five days after the onset of menses). Measurements made at this time included estradiol, progesterone, LH and FSH, which are reported elsewhere (27).

Each subject had a maximal graded exercise test to determine oxygen consumption and lactate threshold. A continuous horizontal running treadmill protocol was used with an initial velocity of 60 m/min. The velocity was increased 10 m/min after each three minute stage until the subject could no longer maintain the workload, at which time the test was terminated. A dry gas meter was used to measure inspired ventilation (Rayfield RAM-9200) with expired ventilation collected in a mixing chamber. Concentrations of O_2 and CO_2 in the mixing chamber were determined using an O_2 analyzer (S3A, Applied Electrochemistry) and a CO_2 analyzer (Beckman LB-2). Each analyzer was calibrated using commercial gases of known concentrations prior to each test. Blood samples were taken at rest and at the end of each stage using an indwelling venous catheter located on the back of the hand. Blood lactate concentrations were determined using a lactate analyzer (model 23L, Yellow Springs Instruments). Lactate threshold was determined by examining the blood lactate-running velocity values from the maximal exercise test. The highest running velocity obtained for which there was no elevation in blood lactate above baseline values was used as the lactate threshold. This value was associated with a heart rate, running velocity, and oxygen consumption value. The running velocity value was used to differentiate between the two training intensities.

Body composition assessments were made using hydrostatic weighing. Subjects were first weighed in air and then underwater on an autopsy scale accurate to 10g. The procedure was repeated eight to ten times per subject with the last three values used as the estimate of body density. Residual volume was measured using the Wilmore O2 dilution technique (32). Body fat was then calculated using the revised formula of Brozek et al (5). Serial measurements were made at the beginning and every four menstrual cycles for body fat analysis, maximal oxygen consumption, and lactate threshold. These measurements were not made at the exact time of the dietary records, but at approximately the same intervals. Due to the difference in some of the intervals, however, fewer subjects (n=10) had body composition data which corresponded to their dietary records. For this reason, body composition data is presented for only a subset of the subjects.

The subjects were randomly divided into two training groups. One group always trained at a running velocity which was at or below their lactate threshold (@LT). The other group trained at velocities above their lactate threshold, at 50% of the difference between their running velocity at maximal oxygen consumption and lactate threshold, on alternating days (>LT). They trained at the level of their lactate threshold on the alternate days.

The women began the training program running 6.25 miles per week, with their mileage increasing by 1.25 miles every other week. By five months, the women had reached a weekly distance of twenty-four miles per week. The mileage was then held constant until the six month. They completed their mileage in four to six days each week. Running velocity was monitored for each subject three times per week to ensure adherence to the appropriate intensity. They were not supervised for the remainder of their sessions. The subjects did not all begin the training program at the same time of the year.

The subjects were advised to continue their usual eating habits throughout the study. The subjects were instructed as to how to accurately record their intake, with a three-day practice record obtained prior to beginning the study. The subjects began keeping seven-day dietary records during the first week of training which served as baseline data. The seven-day records were kept during the early follicular phase of every other menstrual cycle in order to be consistent with the onset of menses. The subjects were given no feedback on the dietary records, or any nutrition education. Some subjects became irregular in their menstrual cycles during the study, which may have affected the amount of time lapsing between some of the food records. For this reason, records were used if they were within one month of the desired time period.

The records were reviewed by a dietitian for completeness and accuracy. The subjects were contacted if additional information was needed. Supplement intake was also recorded, with these values subtracted from the records to obtain actual dietary intake. The dietary records were analyzed using the Nutripractor nutritional analysis software program (Practorcare, San Diego, California) for energy, macronutrients, and selected micronutrients. Averages of the seven-day records were used in the analysis.

Statistical analysis was performed using the Statistical Analysis System (SAS) with the dietary and body composition data as the dependent variables and training intensity and time as the independent variables. The dietary records at baseline, three months, and six months were statistically analyzed in SAS using a multivariate analysis of variance (MANOVA) Wilks' Lambda test for time and group by time effects. If significance was found, a contrast procedure was used to locate the significance. In addition, a one-way ANOVA was used to test for differences between groups at each time period. A trend analysis procedure was used in SAS, after collapsing the groups, to locate linear and quadratic trends in the data.

Results

The subjects consumed an average of about 1700 calories per day, of which about 14 to 15% of the calories were from protein, 30 to 35% from fat, and 48 to 51% were from carbohydrates (Table 1). Mean body weight remained at approximately 67 to 68 kilograms while per cent body fat showed a slight decline which was not statistically significant (Table 2). Mean height was 166.6cm for the @LT group and 163.7cm for the >LT group.

No significant differences were found in energy intake, macronutrient composition of the diet, body weight, or body fat between the different groups at baseline, three, or six months or over time when the groups were collapsed. In the subjects completing three months of training (n=21), significant differences between groups were found in potassium intake (p=0.006, Table 4), calcium intake (p=0.048, Table 4), magnesium intake (p=0.016, Table 4), zinc intake (p=0.022, Table 4), and folate intake (p=0.017, Table 5). The @LT group had lower intakes than the >LT group for all of these nutrients. A significant decrease from baseline values across time was seen for both groups combined with sodium from 2727mg to 1989mg at the three month period (p=0.004, Table 4). Magnesium intake also decreased significantly across time for both groups combined from 228mg at the three month period versus 192mg at baseline (p=0.027, Table 4). Significant group by time differences were seen in potassium intake at baseline versus three months (p=0.005) and at three versus six months (p=0.013, Table 4). Again, the @LT group had the lower intakes at each time period. The @LT group tended to decrease their potassium intake at three months while the >LT group tended to increase at the three month period as compared to baseline.

The women consumed diets below the RDA for calcium, magnesium, zinc and iron with average intakes across six months for the entire subject group of 725mg, 209mg, 7mg, and 13mg respectively. Twenty-nine per cent of the women consumed less than 2/3 of the RDA for calcium at baseline, 38% at three months, and 33% at six months. Their average intake across all three time periods is higher than the typical intake of 530 mg in American women (8). Thirty-three per cent of the subjects consumed less than 2/3 of the RDA for magnesium at baseline, 62% at three months, and 43% at six months. The subjects had an average zinc intake below the RDA for all time periods, with 67% consuming less than 2/3 of the RDA at baseline, 71% at three months, and 57% at six months. Average iron intake also tended to be low, with 75% of the women consuming diets below the recommended 15mg per day. Twenty-four per cent of the subjects consumed less than 2/3 of the RDA at baseline, 38% at three months, and 29% at six months. Average folate intake was above the recommended 180 mcg per day, but over half of the women had average intakes below this level. Fourteen per cent of the women consumed less than 2/3 of the RDA at baseline, 24% at three months, and 19% at six months. The average vitamin B6 intake was 1.26mg, which is above the usual intake for U.S. women at 1.16mg per day (8), but below the RDA of 1.6mg. Thirty-three per cent of the subjects consumed less than 2/3 of the RDA at baseline, with 43%

below this level at three and six months. Vitamin C intake was well above recommended levels with an overall average intake of about 88mg.

Average intakes including supplements are shown in Table 6. At baseline, 15 of the subjects were taking some form of a vitamin or mineral supplement. This declined to 14 at three months and 11 at six months. The most frequently used supplement was iron, with several of the subjects also taking vitamin C or multivitamins. With the exception of iron, supplements did not seem to bring intake of the problem nutrients to an adequate level.

A trend analysis procedure showed a significant quadratic trend in vitamin D intake (p=0.023, Figure 1), with a decline at three months and then an increase at six months. Grams of fat consumed (p=0.044), magnesium intake (p=0.049), and sodium intake (p=0.003) showed the same type of trend as vitamin D intake across the six month period (Figures 2 through 4). Cholesterol intake showed a significant linear trend downward (p=0.027) across the six months (Figure 5). Data on lactate threshold and maximal oxygen consumption is presented elsewhere (27).

Discussion

The present study was undertaken to determine the effects of a running program with two differing training intensities on the energy intake, dietary composition, and body composition of female subjects. Studies have noted appetite suppression to occur with high intensity exercise in rats (12, 19) as well as humans (14). High intensity exercise may result in increased lactic acid production (2), increased catecholamine production (6) or increased core temperatures (4). These factors have been suggested as possible causes of appetite suppression. Cognitive factors such as external discomfort or distraction may also play a role in this mechanism (29). However, in this study no differences in energy intake were seen between women training at high exercise intensities and those training at lower intensities.

Ballor et al. (3) found that exercise intensity did not affect the body composition or rate of weight loss in obese women on a self-selected 1200 calorie diet. The authors had hypothesized that the group exercising at lower intensities would have a greater loss of body fat due to the greater use of fat as a fuel as compared to the group exercising at high intensities. As with the present study, this was not shown to be true. There is, however, the possibility that the difference in intensities between the two groups was not large enough to result in a difference.

Energy intake for both groups at baseline and at month six was approximately 1700 calories per day. It was interesting that no significant changes were seen in energy intake in either group over time despite increasing activity levels. The subjects were eventually running twenty-four miles per week by the last month of the study. This would result in a caloric expenditure of approximately 2400 calories per week, assuming that they were expending about 100 calories per mile. When divided into seven days, this would amount to an additional caloric need of about 350 calories per day. Similarly, Staten (28) found no increase in energy intake despite an additional caloric expenditure of 441 calories per day in female subjects. It is possible that the women actually increased their intake enough to allow them to maintain their energy balance but that the records were not sensitive enough to detect these changes, or that underreporting of food intake may have occurred. Mertz et al. (21) found underreporting in seven-day dietary records to be 18%. A similar percentage, 23%, was noted by Lissner et al. (17). This occurred despite thorough instruction by dietitians in the recording of their food intake data. However, seven-day food records have also been found to be accurate in estimating usual intake to within 10% (10, 15). Additionally, Titchenal (30) suggested that relative changes should still be evident with dietary records as long as underreporting occurs consistently.

In the present study, steps were taken to reduce the possible inaccuracy of the records. The subjects did receive instruction by a dietitian in keeping accurate intake records and kept a three-day practice record prior to the study. All records were reviewed by a dietitian and if needed, the subjects were contacted with further questions about their records.

Other studies have shown results similar to these (11, 28), which may indicate that other explanations are needed to determine why intake did not appear to increase with exercise training, and why no changes in body weight were seen. Janssen et al. (11) found that female subjects did not change their energy intake during eighteen months of training for a marathon. Additionally, the women had no changes in body composition throughout the study. Staten (28) found that female subjects did not change their energy intake during five days of exercise training, despite an additional caloric expenditure of 441 calories per day. No significant changes in body weight were noted, although this may have been due to the short duration of the study. In contrast to these studies, Nieman et al. (23) found that mildly obese women had a decrease in their energy intake with exercise training. However, there was no significant change in body weight or body composition during the fifteen weeks of the study. Woo and Pi-Sunyer (34) showed that non-obese women increased their energy intake in response to an increased energy expenditure. The subjects were able to maintain their body weight throughout the two nineteen-day exercise periods. Overall, it seems that exercise does not consistently affect energy intake or body composition in female subjects, although it is difficult to make comparisons between the studies in this area due to the wide range of methodologies used.

The results of this study may be partially explained by the possibility of an increased fuel efficiency which allowed these subjects to maintain their body weight despite being in an apparent state of negative energy balance. Deuster et al.(7) suggested that aerobic training may increase the efficiency of digestive and energy metabolism. This may be exaggerated in women with higher body fats such as the mean 30 per cent body fat noted in these women.

The subjects may also have become more efficient at other components of their daily energy expenditure to accommodate the additional energy cost of exercise, such as their sleeping metabolic rate. A decrease in sleeping metabolic rate was noted following exercise training in women by Woo et al. (33). Horten (9) suggests that exercise may potentiate the thermic effect of food, another component of twenty-four hour energy expenditure, in lean individuals which would result in a greater energy expenditure. He adds, however, that this may not occur in overweight individuals. This could result in a lower energy expenditure, perhaps enough to compensate for the caloric cost of exercise. Titchenal (30) suggests that a reduction in spontaneous activity may occur in some individuals engaging in an exercise program to accommodate the additional energy expenditure, allowing them to maintain their energy intake and weight despite increased activity levels.

This study also did not find any alterations in the macronutrient composition of the subject's diets. Other studies have shown changes in diet composition to occur with the adoption of an exercise program. Carbohydrate intake has been shown to increase with aerobic activity, possibly related to fuel utilization during exercise (11). Pate et al. (23) found that female runners reported consuming more carbohydrates and less fat and protein than inactive women. The subjects in the present study consumed diets which were approximately 15% protein, 34% fat, and 50% carbohydrate. Although this is close to current recommendations for percentage of fat intake for optimal health, the carbohydrate level is below that recommended for physically active individuals.

In the present study, significant quadratic trends were seen with grams of fat consumed and sodium intake, with the subjects showing a decline in intake at three months and then an increase at six months. Cholesterol intake showed a significant linear trend downward over the six month period. It is possible that the subjects had a greater awareness and interest in consuming a healthier diet, at least in the first three months of the study. Other studies have shown positive dietary practices in active individuals, such as decreased saturated fat and cholesterol intakes and higher fiber intakes (24). Armstrong et al. (1) found that active individuals reported consuming increased amounts of fresh fruits and vegetables, whole grain products, poultry, and fish, and reduced levels of red meat and eggs. Deuster et al. (7) found women runners to have higher intakes of fiber due to an increased consumption of fresh fruits and vegetables. Nieman et al. (22) found that runners consumed more carbohydrates and less fat than the general population, and had a higher fiber intakes and lower saturated fat and cholesterol intakes. Interestingly, both Pate et al. (24) and Nieman et al. (22) found surprisingly low calorie intakes in their physically active subjects.

Studies have also noted active individuals, particularly women, to consume diets inadequate in certain nutrients. The subjects in this study consumed diets inadequate in calcium, magnesium, zinc and iron. However, when the intakes of the women in this study were examined including supplements, iron intake was well above recommended levels. Calcium, magnesium, and zinc intakes remained inadequate. These nutrients have been shown to be problematic for women in general, but may pose an even greater problem for physically active females. Deuster et al. (7) noted female runners to have diets low in zinc, iron, and copper while calcium intake was found to be adequate. Pate et al. (24) found low intakes of magnesium, vitamin D, vitamin B6, zinc, calcium, and iron in female runners. Welch et al. (31) studied the dietary intakes of female college athletes, and found problem nutrients to be folacin, vitamin B6, vitamin B12, calcium, and iron. Many negative health effects could occur with consistently inadequate intakes of these minerals, including anemia (7) and reduced bone densities (16). This data may indicate that more emphasis should be placed on educating physically active individuals, especially women, on the importance of consuming a nutritionally adequate diet. Instruction of food sources for problem nutrients would also be helpful. A multivitamin/mineral supplement may be advisable if intake in general is low or if dietary quality is poor to ensure adequacy, especially for active individuals who may have increased needs (8).

These results indicate that if weight reduction is desired, both increased activity and dietary modification are needed to ensure success. Exercise alone did not appear to be successful in bringing about changes in body weight or body fat, although it did result in some transient positive dietary changes. Exercise intensity did not appear to be a factor influencing body composition or dietary intake. Further research should focus on the mechanisms involved in fuel efficiency or other alterations in daily energy expenditure as a possible explanation for results such as these.

Table 1. Average Energy and Macronutrient Intake for Women Training At or Above Their Lactate Threshold

Variable	Baseline	Month 3	Month 6
Calories			
@LT	1715.7*	1508.0	1732.6
	(130.5)	(110.3)	(119.2)
>LT	1698.2	1688.0	1726.4
	(136.9)	(115.7)	(125.0)
Per Cent Protein			
@LT	14.7	14.9	14.2
	(0.7)	(0.8)	(0.8)
>LT	16.0	15.7	14.1
	(0.8)	(0.9)	(0.9)
Per Cent Fat			
@LT	35.8	34.8	34.6
	(2.1)	(2.8)	(2.0)
>LT	33.4	30.8	35.8
	(2.2)	(3.0)	(2.1)
Per Cent Carbohydrate			
@LT	48.0	49.7	51.2
	(2.4)	(3.2)	(2.7)
>LT	49.0	50.9	50.0
	(2.5)	(3.4)	(2.9)
Grams of Fat			
@LT	68.8	59.7	66.8
	(7.3)	(6.8)	(7.0)
>LT	63.9	57.6	69.7
	(7.6)	(7.2)	(7.3)
Grams of Protein			
@LT	62.7	55.5	61.7
	(4.7)	(4.7)	(5.7)
>LT	66.4	66.0	60.4
	(4.9)	(4.9)	(5.9)
Grams of Carbohydrate			
@LT	207.1	183.8	221.2
	(19.2)	(17.4)	(17.3)
>LT	207.3	216.3	210.6
	(20.2)	(18.2)	(18.1)

* average (standard error); @LT, training velocity at lactate threshold group (n=11); >LT, training velocity greater than lactate threshold group (n=10). None of the averages were significantly different.

Table 2. Subject Characteristics

Variable	Baseline	Month 3	Month 6
Body Weight (kg)			
@LT	68.6*	68.7	68.3
	(4.7)	(4.6)	(4.1)
>LT	67.0	66.6	66.4
	(4.7)	(4.6)	(4.1)
Per Cent Body Fat			
@LT	29.4	29.3	26.9
	(0.0)	(0.0)	(0.0)
>LT	30.7	30.8	28.9
	(0.0)	(0.0)	(0.0)

*average (standard error); @LT, training velocity at lactate threshold group (n=5); >LT, training velocity greater than lactate threshold group (n=5). Average height, @LT=166.6cm; >LT=163.7. None of the averages were significantly different.

Table 3. Average Cholesterol, Alcohol, and Dietary Fiber Intakes for Women Training at or above Their Lactate Threshold

Variable	Baseline	Month 3	Month 6
Cholesterol (mg)			
@LT	329.1*	247.5	219.2
	(40.5)	(37.7)	(20.7)
>LT	217.8	239.4	196.6
	(42.4)	(39.6)	(21.7)
Alcohol (g)			
@LT	7.7	6.5	5.6
	(2.8)	(3.5)	(2.6)
>LT	8.9	10.5	7.9
	(2.8)	(3.5)	(2.6)
Dietary Fiber (g)			
@LT	3.3	2.3	3.2
	(0.9)	(0.9)	(0.8)
>LT	3.9	3.6	3.1
	(0.9)	(0.9)	(0.8)

* average (standard error); @LT, training velocity at lactate threshold group (n=11); >LT, training velocity greater than lactate threshold group (n=10). No significant differences were seen.

Table 4. Average Dietary Electrolyte and Mineral Intakes for Women Training At or Above Their Lactate Threshold

Variable	Baseline	Month 3	Month 6
Sodium (mg)[a]			
@LT	2716.6*	1688.1	2556.3
	(276.6)	(240.6)	(264.8)
>LT	2738.1	2290.3[b]	2664.5
	(290.1)	(252.3)	(277.7)
Potassium (mg)[a,c]			
@LT	2198.4	1644.3	2097.1
	(221.2)	(220.4)	(228.4)
>LT	2411.7	2628.6[b]	2233.8
	(232.0)	(231.2)	(277.7)
Calcium (mg)			
@LT	699.8	558.2	644.1
	(83.3)	(84.4)	(85.3)
>LT	832.9	831.2[b]	784.8
	(96.1)	(97.5)	(98.5)
Iron (mg)			
@LT	11.0	13.7	13.5
	(1.3)	(3.2)	(1.8)
>LT	14.2	13.8	13.8
	(1.5)	(3.5)	(1.9)
Magnesium (mg)[a]			
@LT	204.9	152.7	191.5
	(22.0)	(20.4)	(24.7)
>LT	250.0	231.0[b]	225.7
	(23.1)	(21.4)	(25.9)
Zinc (mg)			
@LT	7.0	5.4	6.5
	(0.6)	(0.6)	(0.8)
>LT	7.4	7.7[b]	7.2
	(0.6)	(0.6)	(0.8)
Phosphorus (mg)			
@LT	1039.7	852.3	976.9
	(88.3)	(78.8)	(95.8)
>LT	1073.3	1032.8	980.6
	(84.2)	(75.1)	(91.4)

* average (standard error); @LT, training velocity at lactate threshold group (n=11); >LT, training velocity greater than lactate threshold group (n=10).

[a] $p<0.05$ Baseline vs. Month 3

[b] $p<0.05$, significant group difference

[c] $p<0.05$ Month 3 vs. Month 6

Table 5. Average Dietary Vitamin Intakes for Women Training At or Above Their Lactate Threshold

Variable	Baseline	Month 3	Month 6
Thiamin (mg)			
@LT	1.1*	1.0	1.1
	(0.1)	(0.2)	(0.2)
>LT	1.2	1.4	1.2
	(0.1)	(0.2)	(0.2)
Niacin (mg)			
@LT	14.9	14.8	15.4
	(1.4)	(2.2)	(1.1)
>LT	18.2	20.2	14.1
	(1.6)	(2.6)	(1.3)
Riboflavin (mg)			
@LT	1.4	1.8	1.4
	(0.1)	(0.4)	(0.2)
>LT	1.6	1.8	1.5
	(0.2)	(0.4)	(0.2)
Vitamin B6 (mg)			
@LT	1.3	1.1	1.2
	(0.1)	(0.2)	(0.1)
>LT	1.4	1.6	1.1
	(0.1)	(0.2)	(0.1)
Vitamin B12 (mcg)			
@LT	4.8	10.5	4.2
	(3.9)	(5.0)	(3.1)
>LT	9.1	3.9	7.3
	(4.1)	(5.2)	(3.2)
Folacin (mcg)			
@LT	179.4	135.8	190.8
	(24.2)	(37.5)	(22.6)
>LT	214.9	278.2*	187.6
	(25.4)	(39.4)	(23.7)
Pantothenic Acid (mg)			
@LT	3.3	2.8	2.8
	(0.3)	(0.4)	(0.3)
>LT	3.2	3.6	2.8
	(0.3)	(0.4)	(0.3)
Vitamin A (IU)			
@LT	4959.7	3430.4	4699.9
	(954.7)	(658.5)	(665.7)
>LT	5152.0	4447.8	3866.03
	(1001.3)	(690.6)	(698.1)

Vitamin C (mg)			
@LT	93.12	71.8	84.8
	(12.2)	(17.1)	(10.2)
>LT	77.8	120.2	78.4
	(12.8)	(18.0)	(10.7)
Vitamin D (IU)			
@LT	224.6	60.7	171.8
	(95.0)	(30.4)	(42.3)
>LT	154.6	95.6	84.0
	(99.6)	(31.9)	(44.4)
Vitamin E (IU)			
@LT	8.0	5.0	6.0
	(1.5)	(1.8)	(2.1)
>LT	7.6	7.9	9.5
	(1.5)	(1.7)	(2.0)

* Average (standard error); @LT, training velocity at lactate threshold group (n=11); >LT, training velocity greater than lactate threshold group (n=10).

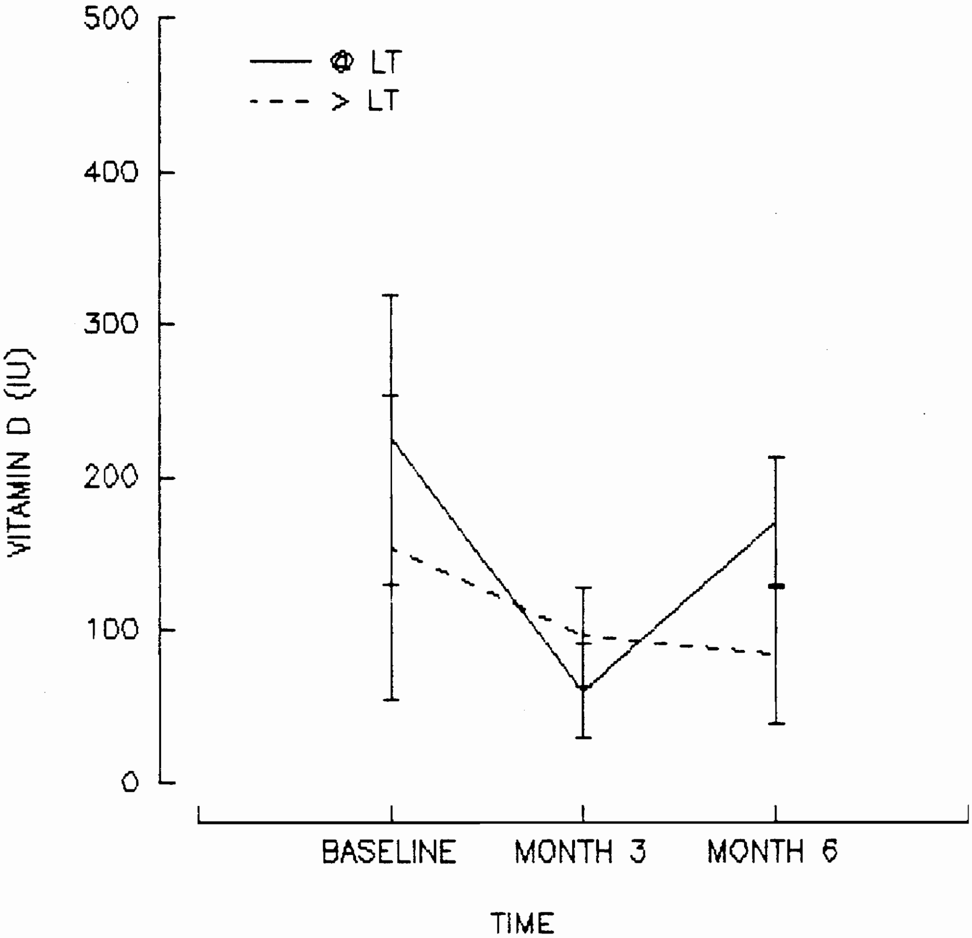
▲ $p<0.05$, significant group difference

Table 6. Average Intakes Including Supplements for Women Training At or Above Their Lactate Threshold

Variable	Baseline	Month 3	Month 6
Calcium (mg)			
@LT(n=11)	752.6(105.6)*	653.5(86.0)	669.2(80.9)
>LT(n=10)	832.9(105.8)	831.2(94.0)	784.8(118.8)
Iron (mg)			
@LT	47.4(10.9)	40.6(8.0)	23.5(5.3)
>LT	54.6(15.0)6	52.6(20.5)	47.3(13.2)
Magnesium (mg)			
@LT	213.1(16.1)	153.5(20.7)	192.3(23.4)
>LT	263.7(25.6)	243.5(26.3)	229.6(30.7)
Phosphorus (mg)			
@LT	1039.8(100.0)	852.3(59.4)	976.9(95.1)
>LT	1101.8(78.1)	1083.4(88.6)	1006.4(101.6)
Potassium (mg)			
@LT	2198.9(226.4)	1644.9(166.3)	2103.4(226.7)
>LT	2412.4(250.3)	2628.7(306.5)	2233.8(265.7)
Zinc (mg)			
@LT	8.8(1.4)	7.6(2.2)	10.1(3.8)
>LT	9.2(1.8)	7.8(0.6)	7.3(0.9)
Vitamin A (IU)			
@LT	5868.8(904.7)	3807.0(611.4)	7426.5(2301.2)
>LT	6509.1(1030.8)	5447.8(1192.1)	4723.2(1592.8)
Vitamin C (mg)			
@LT	207.9(80.3)	293.3(92.7)	203.9(98.8)
>LT	344.2(177.6)	168.8(31.3)	126.5(33.0)
Vitamin D (IU)			
@LT	254.3(123.9)	112.7(46.2)	226.3(71.4)
>LT	154.6(65.3)	95.6(37.8)	99.0(32.0)
Vitamin E (IU)			
@LT	25.3(16.8)	57.4(18.1)	42.8(26.8)
>LT	7.1(1.3)	7.9(2.0)	10.3(2.8)
Thiamin (mg)			
@LT	1.8(0.6)	5.5(4.3)	9.4(7.6)
>LT	2.4(1.1)	2.2(0.9)	2.8(1.2)
Niacin (mg)			
@LT	21.1(6.4)	20.9(4.9)	24.7(7.5)
>LT	29.1(11.1)	28.9(8.8)	23.3(16.1)
Riboflavin (mg)			
@LT	2.2(0.6)	6.2(4.8)	8.8(7.3)
>LT	2.8(1.1)	2.6(0.9)	3.1(1.2)
Pantothenic Acid (mg)			
@LT	5.1(1.3)	7.4(4.4)	10.1(7.6)
>LT	4.9(1.2)	4.6(0.8)	4.6(1.6)

Vitamin B6 (mg)			
@LT	2.0(0.2)	5.4(4.3)	8.7(7.6)
>LT	2.0(0.5)	2.0(0.4)	2.3(1.1)
Vitamin B12 (mcg)			
@LT	6.3(1.7)	15.5(7.7)	11.9(7.6)
>LT	10.3(5.9)	4.4(0.7)	8.7(4.7)
Folacin (mcg)			
@LT	232.5(42.2)	177.4(26.3)	263.6(51.6)
>LT	243.4(31.0)	278.6(56.8)	204.7(37.2)

*mean (standard error)



500
400
300
200
100
0
VITAMIN D (IU)
@ LT
> LT
BASELINE
MONTH 3
MONTH 6
TIME

FIGURE 1

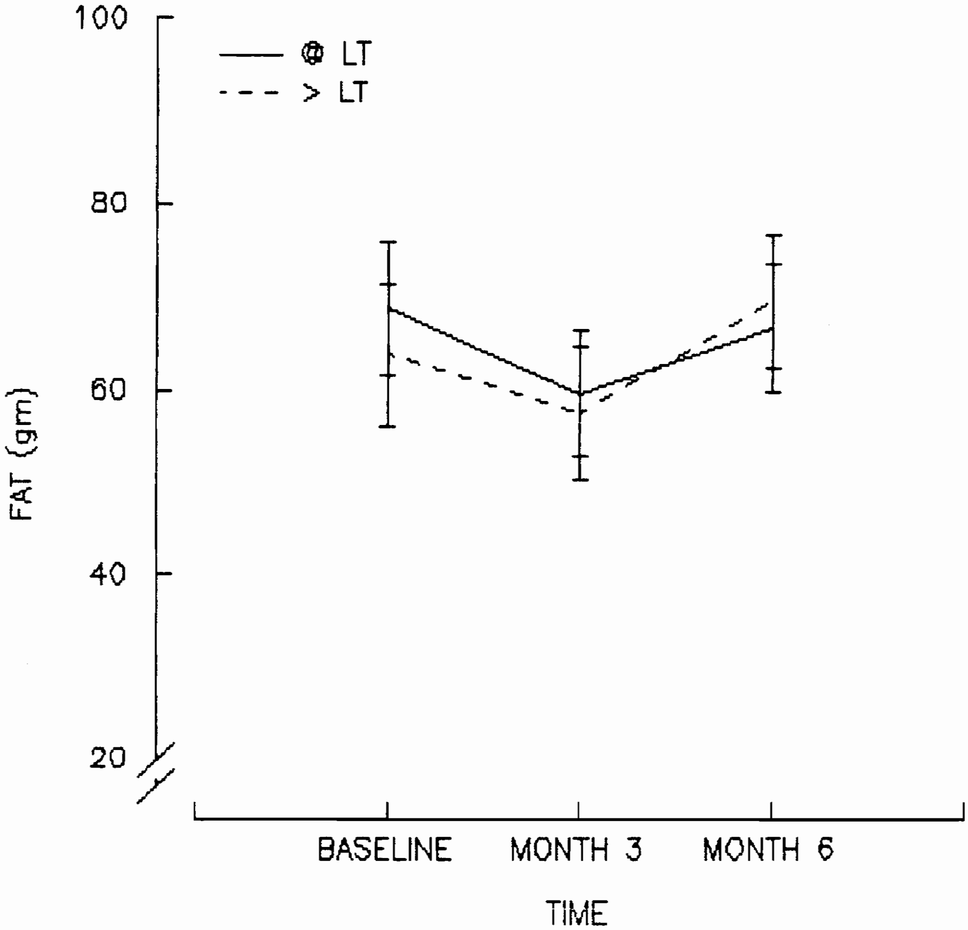
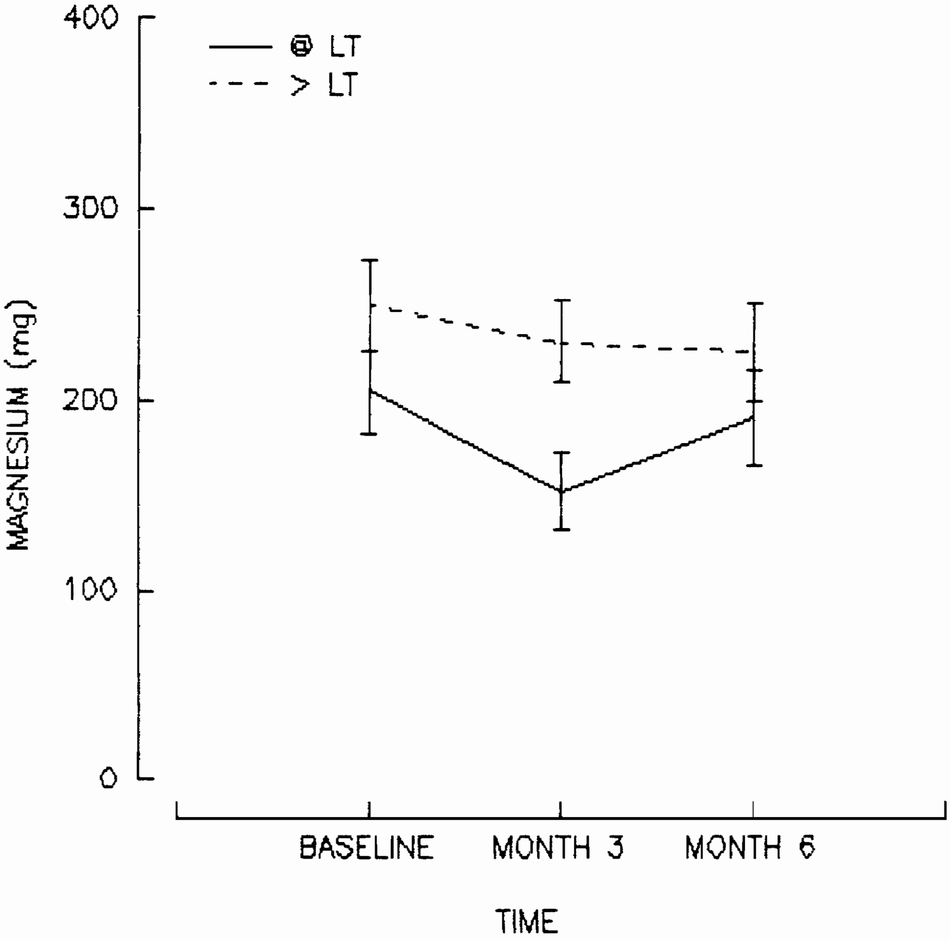
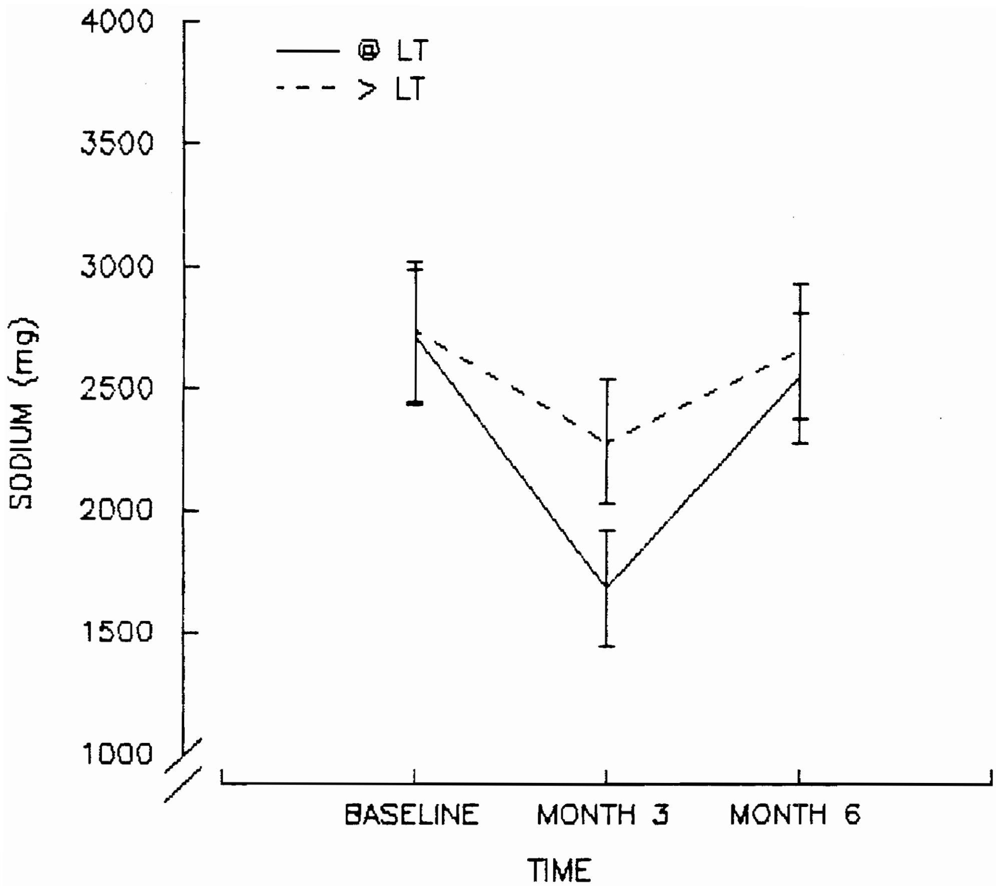


FIGURE 2



400
300
200
100
0
MAGNESIUM (mg)
@ LT
> LT
BASELINE
MONTH 3
MONTH 6
TIME

FIGURE 3



4000
3500
3000
2500
2000
1500
1000
SODIUM (mg)
@ LT
> LT
BASELINE
MONTH 3
MONTH 6
TIME

FIGURE 4

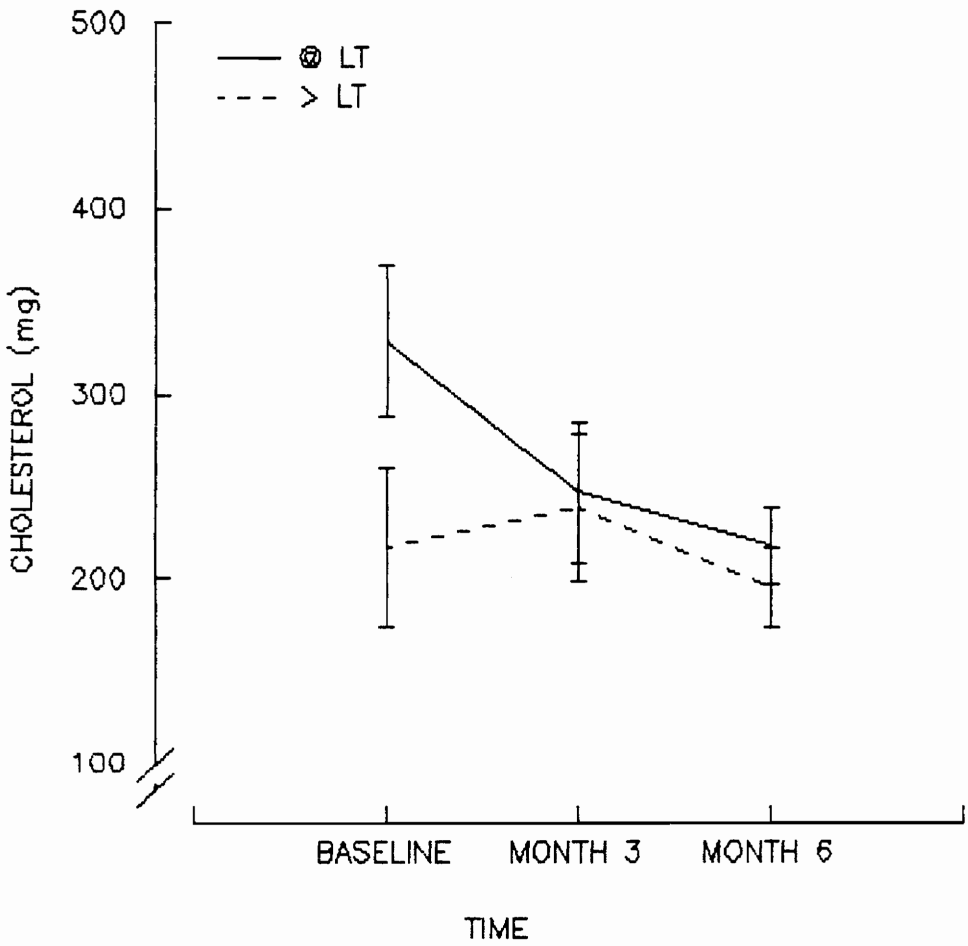

500
400
300
200
100
CHOLESTEROL (mg)
@ LT
> LT
BASELINE
MONTH 3
MONTH 6
TIME

FIGURE 5

Figure Captions

Figure 1. Changes in vitamin D intake for women during a six-month aerobic training program.

Figure 2. Changes in dietary fat intake in grams for women during a six-month aerobic training program.

Figure 3. Changes in magnesium intake in women during a six-month aerobic training program.

Figure 4. Changes in sodium intake in women during a six-month aerobic training program.

Figure 5. Changes in cholesterol intake in women during a six-month aerobic training program.

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Chapter IV

SUMMARY

The energy balance concept indicates that if energy expenditure is increased with no change in energy intake, a decrease in body weight should occur. The body would rely on its own stores to provide additional energy. However, research has shown a variety of responses to increased levels of physical activity. Individual responses appear to be highly variable. Factors such as sex, body weight status, and the duration and intensity of exercise may be important in determining how an individual will respond to exercise training.

Some research has indicated that lean males may be more likely to increase their intake with increased activity levels than lean females (Staten, 1991; Janssen et al., 1989). The women in these studies were able to maintain their body weight, despite being in an apparent state of negative energy balance.

This has also been noted in obese individuals (Kissileff et al., 1990; Woo et al., 1982). However, research has also shown successful weight loss in overweight individuals with only a modest increase in physical activity (Martin and Kauwell, 1990). It may be possible that some individuals may avoid a state of negative energy balance by an increased fuel efficiency or alterations in other components of daily energy expenditure, such as the sleeping metabolic rate or the thermic effect of food. A reduction in spontaneous activity could also occur, allowing the body to accommodate the increased caloric costs of exercise. However, these are often difficult factors to measure.

Studies have indicated that physically active individuals tend to consume healthier diets (Pate et al., 1990; Armstrong et al., 1990). Active individuals tend to consume diets lower in saturated fats and cholesterol and higher in carbohydrates and fiber (Pate et al., 1990; Nieman et al., 1989; Deuster et al., 1986). The adoption of an exercise program may encourage positive changes in dietary habits, possibly due to a greater interest in health or concern over performance. Many studies have also shown surprisingly low energy intakes in active individuals as well as low intakes of certain minerals, particularly in women (Pate et al., 1990; Nieman et al., 1989; Deuster et al., 1986).

The purpose of this study was to investigate long term changes in energy intake, diet composition and body composition in females during an exercise training program. Twenty-four untrained women aged 18 to 40 began a running program for six months. The subjects were randomly divided into two groups. One group always trained at or below their lactate threshold, as determined by blood lactate measurements made during a maximal exercise test prior to the study. The other group trained above their lactate threshold on alternate days, and below this level the remainder of the time. By the conclusion of the study, the subjects were running twenty-four miles per week.

Each subject had body composition measurements made using hydrostatic weighing prior to the study and again at approximately three and six months of the study. Subjects kept seven-day food diaries at baseline and again during every other menstrual cycle for six months. Twenty-one subjects remained at six months, and ten at twelve months. The study had originally been designed to last for twelve to eighteen months, however, due to the large dropout rate the study was limited to the first six months of training.

No significant changes were noted in energy intake, macronutrient composition, body weight, or body fat for either group over time. Significant group differences were seen at three months in potassium intake, calcium intake, magnesium intake, folate intake, and zinc intake. The group training always at or below their lactate threshold had the lower intakes. It is unclear how exercise intensity may have resulted in these changes between the two groups. Magnesium and sodium intake decreased significantly by three months as compared to baseline values. Group by time differences were seen in potassium intake at baseline versus three months and at three versus six months. The women in general consumed diets low in calcium, zinc, magnesium, and iron. Low levels of iron and zinc may have been due to low rates of meat consumption. Iron consumption was adequate when supplements were added to the dietary values, however, most of the other nutrients mentioned remained below recommended levels. Overall, the women consumed diets which were about 15% protein, 30 to 35% fat, and 48 to 50% carbohydrate. Although the percentage of dietary fat was close to meeting current dietary guidelines, the percentage of calories from carbohydrates is lower than recommended for active individuals. The women in the study exhibited a wide variety of eating patterns. Some ate the recommended three well-balanced meals per day while several would eat only one or two meals per day, which were frequently not well-balanced.

A trend analysis procedure showed a significant quadratic trend in vitamin D intake, grams of fat consumed, magnesium intake, and sodium intake. Intake decreased at three months from baseline and rose again by six months. Cholesterol intake showed a significant linear trend downward. The trend analysis data may indicate that the women did make some transient positive dietary changes with a decline in fat, sodium, and cholesterol intake. With the exception of cholesterol intake, these changes tended to return back toward baseline values by six months.

Research Implications

The results of this study suggest that exercise intensity is not a factor in determining changes in body weight, energy intake, or dietary composition in this subject population. Although weight loss was not a goal of this study, exercise alone did not seem to produce changes in general in body weight or body fat. Thus, if weight loss is desired, both dietary counselling and exercise are crucial.

This data indicates that more nutrition education is needed to instruct individuals in proper food choices to ensure a nutritionally adequate diet. As with many other dietary studies of women, calcium and iron appeared to be problem nutrients. Supplements may be indicated for those who have low intakes in general or those with increased needs.

Further research is needed to investigate how individuals may maintain their weight in an apparent state of negative energy balance. Possibilities include an increased fuel efficiency, a decreased caloric cost of other daily activities, or inaccuracies in self-reported dietary data. Underreporting of actual intake has been noted in other studies (Mertz et al., 1991; Lissner et al., 1989). The rate of underreporting was shown to be about 20% in these studies, which would probably be sufficient to cover the increased caloric costs of exercise in this study.

These subjects were also given no feedback on their intake records, which may have affected their compliance as the study progressed. However, while dietary records are not a perfect tool, they can provide valid information especially if subjects are instructed in how to accurately record their intake. A superior method would be covert observation of actual intake, however, this is not really possible in free-living subjects.

As other studies have shown results similar to these, the possibilities of decreased spontaneous activity or other alterations in daily energy expenditure should be examined further. The subjects may have experienced a decline in their sleeping metabolic rate or in the thermic affect of food. Overall, it seems as if exercise training does not consistently affect energy intake or body composition in female subjects.

Recommendations for Further Study

The following recommendations for further study are made due to the results of this investigation:

1. Investigate the possibility of an increased fuel efficiency. Basal energy expenditure measurements done serially throughout the study would provide insight into possible alterations in energy expenditure.
2. The use of a formula diet, with the caloric requirements determined to maintain weight prior to

initiating an exercise program, would eliminate the need for dietary records. This would eliminate the question of their accuracy as a possible explanation for results such as these, although shorter study periods would likely be required.

3. Further research into the effect of exercise intensity on body composition and intake should use larger differences in intensity than were used in this study. It is possible that the two intensities used in the present study were not great enough to elicit a response.

4. Levels of exercise with a greater caloric expenditure would be more likely to be detected with the use of intake records. While an intake record may not be sensitive enough to detect a 300-calorie increase in caloric intake, it would likely detect a 500 or 600 calorie increase.

5. Further investigations in this area should focus on separating lean, overweight, and obese individuals. The women in this study did vary quite a bit from being lean to almost 40% body fat. Results may have been clearer had the subjects had a narrower range of per cent body fats.

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Appendix A

DETAILED METHODOLOGY

METHODOLOGY

Subject Screening and Selection

This study was conducted using data previously collected as part of a larger study conducted at the University of Virginia. Fifty-five women aged 18 to 40 were recruited from the Charlottesville, Virginia area. They were required to have a history of normal menstrual cycles (greater than ten per year) and could not be taking any medications including oral contraceptives. The women were screened to remove anyone with metabolic or renal disease, eating disorders, or prior orthopedic injuries. No one was accepted if they were involved in a regular exercise program (ie. ran more than the equivalent of ten miles per week). All subjects agreed to refrain from "fad" diets during the course of the study. Subjects with a body fat greater than 40% were excluded from the study. Twenty-four women began the study, with twenty-one remaining at six months.

Experimental Procedures

The subjects were admitted to the University of Virginia Clinical Research Center prior to the onset of the study during the early follicular phase of their menstrual cycle (two to five days after the onset of menses). Measurements made at this time included height, body composition, peak oxygen consumption, lactate threshold, and hormonal data including LH and FSH which are reported elsewhere (Rogol et al., 1992). These measurements were repeated every fourth menstrual cycle.

Peak oxygen consumption was determined using a continuous horizontal running treadmill protocol. Initial velocity was 60m/min and was increased 10m/min after each three minute stage. No vertical grade was used. The test was terminated when the subject could not continue to maintain the workload. Inspired ventilation was measured using a dry gas meter (Rayfield RAM-9200). Expired gases were collected in a mixing chamber, and O_2 and CO_2 concentrations were determined using an O_2 analyzer (S3A, Applied Electrochemistry) and a CO_2 analyzer (Beckman LB-2). Maximal oxygen consumption was determined as the highest level of oxygen uptake during one minute of the test.

Blood samples were taken at rest and at the end of each stage using an indwelling venous catheter located on the back of the hand. Blood lactate concentrations were determined using an automated lactate analyzer (model 23L, Yellow Springs Instruments). The blood lactate-running velocity values were used to determine the lactate threshold, defined as the highest running velocity for which there was no increase in blood lactate concentration above baseline values. An elevation in lactate greater than 0.2mM was used due to the error associated with the lactate analyzer. This value was associated with a heart rate, running velocity, and oxygen consumption value.

Subjects were randomly assigned to one of two training intensities. One group always trained at a running velocity at or below their lactate threshold (@LT), while the other group trained at a velocity above their lactate threshold on alternating days at a level corresponding to 50% of the difference between their running velocity at maximal oxygen consumption and lactate threshold (>LT).

Body composition measurements were made using hydrostatic weighing. Subjects were first weighed in air and then underwater on an autopsy scale accurate to within 10g. The procedure was repeated eight to ten times per subject with the last three values used as the estimate of body density. Residual volume was measured using the O2 dilution technique of Wilmore. Per cent body fat was then calculated using the revised Brozek formula.

Exercise Protocol

The subjects began the training program by running 6.25 miles per week, with mileage increasing by 1.25 miles every other week until week 20. Mileage remained at 24 miles per week through week 24, or the sixth month of the study. Subjects were supervised three days per week to ensure adherence to the appropriate intensity. They were not supervised for the remaining one to three sessions each week. The subjects did not all begin the study at the same time period.

Dietary Intake Assessment

The subjects were advised to continue their usual eating habits throughout the study. They were instructed as to how to accurately record their intake and kept a three-day practice record prior to the study. They were also given examples of household measures to help better quantify portion sizes. The subjects were told to record all foods and beverages consumed in a seven-day food diary during the first week of training which served as baseline data. Additional salt use as well as vitamin and mineral supplements were recorded. The subjects kept records during the early follicular phase of their menstrual cycle in order to be consistent with the onset of menses. Records were obtained at baseline, three months, and six months. As some women may have become irregular in their menstrual cycles, records were used if they were within one month of the desired time period.

Subjects were not provided with any feedback on their dietary records or any nutrition education. The records were all reviewed by a dietitian for completeness and accuracy. Subjects were contacted if any additional information was needed. The subjects were asked to provide food labels and recipes for items frequently consumed to assist in accurately determining their intakes.

Dietary intake data was entered into the Nutripractor 6000 nutritional analysis program from the written seven-day food diaries kept by each subject. If subjects were taking any supplements, they were subtracted manually from their intake data. For food items not included in the program database, appropriate substitutions were made. Food labels and recipes were often provided by the subjects. Individual ingredients were entered into the computer when recipes were available. Non-caloric items such as diet sodas, tea and coffee were also included in the records and entered into the computer program.

The records were analyzed for energy, macronutrients, and selected micronutrients. Averages of the seven-day records were used in the statistical analyses. The 10th edition of the Recommended Dietary Allowances was used to compare the average intake data with the suggested levels.

Statistical Analysis

Statistical analysis was performed using the Statistical Analysis System (SAS) with the dietary and body composition data as the dependent variables and training intensity and time as the independent variables. A multivariate analysis of variance (MANOVA) Wilks' Lambda test was used to analyze for time and group by time effects.

If significance was found, a contrast procedure was used to locate the significance. A simple one-way analysis of variance (ANOVA) was used to test for differences between groups at each time period. After collapsing the groups, a trend analysis procedure was used to locate linear and quadratic trends in the data. Differences were considered significant at the $p<0.05$ level.

Appendix B

STATISTICAL TABLES

Repeated Measures Analysis of Variance
MANOVA Test Criteria and Exact F Tests

Variable	Wilks' Lambda	DF	F	Pr>F
Calories				
Time	0.8790	(2,18)	1.24	0.3133
Group*Time	0.9203	(2,18)	0.78	0.4735
Per Cent Protein				
Time	0.7554	(2,18)	2.91	0.0801
Group*Time	0.9386	(2,18)	0.59	0.5652
Per Cent Fat				
Time	0.9098	(2,18)	0.89	0.4271
Group*Time	0.9028	(2,18)	0.99	0.3986
Per Cent Carbohydrate				
Time	0.8854	(2,18)	1.17	0.3343
Group*Time	0.9707	(2,18)	0.27	0.7652
Grams of Fat				
Time	0.7960	(2,18)	2.31	0.1282
Group*Time	0.9365	(2,18)	0.61	0.5543
Grams of Protein				
Time	0.8991	(2,18)	1.01	0.3839
Group*Time	0.9094	(2,18)	0.90	0.4255
Grams of Carbohydrate				
Time	0.9324	(2,18)	0.65	0.5325
Group*Time	0.8647	(2,18)	1.41	0.2702
Cholesterol				
Time	0.7620	(2,18)	2.81	0.0866
Group*Time	0.7782	(2,18)	2.56	0.1047
Alcohol				
Time	0.9301	(2,18)	0.64	0.5401
Group*Time	0.9614	(2,18)	0.34	0.7158
Fiber				
Time	0.8788	(2,18)	1.24	0.3128
Group*Time	0.8498	(2,18)	1.59	0.2312

*$p<0.05$

Repeated Measures Analysis of Variance
MANOVA Test Criteria and Exact F Tests

Variable	Wilks' Lambda	DF	F	Pr>F
Sodium				
Time	0.5428	(2,18)	7.58	0.0041*
Group*Time	0.8845	(2,18)	1.18	0.3313
Potassium				
Time	0.8611	(2,18)	1.45	0.2604
Group*Time	0.6741	(2,18)	4.35	0.0287*
Iron				
Time	0.9300	(2,18)	0.64	0.5397
Group*Time	0.8760	(2,18)	1.20	0.3244
Calcium				
Time	0.9347	(2,18)	0.63	0.5443
Group*Time	0.9515	(2,18)	0.46	0.6393
Phosphorus				
Time	0.7695	(2,18)	2.70	0.0946
Group*Time	0.9178	(2,18)	0.81	0.4621
Zinc				
Time	0.8819	(2,18)	1.21	0.3227
Group*Time	0.8062	(2,18)	2.16	0.1439
Magnesium				
Time	0.6701	(2,18)	4.43	0.0272*
Group*Time	0.8874	(2,18)	1.14	0.3411
Vitamin A				
Time	0.8444	(2,18)	1.66	0.2183
Group*Time	0.8562	(2,18)	1.51	0.2474
Vitamin C				
Time	0.9279	(2,18)	0.70	0.5098
Group*Time	0.7615	(2,18)	2.82	0.0861
Vitamin D				
Time	0.7553	(2,18)	2.92	0.0800
Group*Time	0.8176	(2,18)	2.01	0.1632

$*p<0.05$

Repeated Measures Analysis of Variance
MANOVA Test Criteria and Exact F Tests

Variable	Wilks'Lambda	DF	F	Pr>F
Vitamin E				
Time	0.8618	(2,18)	1.28	0.3042
Group*Time	0.8549	(2,18)	1.36	0.2854
Riboflavin				
Time	0.9276	(2,18)	0.70	0.5085
Group*Time	0.9954	(2,18)	0.04	0.9595
Niacin				
Time	0.8005	(2,18)	2.24	0.1350
Group*Time	0.7213	(2,18)	3.48	0.0529
Thiamin				
Time	0.9921	(2,18)	0.07	0.9308
Group*Time	0.9513	(2,18)	0.46	0.6379
Vitamin B6				
Time	0.7829	(2,18)	2.50	0.1105
Group*Time	0.7426	(2,18)	3.12	0.0687
Vitamin B12				
Time	0.8678	(2,18)	1.37	0.2791
Group*Time	0.9222	(2,18)	0.76	0.4825
Folacin				
Time	0.9772	(2,18)	0.21	0.8122
Group*Time	0.7783	(2,18)	2.56	0.1047
Pantothenic Acid				
Time	0.8194	(2,18)	1.98	0.1666
Group*Time	0.8244	(2,18)	1.92	0.1759
Body Weight				
Time	0.9794	(2,7)	0.07	0.9298
Group*Time	0.9653	(2,7)	0.13	0.8837
Body Fat				
Time	0.6888	(2,7)	1.58	0.2713
Group*Time	0.9903	(2,7)	0.03	0.9663

$*p<0.05$

Repeated Measures Analysis of Variance
Analysis of Variance of Contrast Variables

Sodium

Contrast	F
Baseline vs. Month 3	0.0119*
Baseline vs. Month 6	0.7586
Month 3 vs. Month 6	0.1327

Potassium

Contrast	F
Baseline vs. Month 3	0.0047*
Baseline vs. Month 6	0.9372
Month 3 vs. Month 6	0.0129*

Magnesium

Contrast	F
Baseline vs. Month 3	0.0348*
Baseline vs. Month 6	0.9558
Month 3 vs. Month 6	0.1130

$*p<0.05$

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Kilocalories

Baseline					
Source	SS	df	MS	F	P
Model	1608.00	1	1608.00	0.01	0.9272
Error	3559440.75	19	187338.99		

Month 3					
Source	SS	df	MS	F	P
Model	169753.72	1	169753.72	1.27	0.2742
Error	2544529.83	19	133922.62		

Month 6					
Source	SS	df	MS	F	P
Model	199.94	1	199.94	0.00	0.9718
Error	2970414.82	19	156337.62		

One-Way ANOVA

Analysis of Group Effects

Summary - Per Cent Dietary Fat

Baseline					
Source	SS	df	MS	F	P
Model	30.81	1	30.81	0.63	0.4368
Error	927.77	19	48.83		

Month 3					
Source	SS	df	MS	F	P
Model	81.74	1	81.74	0.92	0.3498
Error	1690.25	19	88.96		

Month 6					
Source	SS	df	MS	F	P
Model	6.98	1	6.98	0.16	0.6897
Error	806.73	19	42.46		

One-Way ANOVA

Analysis of Group Effects

Summary - Per Cent Dietary Carbohydrate

Baseline					
Source	SS	df	MS	F	P
Model	4.47	1	4.47	0.07	0.7915
Error	1183.23	19	62.28		

Month 3					
Source	SS	df	MS	F	P
Model	7.95	1	7.95	0.07	0.7928
Error	2130.47	19	112.13		

Month 6					
Source	SS	df	MS	F	P
Model	14.11	1	14.11	0.17	0.6830
Error	1558.29	19	82.02		

One-Way ANOVA

Analysis of Group Effects

Summary - Per Cent Dietary Protein

Baseline					
Source	SS	df	MS	F	P
Model	8.35	1	8.35	1.42	0.2484
Error	111.94	19	5.89		

Month 3					
Source	SS	df	MS	F	P
Model	3.77	1	3.77	0.53	0.4763
Error	135.65	19	7.14		

Month 6					
Source	SS	df	MS	F	P
Model	0.06	1	0.06	0.01	0.9273
Error	140.47	19	7.39		

One-Way ANOVA

Analysis of Group Effects

Summary - Grams of Dietary Carbohydrate

Baseline

Source	SS	df	MS	F	P
Model	0.24	1	0.24	0.00	0.9940
Error	77131.19	19	4059.54		

Month 3

Source	SS	df	MS	F	P
Model	5537.35	1	5537.35	1.67	0.2122
Error	63132.42	19	3322.76		

Month 6

Source	SS	df	MS	F	P
Model	591.63	1	591.63	0.18	0.6761
Error	62426.12	19	3285.59		

One-Way ANOVA

Analysis of Group Effects

Summary - Grams of Dietary Fat

Baseline					
Source	SS	df	MS	F	P
Model	126.21	1	126.21	0.22	0.6462
Error	11.18.65	19	579.93		
Month 3					
Source	SS	df	MS	F	P
Model	24.00	1	24.00	0.05	0.8312
Error	9766.79	19	514.04		
Month 6					
Source	SS	df	MS	F	P
Model	44.65	1	44.65	0.08	0.7757
Error	10155.22	19	534.49		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Alcohol

Baseline

Source	SS	df	MS	F	P
Model	6.39	1	6.39	0.08	0.7816
Error	1450.42	19	80.58		

Month 3

Source	SS	df	MS	F	P
Model	80.12	1	80.12	0.66	0.4273
Error	2185.99	19	121.44		

Month 6

Source	SS	df	MS	F	P
Model	26.94	1	26.94	0.40	0.5339
Error	1205.43	19	66.97		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Cholesterol

Baseline

Source	SS	df	MS	F	P
Model	64831.63	1	64831.63	3.60	0.0731
Error	342155.49	19	18008.18		

Month 3

Source	SS	df	MS	F	P
Model	340.36	1	340.36	0.02	0.8843
Error	297235.76	19	15643.99		

Month 6

Source	SS	df	MS	F	P
Model	2683.49	1	2683.49	0.57	0.4588
Error	89145.22	19	4691.85		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Niacin

Baseline					
Source	SS	df	MS	F	P
Model	54.99	1	54.99	2.42	0.1362
Error	431.51	19	22.71		
Month 3					
Source	SS	df	MS	F	P
Model	149.63	1	149.63	2.50	0.1307
Error	1139.21	19	59.96		
Month 6					
Source	SS	df	MS	F	P
Model	9.01	1	9.01	0.62	0.4411
Error	276.36	19	14.55		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Thiamin

Baseline

Source	SS	df	MS	F	P
Model	0.06	1	0.06	0.45	0.5084
Error	2.69	19	0.14		

Month 3

Source	SS	df	MS	F	P
Model	0.52	1	0.52	1.25	0.2771
Error	7.93	19	0.42		

Month 6

Source	SS	df	MS	F	P
Model	0.02	1	0.02	0.05	0.8196
Error	5.63	19	0.29		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Calcium

Source	SS	df	MS	F	P
Baseline					
Model	91051.82	1	91051.82	1.09	0.3086
Error	1580394.21	19	83178.64		
Month 3					
Model	383479.22	1	383479.22	4.48	0.0476*
Error	1625182.29	19	85535.91		
Month 6					
Model	101750.23	1	101750.23	1.17	0.2939
Error	1659041.73	19	87317.99		

*p<0.05

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Riboflavin

Baseline					
Source	SS	df	MS	F	P
Model	0.10	1	0.10	0.46	0.5040
Error	4.13	19	0.22		

Month 3					
Source	SS	df	MS	F	P
Model	0.00	1	0.00	0.00	0.9944
Error	31.21	19	1.64		

Month 6					
Source	SS	df	MS	F	P
Model	0.13	1	0.13	0.35	0.5608
Error	7.23	19	0.38		

Jne-Way ANOVA

Analysis of Group Effects

Summary - Dietary Pantothenic Acid

Baseline					
Source	SS	df	MS	F	P
Model	0.03	1	0.03	0.03	0.8564
Error	16.47	19	0.87		

Month 3					
Source	SS	df	MS	F	P
Model	3.53	1	3.53	2.29	0.1467
Error	29.27	19	1.54		

Month 6					
Source	SS	df	MS	F	P
Model	0.01	1	0.01	0.01	0.9242
Error	21.68	19	1.14		

One-WAy ANOVA

Analysis of Group Effects

Summary - Dietary Vitamin E

Baseline					
Source	SS	df	MS	F	P
Model	0.71	1	0.71	0.03	0.8580
Error	363.06	17	21.36		

Month 3					
Source	SS	df	MS	F	P
Model	40.41	1	40.41	1.41	0.2511
Error	486.68	17	28.63		

Month 6					
Source	SS	df	MS	F	P
Model	56.46	1	56.46	1.37	0.2574
Error	698.90	17	41.11		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Vitamin C

Baseline

Source	SS	df	MS	F	P
Model	1225.44	1	1225.44	0.75	0.3984
Error	31196.56	19	1641.92		

Month 3

Source	SS	df	MS	F	P
Model	12255.58	1	12255.58	3.80	0.0662
Error	61313.63	19	3227.03		

Month 6

Source	SS	df	MS	F	P
Model	215.35	1	215.35	0.19	0.6678
Error	21533.11	19	1133.32		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Fiber

Baseline					
Source	SS	df	MS	F	P
Model	1.49	1	1.49	0.18	0.6759
Error	157.53	19	8.29		
Month 3					
Source	SS	df	MS	F	P
Model	8.85	1	8.85	1.08	0.3125
Error	156.20	19	8.22		
Month 6					
Source	SS	df	MS	F	P
Model	0.13	1	0.13	0.02	0.8856
Error	119.61	19	6.29		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Vitamin B6

Baseline					
Source	SS	df	MS	F	P
Model	0.09	1	0.09	0.51	0.4843
Error	3.66	19	0.19		
Month 3					
Source	SS	df	MS	F	P
Model	1.29	1	1.29	2.33	0.1435
Error	10.55	19	0.56		
Month 6					
Source	SS	df	MS	F	P
Model	0.08	1	0.08	0.39	0.5388
Error	3.79	19	0.19		

One-WAy ANOVA

Analysis of Group Effects

Summary - Dietary Vitamin B12

Baseline

Source	SS	df	MS	F	P
Model	96.98	1	96.98	0.58	0.4542
Error	3155.62	19	166.09		

Month 3

Source	SS	df	MS	F	P
Model	229.86	1	229.86	0.85	0.3681
Error	5138.56	19	270.45		

Month 6

Source	SS	df	MS	F	P
Model	50.50	1	50.50	0.49	0.4914
Error	1948.98	19	102.58		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Sodium

Baseline

Source	SS	df	MS	F	P
Model	2423.15	1	2423.15	0.00	0.9578
Error	15986282.35	19	841383.28		

Month 3

Source	SS	df	MS	F	P
Model	1899872.19	1	1899872.19	2.98	0.1003
Error	12097046.74	19	636686.67		

Month 6

Source	SS	df	MS	F	P
Model	61278.31	1	61278.31	0.08	0.7811
Error	14654631.28	19	771296.38		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Vitamin D

Baseline

Source	SS	df	MS	F	P
Model	25689.14	1	25689.14	0.26	0.6168
Error	1885859.71	19	99255.77		

Month 3

Source	SS	df	MS	F	P
Model	6359.53	1	6359.53	0.62	0.4391
Error	193478.18	19	10183.06		

Month 6

Source	SS	df	MS	F	P
Model	40377.97	1	40377.97	2.05	0.1682
Error	373729.22	19	19669.96		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Zinc

Baseline					
Source	SS	df	MS	F	P
Model	0.85	1	0.85	0.26	0.6179
Error	62.87	19	3.31		

Month 3					
Source	SS	df	MS	F	P
Model	25.86	1	25.86	6.25	0.0217*
Error	75.56	19	4.14		

Month 6					
Source	SS	df	MS	F	P
Model	2.77	1	2.77	0.40	0.5361
Error	132.70	19	6.98		

*p<0.05

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Magnesium

Baseline					
Source	SS	df	MS	F	P
Model	10676.68	1	10676.68	2.00	0.1730
Error	101178.26	19	5325.17		

Month 3					
Source	SS	df	MS	F	P
Model	32109.71	1	32109.71	7.03	0.0158*
Error	86778.56	19	4567.29		

Month 6					
Source	SS	df	MS	F	P
Model	6111.35	1	6111.35	0.91	0.3522
Error	127659.25	19	6718.91		

*$p<0.05$

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Potassium

Baseline					
Source	SS	df	MS	F	P
Model	238245.95	1	238245.95	0.44	0.5139
Error	10228884.96	19	538362.36		

Month 3					
Source	SS	df	MS	F	P
Model	5075247.67	1	5075247.67	9.50	0.0061*
Error	10154808.69	19	534463.62		

Month 6					
Source	SS	df	MS	F	P
Model	97921.47	1	97921.47	0.17	0.6842
Error	10903274.11	19	573856.53		

*p<0.05

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Folacin

Baseline					
Source	SS	df	MS	F	P
Model	6589.65	1	6589.65	1.02	0.3254
Error	122845.49	19	6465.55		

Month 3					
Source	SS	df	MS	F	P
Model	106194.59	1	106194.59	6.86	0.0169*
Error	294244.76	19	15486.57		

Month 6					
Source	SS	df	MS	F	P
Model	54.58	1	54.58	0.01	0.9225
Error	106614.37	19	5611.28		

*p<0.05

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Iron

Baseline

Source	SS	df	MS	F	P
Model	50.62	1	50.62	2.63	0.1222
Error	346.44	19	19.25		

Month 3

Source	SS	df	MS	F	P
Model	0.12	1	0.12	0.00	0.9739
Error	1965.84	19	109.21		

Month 6

Source	SS	df	MS	F	P
Model	0.41	1	0.41	0.01	0.9133
Error	606.11	19	33.67		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Vitamin A

Source	SS	df	MS	F	P
Baseline					
Model	193618.64	1	193618.64	0.02	0.8909
Error	190489982.39	19	10025788.55		
Month 3					
Model	5421143.26	1	5421143.26	1.14	0.2997
Error	90614878.69	19	4769204.14		
Month 6					
Model	3642491.08	1	3642491.08	0.75	0.3981
Error	92604526.52	19	4873922.45		

One-Way ANOVA

Analysis of Group Effects

Summary - Dietary Phosphorus

Baseline					
Source	SS	df	MS	F	P
Model	5932.98	1	5932.98	0.08	0.7856
Error	1481301.64	19	77963.24		

Month 3					
Source	SS	df	MS	F	P
Model	170834.36	1	170834.36	2.75	0.1134
Error	1178182.09	19	62009.58		

Month 6					
Source	SS	df	MS	F	P
Model	72.61	1	72.61	0.00	0.9779
Error	1745086.03	19	91846.63		

One-Way ANOVA

Analysis of Group Effects

Summary - Body Weight

Baseline					
Source	SS	df	MS	F	P
Model	6.48	1	6.48	0.06	0.8142
Error	878.31	8	109.79		

Month 3					
Source	SS	df	MS	F	P
Model	11.92	1	11.92	0.11	0.7460
Error	848.48	8	106.06		

Month 6					
Source	SS	df	MS	F	P
Model	8.78	1	8.78	0.10	0.7570
Error	684.72	8	85.59		

One-Way ANOVA

Analysis of Group Effects

Summary - Body Fat

Baseline

Source	SS	df	MS	F	P
Model	0.00	1	0.00	0.08	0.7796
Error	0.04	8	0.01		

Month 3

Source	SS	df	MS	F	P
Model	0.00	1	0.00	0.10	0.7591
Error	0.04	8	0.01		

Month 6

Source	SS	df	MS	F	P
Model	0.00	1	0.00	0.40	0.5444
Error	0.02	8	0.00		

Trend Analysis

Dietary Kilocalories

Linear Trend

Source	SS	df	MS	F	P
Mean	5350.17	1	5350.17	0.11	0.7479
Group	336.96	1	336.96	0.01	0.9356

Quadratic Trend

Source	SS	df	MS	F	P
Mean	201848.24	1	204848.24	2.55	0.1266
Group	128557.77	1	128557.77	1.63	0.2177

Per Cent Dietary Protein

Linear Trend

Source	SS	df	MS	F	P
Mean	16.70	1	16.70	3.12	0.0936
Group	4.93	1	4.93	0.92	0.3494

Quadratic Trend

Source	SS	df	MS	F	P
Mean	4.07	1	4.07	1.59	0.2229
Group	0.26	1	0.26	0.10	0.7543

Trend Analysis

Per Cent Dietary Fat

Linear Trend

Source	SS	df	MS	F	P
Mean	3.22	1	3.22	0.18	0.6775
Group	33.56	1	33.56	1.86	0.1886

Quadratic Trend

Source	SS	df	MS	F	P
Mean	61.16	1	61.16	1.80	0.1960
Group	38.38	1	38.38	1.13	0.3018

Per Cent Dietary Carbohydrate

Linear Trend

Source	SS	df	MS	F	P
Mean	38.33	1	38.33	1.19	0.2891
Group	17.24	1	17.24	0.53	0.4735

Quadratic Trend

Source	SS	df	MS	F	P
Mean	10.52	1	10.51	0.29	0.5953
Group	8.84	1	8.84	0.25	0.6261

Trend Analysis

Grams of Dietary Fat

Linear Trend

Source	SS	df	MS	F	P
Mean	36.90	1	36.90	0.29	0.5943
Group	160.50	1	160.50	1.28	0.2727

Quadratic Trend

Source	SS	df	MS	F	P
Mean	1046.21	1	1046.21	4.65	0.0441*
Group	4.59	1	4.59	0.02	0.8880

Grams of Dietary Carbohydrate

Linear Trend

Source	SS	df	MS	F	P
Mean	794.68	1	794.68	0.47	0.5028
Group	307.81	1	307.81	0.18	0.6755

Quadratic Trend

Source	SS	df	MS	F	P
Mean	1851.43	1	1851.43	1.10	0.3079
Group	4968.68	1	4968.68	2.95	0.1024

*$p < 0.05$

Trend Analysis

Grams of Dietary Protein

Linear Trend

Source	SS	df	MS	F	P
Mean	130.13	1	130.13	0.90	0.3547
Group	66.09	1	66.09	0.46	0.5072

Quadratic Trend

Source	SS	df	MS	F	P
Mean	59.81	1	59.81	0.38	0.5452
Group	296.12	1	296.12	1.88	0.1864

Dietary Cholesterol

Linear Trend

Source	SS	df	MS	F	P
Mean	45061.95	1	45061.95	5.71	0.0274*
Group	20567.60	1	20567.60	2.60	0.1230

Quadratic Trend

Source	SS	df	MS	F	P
Mean	107.64	1	107.64	0.01	0.9086
Group	12107.30	1	12107.30	1.52	0.2323

*$p < 0.05$

Trend Analysis

Dietary Alcohol

Linear Trend

Source	SS	df	MS	F	P
Mean	23.89	1	23.89	0.68	0.4194
Group	3.55	1	3.55	0.10	0.7538

Quadratic Trend

Source	SS	df	MS	F	P
Mean	13.53	1	13.53	0.52	0.4787
Group	17.29	1	17.29	0.67	0.4241

Dietary Fiber

Linear Trend

Source	SS	df	MS	F	P
Mean	2.09	1	2.09	0.62	0.4413
Group	1.26	1	1.26	0.37	0.5488

Quadratic Trend

Source	SS	df	MS	F	P
Mean	2.21	1	2.21	1.65	0.2145
Group	4.32	1	4.32	3.23	0.0880

Trend Analysis

Dietary Sodium

Linear Trend

Source	SS	df	MS	F	P
Mean	143300.51	1	143300.51	0.21	0.6505
Group	19665.22	1	19665.22	0.03	0.8664

Quadratic Trend

Source	SS	df	MS	F	P
Mean	6452312.29	1	6452312.29	11.60	0.0030*
Group	1008556.49	1	1008556.49	1.81	0.1940

Dietary Potassium

Linear Trend

Source	SS	df	MS	F	P
Mean	204129.77	1	204129.77	1.97	0.1768
Group	15344.08	1	15344.08	0.15	0.7048

Quadratic Trend

Source	SS	df	MS	F	P
Mean	136150.86	1	136150.86	0.54	0.4700
Group	2287384.97	1	2287384.97	9.13	0.0070

$*p<0.05$

Trend Analysis

Dietary Phosphorus

Linear Trend

Source	SS	df	MS	F	P
Mean	63467.70	1	63467.70	2.38	0.1396
Group	2346.46	1	2346.46	0.09	0.7701

Quadratic Trend

Source	SS	df	MS	F	P
Mean	78742.33	1	78742.33	1.45	0.2439
Group	91537.08	1	91537.08	1.68	0.2103

Dietary Zinc

Linear Trend

Source	SS	df	MS	F	P
Mean	1.15	1	1.15	0.43	0.5192
Group	0.28	1	0.28	0.10	0.7511

Quadratic Trend

Source	SS	df	MS	F	P
Mean	3.31	1	3.31	1.11	0.3056
Group	9.58	1	9.58	3.21	0.0891

Trend Analysis

Dietary Iron

Linear Trend

Source	SS	df	MS	F	P
Mean	11.13	1	11.13	1.35	0.2598
Group	20.96	1	20.96	2.55	0.1278

Quadratic Trend

Source	SS	df	MS	F	P
Mean	5.99	1	5.99	0.08	0.7758
Group	8.31	1	8.31	0.12	0.7376

Dietary Calcium

Linear Trend

Source	SS	df	MS	F	P
Mean	27741.30	1	27741.30	0.91	0.3521
Group	148.52	1	148.52	0.00	0.9451

Quadratic Trend

Source	SS	df	MS	F	P
Mean	28647.37	1	28647.37	0.43	0.5176
Group	63609.29	1	63609.29	0.97	0.3382

Trend Analysis

Dietary Magnesium

Linear Trend

Source	SS	df	MS	F	P
Mean	3720.83	1	3720.83	1.96	0.1781
Group	316.33	1	316.33	0.17	0.6880

Quadratic Trend

Source	SS	df	MS	F	P
Mean	9596.17	1	9596.17	4.42	0.0492*
Group	5214.45	1	5214.45	2.40	0.1379

Dietary Vitamin A

Linear Trend

Source	SS	df	MS	F	P
Mean	6257265.94	1	6257265.94	2.76	0.1129
Group	2757848.98	1	2757848.98	1.22	0.2836

Quadratic Trend

Source	SS	df	MS	F	P
Mean	7450024.46	1	7450024.46	1.48	0.2387
Group	6252971.04	1	6252971.04	1.24	0.2790

*$p < 0.05$

Trend Analysis

Dietary Vitamin C

Linear Trend					
Source	SS	df	MS	F	P
Mean	158.75	1	158.75	0.25	0.6254
Group	206.69	1	206.69	0.32	0.5779

Quadratic Trend					
Source	SS	df	MS	F	P
Mean	2181.66	1	2181.66	1.05	0.3180
Group	12248.37	1	12248.37	5.90	0.0252

Dietary Vitamin D

Linear Trend					
Source	SS	df	MS	F	P
Mean	39854.86	1	39854.86	1.03	0.3228
Group	826.80	1	826.80	0.02	0.8853

Quadratic Trend					
Source	SS	df	MS	F	P
Mean	90694.66	1	90694.66	6.13	0.0029*
Group	45190.56	1	45190.56	3.05	0.0966

*p<0.05

Trend Analysis

Dietary Vitamin E

Linear Trend

Source	SS	df	MS	F	P
Mean	0.10	1	0.10	0.01	0.9343
Group	34.89	1	34.89	2.38	0.1416

Quadratic Trend

Source	SS	df	MS	F	P
Mean	22.02	1	22.02	2.72	0.1175
Group	6.08	1	6.08	0.75	0.3983

Dietary Thiamin

Linear Trend

Source	SS	df	MS	F	P
Mean	0.00	1	0.00	0.02	0.8944
Group	0.01	1	0.01	0.08	0.7748

Quadratic Trend

Source	SS	df	MS	F	P
Mean	0.02	1	0.02	0.09	0.7637
Group	0.19	1	0.19	0.97	0.3364

Trend Analysis

Dietary Riboflavin

Linear Trend

Source	SS	df	MS	F	P
Mean	0.07	1	0.07	0.59	0.4514
Group	0.00	1	0.00	0.01	0.9227

Quadratic Trend

Source	SS	df	MS	F	P
Mean	1.10	1	1.10	1.15	0.2961
Group	0.08	1	0.08	0.09	0.7728

Dietary Niacin

Linear Trend

Source	SS	df	MS	F	P
Mean	34.20	1	34.20	3.36	0.0824
Group	54.25	1	54.25	5.34	0.0323

Quadratic Trend

Source	SS	df	MS	F	P
Mean	45.19	1	45.19	1.94	0.1803
Group	66.99	1	66.99	2.87	0.1066

Trend Analysis

Dietary Vitamin B6

Linear Trend

Source	SS	df	MS	F	P
Mean	0.33	1	0.33	3.42	0.0801
Group	0.18	1	0.18	1.80	0.1958

Quadratic Trend

Source	SS	df	MS	F	P
Mean	0.17	1	0.17	0.58	0.4573
Group	0.84	1	0.84	2.89	0.1056

Dietary Vitamin B12

Linear Trend

Source	SS	df	MS	F	P
Mean	16.56	1	16.56	2.36	0.1407
Group	3.76	1	3.76	0.54	0.4728

Quadratic Trend

Source	SS	df	MS	F	P
Mean	10.65	1	10.65	0.04	0.8399
Group	372.51	1	372.51	1.47	0.2407

Trend Analysis

Dietary Folacin

Linear Trend

Source	SS	df	MS	F	P
Mean	658.07	1	658.07	0.35	0.5603
Group	3921.86	1	3921.86	2.09	0.1642

Quadratic Trend

Source	SS	df	MS	F	P
Mean	2666.13	1	2666.13	0.23	0.6371
Group	55673.28	1	55673.28	4.80	0.0411

Dietary Pantothenic Acid

Linear Trend

Source	SS	df	MS	F	P
Mean	2.02	1	2.02	4.18	0.0551
Group	0.00	1	0.00	0.00	0.9457

Quadratic Trend

Source	SS	df	MS	F	P
Mean	0.23	1	0.23	0.32	0.5768
Group	2.71	1	2.71	3.77	0.0673

Trend Analysis

Body Weight

Linear Trend

Source	SS	df	MS	F	P
Mean	0.99	1	0.99	0.13	0.7258
Group	0.09	1	0.09	0.01	0.9166

Quadratic Trend

Source	SS	df	MS	F	P
Mean	0.00	1	0.00	0.00	1.0000
Group	0.33	1	0.33	0.14	0.7163

Body Fat

Linear Trend

Source	SS	df	MS	F	P
Mean	0.00	1	0.00	3.02	0.1203
Group	0.00	1	0.00	0.08	0.7862

Quadratic Trend

Source	SS	df	MS	F	P
Mean	0.00	1	0.00	3.52	0.0973
Group	0.00	1	0.00	0.06	0.8179

Appendix C

ADDITIONAL ANALYSES

This study was part of a larger study conducted at the University of Virginia. Dietary data was obtained throughout the actual one-year study period for those women completing the entire study. Fifty-five women were originally recruited for participation in the study, but only ten women remained after one year who had complete dietary records. A repeated measures procedure was not appropriate across all time periods because of the high attrition rate. For this reason, the smaller amounts of data from the women completing nine and twelve months of training was analyzed separately and not included in the major portion of the document. It was decided that this data was still unique, in that very few studies have dietary data for a full year. For this reason, this data will be presented here.

The data was analyzed statistically in SAS using a separate repeated measures analysis of variance for the groups completing nine months, and again for the groups completing twelve months. A Tukey's HSD test was used to locate group significances, when seen. Vitamin C intake was significantly different between groups at baseline and at twelve months, with the @LT group having the higher intakes. Vitamin E intake was significantly lower across time in the group completing nine months. These were the only significant differences seen. Exercise intensity did not appear to have an affect on energy intake or the macronutrient composition of the subjects diets.

Summary ANOVA - Dietary Kilocalories

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	1534.40	1	1534.40	0.01	0.9332
Error (Group)	2079221.27	10	207922.13		
Time	236473.05	1	236473.05	2.71	0.1309
Time* Group	1057.35	1	1057.35	0.01	0.9146
Error (Time)	873274.06	10	87327.41		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	89107.21	1	89107.21	0.43	0.5282
Error (Group)	1639904.04	8	204988.01		
Time	7928.32	1	7928.32	0.04	0.8412
Time* Group	204355.02	1	204355.02	1.10	0.3239
Error (Time)	1479916.36	8	184989.55		

Summary ANOVA - Grams of Dietary Carbohydrate

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	967.87	1	967.87	0.17	0.6906
Error (Group)	57640.86	10	5764.09		
Time	585.39	1	585.39	0.34	0.5702
Time* Group	838.39	1	838.39	0.49	0.4984
Error (Time)	16989.74	10	1698.97		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	6813.12	1	6813.12	2.83	0.1309
Error (Group)	19250.67	8	2406.33		
Time	396.46	1	396.46	0.11	0.7465
Time* Group	2039.14	1	2039.14	0.58	0.4696
Error (Time)	28320.56	8	3540.07		

Summary ANOVA - Grams of Dietary Protein

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	104.79	1	104.79	0.49	0.5006
Error (Group)	2145.41	10	214.54		
Time	36.88	1	36.88	0.14	0.7130
Time* Group	65.04	1	65.04	0.25	0.6261
Error (Time)	2574.89	10	257.49		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	13.60	1	13.60	0.04	0.8373
Error (Group)	2419.49	8	302.44		
Time	61.60	1	61.60	0.43	0.5303
Time* Group	141.44	1	141.44	0.99	0.3494
Error (Time)	1145.51	8	143.19		

Summary ANOVA - Grams of Dietary Fat

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	260.24	1	260.24	0.27	0.6150
Error (Group)	9660.03	10	966.00		
Time	998.33	1	998.33	3.77	0.0809
Time* Group	18.64	1	18.64	0.07	0.7962
Error (Time)	2649.68	10	264.97		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	31.33	1	31.33	0.03	0.8636
Error (Group)	7957.93	8	994.74		
Time	315.76	1	315.76	0.42	0.5329
Time* Group	537.32	1	537.32	0.72	0.4201
Error (Time)	5950.26	8	743.78		

Summary ANOVA - Per Cent Dietary Carbohydrate

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	18.06	1	18.06	0.16	0.6959
Error (Group)	1115.59	10	111.56		
Time	8.86	1	8.86	0.67	0.4313
Time* Group	0.08	1	0.08	0.01	0.9379
Error (Time)	131.73	10	13.17		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	64.32	1	64.32	0.72	0.4208
Error (Group)	714.54	8	89.32		
Time	47.26	1	47.26	1.39	0.2719
Time* Group	0.29	1	0.29	0.01	0.9282
Error (Time)	271.49	8	33.94		

Summary ANOVA - Per Cent Dietary Protein

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	3.86	1	3.86	0.23	0.6441
Error (Group)	170.35	10	17.04		
Time	17.98	1	17.98	1.02	0.3359
Time* Group	0.02	1	0.02	0.00	0.9761
Error (Time)	175.91	10	17.59		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	4.61	1	4.61	0.43	0.5299
Error (Group)	85.49	8	10.69		
Time	1.40	1	1.40	0.20	0.6697
Time* Group	1.26	1	1.26	0.18	0.6858
Error (Time)	57.02	8	7.13		

Summary ANOVA - Per Cent Dietary Fat

Baseline versus Nine Months					
Source	SS	df	MS	F	P
Group	29.75	1	29.75	0.25	0.6279
Error (Group)	1189.84	10	118.98		
Time	46.26	1	46.26	3.81	0.0794
Time* Group	0.99	1	0.99	0.08	0.7807
Error (Time)	121.33	10	12.13		

Baseline versus Twelve Months					
Source	SS	df	MS	F	P
Group	0.28	1	0.28	0.00	0.9539
Error (Group)	618.36	8	77.30		
Time	54.22	1	54.22	1.40	0.2701
Time* Group	1.79	1	1.79	0.05	0.8349
Error (Group)	309.01	8	38.63		

Summary ANOVA - Dietary Cholesterol

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	56810.55	1	56810.55	2.41	0.1519
Error (Group)	236150.67	10	23615.07		
Time	7495.26	1	7495.26	0.69	0.4264
Time* Group	7481.84	1	7481.84	0.69	0.4268
Error (Time)	109061.28	10	10906.13		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	16827.42	1	16827.42	0.50	0.4999
Error (Group)	269720.09	8	33715.01		
Time	16184.50	1	16184.50	1.96	0.1988
Time* Group	874.49	1	874.49	0.11	0.7530
Error (Time)	65968.44	8	8246.06		

Summary ANOVA - Dietary Fiber

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	1.60	1	1.60	0.10	0.7641
Error (Group)	168.46	10	16.85		
Time	1.59	1	1.59	0.53	0.4836
Time* Group	8.64	1	8.64	2.87	0.1209
Error (Time)	30.06	10	3.01		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	2.36	1	2.36	0.22	0.6505
Error (Group)	85.20	8	10.65		
Time	19.45	1	19.45	2.33	0.1652
Time* Group	9.80	1	9.80	1.18	0.3098
Error (Time)	66.72	8	8.34		

Summary ANOVA - Dietary Alcohol

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	0.12	1	0.12	0.00	0.9635
Error (Group)	485.81	9	53.98		
Time	9.18	1	9.18	0.43	0.5279
Time* Group	6.16	1	6.16	0.29	0.6039
Error (Time)	191.73	9	21.30		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	136.82	1	136.82	2.13	0.1822
Error (Group)	512.88	8	64.11		
Time	23.39	1	23.39	0.37	0.5573
Time* Group	31.07	1	31.07	0.50	0.5004
Error (Time)	499.14	8	62.39		

Summary ANOVA - Dietary Magnesium

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	10032.77	1	10032.77	1.31	0.2785
Error (Group)	76397.88	10	76397.88		
Time	2901.36	1	2901.36	1.46	0.2553
Time* Group	3351.68	1	3351.68	1.68	0.2237
Error (Time)	19919.96	10	1991.99		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	4252.04	1	4252.04	0.62	0.4521
Error (Group)	54459.42	8	6807.43		
Time	5085.53	1	5085.53	1.08	0.3290
Time* Group	5163.50	1	5163.50	1.10	0.3255
Error (Time)	37649.85	8	4706.23		

Summary ANOVA - Dietary Zinc

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	5.29	1	5.29	1.00	0.3413
Error (Group)	53.01	10	5.30		
Time	0.57	1	0.57	0.20	0.6655
Time* Group	3.88	1	3.88	1.36	0.2711
Error (Time)	28.60	10	2.86		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	0.29	1	0.29	0.05	0.8338
Error (Group)	48.84	8	6.11		
Time	0.00	1	0.00	0.00	0.9923
Time* Group	1.29	1	1.29	0.47	0.5141
Error (Time)	22.19	8	2.77		

Summary ANOVA - Dietary Phosphorus

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	1601.32	1	1601.32	0.01	0.9274
Error (Group)	1833433.80	10	183343.38		
Time	791.43	1	791.43	0.01	0.9383
Time* Group	2824.91	1	2824.91	0.02	0.8839
Error (Time)	1258138.16	10	125813.82		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	15191.80	1	15191.80	0.13	0.7243
Error (Group)	788789.02	7	112684.15		
Time	21808.89	1	21808.89	0.58	0.4695
Time* Group	194071.09	1	194071.09	5.20	0.0566
Error (Time)	261148.43	7	37306.92		

Summary ANOVA - Dietary Iron

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	74.91	1	74.91	2.73	0.1294
Error (Group)	274.27	10	27.43		
Time	11.96	1	11.96	0.79	0.3960
Time* Group	5.96	1	5.96	0.39	0.5453
Error (Time)	152.05	10	15.21		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	30.14	1	30.14	0.53	0.4857
Error (Group)	451.32	8	56.41		
Time	11.25	1	11.25	0.26	0.6255
Time* Group	65.98	1	65.98	1.51	0.2539
Error (Time)	349.33	8	349.33		

Summary ANOVA - Dietary Calcium

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	109944.81	1	109944.81	1.02	0.3371
Error (Group)	1081627.76	10	108162.78		
Time	29638.48	1	29638.48	0.54	0.4803
Time* Group	1258.60	1	1258.60	0.02	0.8829
Error (Time)	551370.93	10	55137.09		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	816.96	1	816.96	0.01	0.9338
Error (Group)	1008763.96	9	112084.88		
Time	37309.15	1	37309.15	1.21	0.3004
Time* Group	27124.15	1	27124.15	0.88	0.3733
Error (Time)	278160.04	9	30906.67		

Summary ANOVA - Dietary Sodium

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	858218.07	1	858218.07	0.80	0.3889
Error (Group)	11732881.45	11	1066625.59		
Time	295481.48	1	295481.48	0.99	0.3414
Time* Group	153784.88	1	153784.88	0.51	0.4881
Error (Time)	3287244.99	11	298840.45		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	16946.88	1	16946.88	0.01	0.9098
Error (Group)	9926332.82	8	1240791.60		
Time	555137.22	1	555137.21	1.92	0.2029
Time* Group	148087.82	1	148087.82	0.51	0.4942
Error (Time)	2309160.78	8	288645.10		

Summary ANOVA - Dietary Potassium

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	1082263.01	1	1082263.01	1.76	0.2138
Error (Group)	6138688.87	10	613868.89		
Time	359537.76	1	359537.76	1.60	0.2346
Time* Group	874665.62	1	874665.62	3.89	0.0768
Error (Time)	2246788.91	10	224678.89		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	85477.31	1	85477.31	0.11	0.7471
Error (Group)	6138041.01	8	767255.13		
Time	548467.87	1	548467.87	0.76	0.4090
Time* Group	783812.16	1	783812.16	1.08	0.3280
Error (Time)	5779467.21	8	722433.40		

Summary ANOVA - Dietary Thiamin

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	0.03	1	0.03	0.19	0.6687
Error (Group)	1.74	10	0.17		
Time	0.13	1	0.13	1.56	0.2401
Time* Group	0.04	1	0.04	0.43	0.5244
Error (Time)	0.85	10	0.09		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	0.01	1	0.01	0.05	0.8251
Error (Group)	1.25	8	0.16		
Time	0.13	1	0.13	1.02	0.3410
Time* Group	0.01	1	0.01	0.10	0.7594
Error (Time)	0.98	8	0.12		

Summary ANOVA - Dietary Niacin

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	85.57	1	85.57	3.58	0.0879
Error (Group)	239.31	10	23.93		
Time	0.04	1	0.04	0.00	0.9744
Time* Group	5.37	1	5.37	0.13	0.7230
Error (Time)	404.06	10	40.41		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	15.04	1	15.04	0.55	0.4794
Error (Group)	218.59	8	27.32		
Time	0.04	1	0.04	0.00	0.9704
Time* Group	0.02	1	0.02	0.00	0.9782
Error (Time)	237.25	8	29.66		

Summary ANOVA - Dietary Riboflavin

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	0.21	1	0.21	0.84	0.3809
Error (Group)	2.49	10	0.25		
Time	0.27	1	0.27	2.76	0.1276
Time* Group	0.00	1	0.00	0.00	0.9590
Error (Time)	0.96	10	0.10		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	0.01	1	0.01	0.02	0.8851
Error (Group)	2.56	8	0.32		
Time	0.05	1	0.05	0.37	0.5621
Time* Group	0.01	1	0.01	0.04	0.8527
Error (Time)	1.06	8	0.13		

Summary ANOVA - Dietary Vitamin B6

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	0.01	1	0.01	0.02	0.9026
Error (Group)	3.06	10	0.31		
Time	0.00	1	0.00	0.01	0.9220
Time* Group	0.01	1	0.01	0.02	0.8858
Error (Time)	3.72	10	0.37		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	0.00	1	0.00	0.02	0.8919
Error (Group)	1.74	8	0.22		
Time	0.11	1	0.11	0.51	0.4957
Time* Group	0.06	1	0.06	0.25	0.6288
Error (Time)	1.78	8	0.22		

Summary ANOVA - Dietary Vitamin B12

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	13.32	1	13.32	0.82	0.3860
Error (Group)	162.11	10	16.21		
Time	15.68	1	15.68	1.31	0.2798
Time* Group	17.99	1	17.99	1.50	0.2490
Error (Time)	120.09	10	12.01		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	0.83	1	0.83	0.32	0.5867
Error (Group)	20.72	8	2.59		
Time	1.76	1	1.76	2.18	0.1777
Time* Group	0.92	1	0.92	1.15	0.3157
Error (Time)	6.45	8	0.81		

Summary ANOVA - Dietary Folacin

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	6237.15	1	6237.15	1.00	0.3399
Error (Group)	62109.94	10	6210.99		
Time	1230.95	1	1230.95	0.26	0.6187
Time* Group	83.48	1	83.48	0.02	0.8963
Error (Time)	46673.81	10	4667.38		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	311.25	1	311.25	0.04	0.8386
Error (Group)	56240.67	8	7030.08		
Time	8421.51	1	8421.51	1.90	0.2052
Time* Group	1532.43	1	1532.43	0.35	0.5726
Error (Time)	35424.13	8	4428.02		

Summary ANOVA - Dietary Pantothenic Acid

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	0.96	1	0.96	0.67	0.4306
Error (Group)	14.29	10	1.43		
Time	0.28	1	0.28	0.33	0.5800
Time* Group	2.53	1	2.53	2.96	0.1161
Error (Time)	8.54	10	0.85		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	0.09	1	0.09	0.11	0.7537
Error (Group)	6.96	8	0.87		
Time	0.07	1	0.07	0.08	0.7823
Time* Group	0.02	1	0.02	0.02	0.8823
Error (Time)	6.53	8	0.82		

Summary ANOVA - Dietary Vitamin A

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	578523.60	1	578523.60	0.04	0.8410
Error (Group)	136380531.99	10	13638053.20		
Time	347618.94	1	347618.94	0.05	0.8340
Time* Group	695164.88	1	695164.88	0.09	0.7672
Error (Time)	75101877.78	10	7510187.78		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	6760318.70	1	6760318.70	0.52	0.4916
Error (Group)	104100107.79	8	13012513.47		
Time	8563259.09	1	8563259.09	1.54	0.2500
Time* Group	59600.02	1	59600.02	0.01	0.9201
Error (Time)	44522798.94	8	5565349.87		

Summary ANOVA - Dietary Vitamin C

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	320.40	1	320.40	0.07	0.7990
Error (Group)	46844.71	10	4684.47		
Time	12773.86	1	12773.86	1.39	0.2657
Time* Group	10194.12	1	10194.12	1.11	0.3170
Error (Time)	91905.78	10	9190.58		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	17231.88	1	17231.88	17.92	0.0029*
Error (Group)	7693.22	8	961.65		
Time	696.34	1	696.34	1.05	0.3363
Time* Group	758.71	1	758.71	1.14	0.3168
Error (Time)	5323.27	8	665.41		

*p<0.05

Summary ANOVA - Dietary Vitamin D

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	20880.69	1	20880.69	0.18	0.6841
Error (Group)	1189594.53	10	118959.45		
Time	68838.53	1	68838.53	0.93	0.3586
Time* Group	15295.95	1	15295.95	0.21	0.6598
Error (Time)	743484.20	10	74348.42		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	34825.17	1	34825.17	1.36	0.2778
Error (Group)	205446.47	8	25680.81		
Time	4597.79	1	4597.79	0.23	0.6435
Time* Group	6749.07	1	6749.07	0.34	0.5763
Error (Time)	159125.02	8	19890.63		

Summary ANOVA - Dietary Vitamin E

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	5.53	1	5.53	0.29	0.6007
Error (Group)	189.33	10	18.93		
Time	49.65	1	49.65	0.0372	0.0372*
Time* Group	42.08	1	42.08	0.0514	0.0514
Error (Time)	86.02	10	8.60		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	22.23	1	22.23	0.43	0.5324
Error (Group)	417.78	8	52.22		
Time	17.11	1	17.11	2.00	0.1954
Time* Group	25.53	1	25.53	2.98	0.1226
Error (Time)	68.55	8	8.57		

*p<0.05

Summary ANOVA - Body Weight

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	255.32	1	255.32	1.31	0.3049
Error (Group)	977.63	5	195.53		
Time	3.65	1	3.65	0.83	0.4036
Time* Group	5.14	1	5.14	1.17	0.3286
Error (Time)	21.96	5	4.39		

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	251.00	1	251.00	1.29	0.3002
Error (Group)	1171.69	6	195.28		
Time	8.48	1	8.48	1.94	0.2127
Time* Group	5.73	1	5.73	1.31	0.2955
Error (Time)	26.19	6	4.36		

Summary ANOVA - Per Cent Body Fat

Baseline versus Nine Months

Source	SS	df	MS	F	P
Group	0.01	1	0.01	1.99	0.2170
Error (Group)	0.02	5	0.00		
Time	0.00	1	0.00	0.50	0.5098
Time* Group	0.00	1	0.00	0.10	0.7602
Error (Time)	0.00	5			

Baseline versus Twelve Months

Source	SS	df	MS	F	P
Group	0.01	1	0.01	2.46	0.1679
Error (Group)	0.03	6	0.00		
Time	0.00	1	0.00	1.74	0.2358
Time* Group	0.00	1	0.00	1.33	0.2934
Error (Time)	0.00	6	0.00		

Tukey's HSD Test
Means with the same letter are not significantly different

Dietary Vitamin C

Baseline

Tukey Grouping	Mean	N	Group
A	158.86	3	<LT
B	81.36	7	>LT

Twelve Months

Tukey Grouping	Mean	N	Group
A	132.54	3	<LT
B	81.93	7	>LT

Average Nutrient Intakes and Characteristics for Subjects Completing Nine and Twelve Months of Training*

Calories	Month 0	Month 9	Month 0	Month 12
@LT	1857.22	1645.42	2133.87	1956.73
	(221.25)	(186.43)	(244.76)	(222.50)
>LT	1827.95	1642.70	1767.63	2031.66
	(169.74)	(74.70)	(155.73)	(224.17)
Per Cent Fat				
@LT	35.55	33.16	33.12	36.06
	(3.30)	(3.73)	(4.55)	(4.37)
>LT	33.73	30.55	32.72	36.97
	(3.92)	(3.51)	(3.45)	(3.07)
Per Cent Protein				
@LT	13.71	15.49	13.63	14.76
	(0.75)	(3.06)	(1.49)	(2.87)
>LT	14.56	16.24	15.54	15.26
	(1.39)	(1.43)	(1.22)	(0.97)
Per Cent Carbohydrate				
@LT	50.43	50.71	53.59	50.50
	(2.66)	(2.81)	(5.34)	(4.06)
>LT	51.23	52.56	49.94	46.33
	(3.60)	(4.49)	(3.30)	(3.39)
Grams of Fat				
@LT	74.57	63.43	79.77	77.13
	(11.99)	(12.12)	(18.31)	(4.10)
>LT	69.75	55.09	65.73	85.71
	(13.04)	(5.63)	(11.69)	(14.50)
Grams of Protein				
@LT	64.58	58.81	73.37	71.40
	(9.92)	(5.10)	(14.76)	(14.02)
>LT	65.47	66.28	65.77	75.40
	(5.64)	(5.12)	(5.16)	(5.13)
Grams of Carbohydrate				
@LT	230.45	208.75	281.80	250.05
	(29.79)	(25.63)	(7.24)	(47.46)
>LT	231.33	233.27	219.49	231.81
	(20.96)	(31.65)	(21.64)	(24.43)
Cholesterol				
@LT	325.68	255.03	265.28	312.92
	(72.70)	(47.98)	(149.18)	(167.05)
>LT	193.06	193.05	187.55	264.06
	(47.76)	(62.77)	(40.24)	(46.17)
Alcohol				
@LT	8.28	5.92	7.06	1.98
	(4.01)	(1.34)	(3.19)	(2.29)
>LT	7.07	6.84	10.04	10.40
	(3.27)	(2.23)	(4.21)	(2.94)

*means (standard error);at 9 mo. @LT(n=6), >LT(n=6);at 12 mo. @LT(n=3), >LT(n=7).

Average Nutrient Intakes for Subjects Completing Nine and Twelve Months of Training*

Fiber	Month 0	Month 9	Month 0	Month 12
@LT	4.33	2.61	5.80	2.12
	(1.87)	(0.70)	(4.19)	(0.96)
>LT	3.64	4.33	3.52	2.90
	(1.40)	(1.42)	(1.17)	(0.90)
Sodium				
@LT	2741.6	2386.1	3183.7	2632.3
	(369.6)	(215.3)	(494.0)	(269.3)
>LT	2602.9	2234.8	2932.3	2756.6
	(362.9)	(225.5)	(467.0)	(294.3)
Potassium				
@LT	2552.9	1926.3	2818.1	2024.7
	(287.9)	(106.4)	(519.1)	(194.6)
>LT	2596.8	2732.8	2528.7	2599.4
	(409.0)	(271.8)	(519.1)	(194.6)
Magnesium				
@LT	239.62	193.99	249.54	179.68
	(22.54)	(10.21)	(34.79)	(28.68)
>LT	256.88	258.52	246.29	246.56
	(41.13)	(39.36)	(36.13)	(32.06)
Zinc				
@LT	7.29	6.18	7.59	7.05
	(0.93)	(1.09)	(1.50)	(1.94)
>LT	7.43	7.91	7.30	7.86
	(0.81)	(0.77)	(0.69)	(0.91)
Calcium				
@LT	818.02	733.25	1009.97	901.27
	(134.73)	(75.13)	(156.24)	(18.81)
>LT	938.90	883.10	872.81	860.20
	(159.32)	(127.05)	(150.74)	(77.23)
Phosphorus				
@LT	1135.45	1168.63	1318.45	1024.34
	(168.04)	(245.44)	(203.90)	(149.14)
>LT	1140.81	1130.60	1036.55	1182.98
	(153.21)	(108.21)	(138.78)	(111.93)
Iron				
@LT	11.55	11.97	12.06	17.66
	(1.16)	(1.51)	(1.92)	(10.67)
>LT	14.09	16.50	13.34	11.01
	(2.61)	(2.57)	(2.32)	(1.95)

*means (standard error)

Average Nutrient Intakes for Subjects Completing Nine and Twelve Months of Training*

Vitamin A	Month 0	Month 9	Month 0	Month 12
@LT	5796.6	5896.3	7258.0	5949.3
	(1095.9)	(1545.5)	(1844.1)	(705.0)
>LT	6447.5	5866.4	6108.5	4561.4
	(2079.6)	(738.2)	(1771.3)	(746.9)
Vitamin C				
@LT	117.43	122.35	158.86	132.54
	(23.64)	(23.07)	(28.95)	(1.33)
>LT	83.52	170.88	81.36	81.93
	(13.87)	(65.32)	(11.79)	(11.36)
Vitamin D				
@LT	314.70	157.08	46.01	53.01
	(235.39)	(90.37)	(15.06)	(54.14)
>LT	205.20	148.58	177.16	103.99
	(106.27)	(49.52)	(93.59)	(31.88)
Vitamin E				
@LT	11.17	5.65	8.45	3.97
	(2.23)	(1.38)	(2.49)	(0.79)
>LT	7.56	7.34	8.29	8.74
	(1.92)	(0.69)	(1.78)	(3.10)
Thiamin				
@LT	1.13	1.06	1.29	1.06
	(0.15)	(0.13)	(0.18)	(0.34)
>LT	1.28	1.06	1.19	1.07
	(0.21)	(0.14)	(0.20)	(0.06)
Niacin				
@LT	15.87	13.87	17.16	16.51
	(2.35)	(1.27)	(3.81)	(4.31)
>LT	17.48	19.34	17.18	17.61
	(3.04)	(3.01)	(2.55)	(1.67)
Riboflavin				
@LT	1.58	1.36	1.66	1.59
	(0.12)	(0.13)	(0.25)	(0.40)
>LT	1.76	1.55	1.65	1.51
	(0.28)	(0.17)	(0.26)	(0.10)
Vitamin B6				
@LT	1.41	1.40	1.42	1.14
	(0.18)	(0.38)	(0.29)	(0.37)
>LT	1.36	1.40	1.33	1.28
	(0.26)	(0.17)	(0.22)	(0.16)
Vitamin B12				
@LT	6.30	2.95	3.00	4.12
	(3.14)	(0.96)	(0.82)	(1.65)
>LT	3.08	3.19	3.02	3.20
	(0.67)	(0.24)	(0.56)	(0.24)

*means (standard error)

Average Nutrient Intakes for Subjects Completing Nine and Twelve Months of Training*

Pantothenic Acid	Month 0	Month 9	Month 0	Month 12
@LT	3.58	2.71	3.45	3.25
	(0.40)	(0.56)	(0.90)	(0.38)
>LT	3.33	3.76	3.23	3.17
	(0.56)	(0.37)	(0.47)	(0.21)
Folacin				
@LT	202.40	220.46	248.70	184.82
	(31.85)	(35.53)	(55.52)	(23.62)
>LT	238.38	248.97	220.99	195.31
	(39.14)	(23.31)	(37.64)	(26.93)
Body Weight				
@LT	67.63	69.89	71.06	68.32
	(9.51)	(11.17)	(13.18)	(9.78)
>LT	61.66	60.03	61.65	61.38
	(3.77)	(2.53)	(2.14)	(1.71)
Per Cent Body Fat				
@LT	27.80	28.50	30.80	27.60
	(0.02)	(0.03)	(0.05)	(0.02)
>LT	23.40	23.40	24.10	23.90
	(0.03)	(0.04)	(0.02)	(0.02)

*means (standard error)

VITA

Brenda Marie Mueller was born in Austin, Texas on July 27, 1967. She grew up in many different places, including Texas, Kansas, Virginia, and Germany, as her father was in the military. She graduated from Lake Braddock Secondary School in Burke, Virginia in 1985 after competing for several years in track, cross country, gymnastics, and soccer. She spent one unhappy year at the University of Texas at Austin, where both of her parents had attended college. She decided to return to Virginia and attend Virginia Tech, where she majored in Human Nutrition and Foods. She completed a Bachelors degree in Dietetics in 1989. While working as a clinical dietitian in Roanoke, she started the Masters Program in Exercise Physiology. Upon finishing the program she plans to move to Boulder, Colorado. She will marry Kevin P. Davy in November of 1992, to whom she owes much gratitude for his continued support throughout the completion of this thesis.