ABSTRACT

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The resting metabolic response to a liquid test meal (Pillsbury Instant Breakfast, Pillsbury Co., MN) was determined in adult male and female Ss (24-59 yrs.). The trained Ss (N = 19) consisted of 15 men and 4 women who regularly ran an average of 35-40 mi/wk. The untrained Ss (N = 23) consisted of 13 men and 10 women who were members of the faculty and classified staff at UW-LaCrosse. The experimental procedure consisted of hydrostatic weighing, ingestion of the test meal and preprandial and postprandial expired air collection. Resting metabolic rate (RMR) was determined from the latter two measurements, and the metabolic response to the meal (i.e., dietary-induced thermogenesis, or DIT) was the difference between pre- and postprandial RMR values. A t-test for independent groups was utilized for statistical analysis of the results. It was determined that DIT, when expressed in ml/kg/min., was significantly greater in the trained Ss than in the untrained Ss ($p < .05$). As hypothesized, there was no significant difference between the 2 groups when DIT was expressed per unit of lean body mass (i.e., in ml/kg LBM/min). It was concluded that the quantity of LBM could play a significant role in determining the metabolic response to food in adults. Further investigation of the capacity of skeletal muscle for thermogenesis is required to clarify the relationship between RMR and DIT.

A COMPARISON OF THE METABOLIC RESPONSE TO FOOD IN TRAINED AND UNTRAINED ADULTS

A Thesis Presented

to

The Graduate Faculty

University of Wisconsin-LaCrosse

In Partial Fulfillment

of the Requirements for the

Master of Science Degree

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by

Brian J. Dixon

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UNIVERSITY OF WISCONSIN - LA CROSSE
College of Health, Physical Education and Recreation
La Crosse, Wisconsin 54601

Candidate: Brian J. Dixon

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science, Adult Fitness/Cardiac Rehabilitation

The candidate has completed his/her oral report.

Thesis Committee Chairperson	June 1, 1987 Date
Thesis Committee Member	May 22, 1987 Date
Thesis Committee Member	May 20, 1987 Date

This thesis is approved for the College of Health, Physical Education and Recreation.

Dean, College of Health, Physical Education and Recreation	June 1, 1987 Date
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TABLE OF CONTENTS

APPENDICES

CHAPTER I

INTRODUCTION

The concept of energy balance is a basic one that is important to the regulation of body weight. This balance occurs when the food energy consumed is equal to the energy expended in doing work plus that which is lost as solid waste and as heat (Rothwell & Stock, 1981).

The regulation of energy balance is achieved through the control of food intake and energy output. For some time, it was assumed that the former plays the biggest role in maintaining energy balance. However, recent evidence has shown that output is also a major factor which, in some cases, may be more important to the regulation of energy balance than food intake (Rothwell & Stock, 1981).

The mechanisms that make up energy expenditure are resting metabolic rate, physical activity, and thermogenesis induced by cold or diet (Rothwell & Stock, 1981). Dietary induced thermogenesis (DIT) is described as the additional energy expenditure due to digestion, absorption, and storage of nutrients in the body (Maddaiah, 1984). Its importance in weight control has been increasingly investigated using a wide range of subjects (i.e., human and nonhuman) and a variety of conditions.

Numerous studies have examined the effect of exercise on DIT. The exercise performed by subjects has typically been short term (i.e., 40 min. or less), submaximal and aerobic in nature. Examples are cycling, treadmill walking and jogging. In these experiments, researchers

compared measurements of DIT at rest with those taken during exercise, to determine if the thermic effect was potentiated or diminished by the activity. DIT was generally determined by measurement of oxygen consumption (VO_2). Though their general protocols vary, the overall procedures are similar enough to allow for comparison of results.

Other studies have examined the effect of overfeeding (and in some cases, underfeeding) on DIT. The time periods during which a subject's diet was manipulated in these studies vary widely, ranging from one day to several weeks. Typically, resting metabolic rate (RMR) was measured before and after the overfeeding period to determine if a thermic effect in response to the increased caloric intake was present. Research on long-term overfeeding was most prevalent from the late 1960s to the mid-1970s, and was conducted on both human and animal subjects (i.e., rats in particular).

Another area of investigation into the thermic effect of food concerns the difference in thermic responses between two different categories of subjects, most often the obese and nonobese. Various researchers have compared DIT values from each group both at rest and during exercise (e.g., Segal & Gutin, 1983b), and in some cases following a period of dietary restriction (Bradfield & Jourdan, 1972). Such research has attempted to pinpoint the possible role of DIT in the onset and management of obesity.

Comparatively little research has been conducted regarding the possible effect of exercise training on DIT in humans. Only Davis et al. (1983) have measured the thermic effect of food in subjects before and after completion of an aerobic exercise program. Kertzer, Davis and

Tagliaferro (1981), Tremblay, Cote and LeBlanc (1983) and LeBlanc, Diamond, Cote and Labrie (1984) compared the metabolic response to food in trained and untrained adults. Results of these studies have been conflicting. Thus, the relationship between DIT and aerobic training appears yet unclear. The present study sought to clarify this relationship by comparing the thermic effect of a meal in non-exercising adults with that in adults who are regular runners.

Statement of the Problem

Basal metabolic rate (BMR), a term which is sometimes used interchangeably with resting metabolic rate (Katch & McArdle, 1981), is a function of lean body mass (LBM). Decreases in BMR have been observed with advancing age (Keys, Taylor & Grande, 1973). These declines have been associated with, and likely caused by, the gradual loss of lean body tissue (Forbes & Reina, 1970; Thompson, Jarvie, Lahey & Cureton, 1982). The difference in BMR and LBM between men at age 25 who are similar in weight to men at age 60 can be compared to the difference in these two parameters between men and women of similar age and weight. When BMR is calculated per unit of LBM, the observed difference between males and females is no longer evident (Katch & McArdle, 1977). Since DIT is determined by measurements of RMR, there would seem to be a relationship between DIT and LBM. Segal, Gutin, Nyman and Pi-Sunyer (1985) found this to be true.

Leon, Conrad, Hunninghake and Serfass (1979) observed that regular exercise alone resulted in a significant loss of body fat and a slight increase in LBM. In this study, six obese young men who underwent a 16-

week program of vigorous treadmill walking lost an average of 5.9 kg of body fat and gained an average of 0.2 kg of lean tissue. This finding supports earlier research by Wilmore, Royce, Girandola, Katch, and Katch (1970) and Pollock, Cureton, and Greninger (1969) which showed that regular aerobic exercise produced significant reduction in body fat in healthy, previously sedentary adults. A position statement by the American College of Sports Medicine (1978) suggests that endurance training can significantly decrease body fat, and can stabilize or slightly increase one's LBM. To produce these changes, the exercise must be rhythmic and aerobic in nature, and must be performed frequently enough (i.e., 3-5 times per week) over a sufficient length of time (i.e., at least 2-4 months). Based on this information, if regular aerobic exercise (i.e., endurance running) can produce these changes in body composition, then regular runners should have higher percentages of LBM (and thus, lower body fat percentages) than their non-exercising counterparts. Since RMR appears to be a function of one's LBM, there may be a difference in DIT between the runners and the controls (non-exercisers). However, when LBM is controlled for, any such difference between the trained and untrained subjects will likely be eliminated.

The purpose of this study was: (1) to examine the possible difference in DIT relative to total body weight between adults who are regular runners and those of similar age who do not perform regular exercise; (2) to examine this difference in DIT relative to lean body mass.

Research Hypotheses

The hypotheses for this study were as follows:

1. It was hypothesized that there would be no significant difference in the thermic response to food at rest between the trained and the untrained groups when DIT was expressed relative to total body weight.

2. It was hypothesized that there would be no significant difference in the thermic response to food between the two groups when DIT was controlled for LBM.

Assumptions

The assumptions for this study were as follows:

1. It was assumed that the hydrostatic weighing procedure did not measurably affect the determination of each subject's true resting metabolic rate.

2. It was assumed that all subjects fasted for at least 12 hours before the day of their test.

Limitations

The limitations for this study were as follows:

1. The results of this study can be applied only to the sample of subjects' reference population.

2. Measurements of oxygen consumption in some subjects may have been influenced by their discomfort in using the mouthpiece.

3. The number of subjects was limited to the number of volunteers for the study.

4. The values for DIT were limited by the amount of time the subjects were in the laboratory following ingestion of the meal.

Delimitations

The delimitations for this study were as follows:

1. The protocol used to determine DIT was 10 min. of measuring oxygen consumption at rest before and after the ingestion of a meal.

2. The test meal used was nutritionally mixed (consisting of protein, carbohydrates and fats) and contained 580 kcal of energy.

Definition of Terms

The key terms to be defined in this study were as follows:

1. Dietary Induced Thermogenesis (DIT) is used interchangeably with the term "thermic effect" of food. It is "the additional energy expended for digestion, absorption and storage of nutrients" (Maddaiah, 1984, p.570). It can be expressed as the difference between energy expenditure before and after food ingestion.

2. Energy Expenditure is used interchangeably with oxygen consumption (VO_2). It is the amount of oxygen consumed per unit of time.

3. Lean Body Mass (LBM) is the total body weight minus the weight of fat (adipose) tissue.

4. Percent Body Fat (% fat) is the percentage of adipose tissue in relation to total body weight as determined by hydrostatic weighing.

5. Postprandial refers to RMR measurements made during the period of time immediately following consumption of the test meal.

6. Preprandial refers to RMR measurements made during the period of time before consumption of the test meal.

7. Respiratory Exchange Ratio (RER) is the ratio of the volume of carbon dioxide expired per min to the volume of oxygen expired per min. It is an indicator of the nutrients or nutrient mixture being metabolized by the body.

8. Resting Metabolic Rate (RMR) is the minimum level of energy required to keep the body alive in the resting state.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

As mentioned in Chapter I, research on DIT covers a wide variety of studies, differing mainly in their use of subjects, methodology and purpose. These investigations vary as to their specific area of emphasis. For the purpose of this discussion, these studies will be presented in the following four categories: (1) thermic effect of food during exercise; (2) the thermic effect of overfeeding; (3) DIT and obesity; (4) the effect of training on DIT.

Thermic Effect of Food During Exercise

Much of the data regarding the effect of postprandial exercise on DIT has been conflicting. One of the early experiments in this area was conducted by Clough and Durnin (1970). The researchers measured the thermic effect of a meal in two groups of men and women: those who were slightly thinner than average, and those who were slightly fatter. DIT during moderate treadmill walking was less than that measured at rest for both groups. Thus, exercise reduced the thermic response to the meal. Miller and Wise (1975) obtained similar results. In their experiment, the energy cost of a light lifting exercise was lower after eating than before eating, in two of three cases. The exception occurred when the subjects' previous day diet was considerably higher than in the first two conditions. The authors concluded that the cost of the postprandial exercise depends on the amount of food eaten on the

previous day (i.e., the greater the amount, the greater the VO_2). In another experiment, DIT was measured at rest on one day and during cycle ergometer exercise on another (Welle, 1984). Readings of VO_2 on both days were taken at one, two, and three hours after the subjects consumed an 800 kcal mixed meal. The exercise was not found to potentiate the thermic effect of the food. Pacy, Barton, Webster and Garrow (1985) also discovered no interaction between exercise and DIT in lean men and women. The elevation of VO_2 following moderate cycling exercise was similar for both conditions (i.e., before and after the 800 kcal mixed meal).

In contrast, Bray, Whipp and Koyal (1974) found that the thermic response to a meal during exercise was twice as great as that observed at rest. Their measurements were made on six adult males who ate breakfast meals of 1000 and 3000 kcal. Exercise was performed on a cycle ergometer. The size of the meal had no significant effect on the magnitude of DIT. These results are supported by those of Segal, Presta and Gutin (1984). The researchers observed that in their adult male subjects of normal weight, cycle ergometer exercise following a meal produced a significant increase in DIT over the resting value. Zahorska-Markiewicz (1980) and Segal and Gutin (1983a, 1983b) obtained similar results for normal weight women. Glick, Shvartz, Magazanik and Modan (1977) observed an increase in VO_2 during postprandial exercise over those values for exercise before eating. However, this increase was not compared to any corresponding pre- and postprandial VO_2 difference at rest.

Thermic Effect of Overfeeding

Several experiments that examined the effect of long-term overfeeding on DIT have produced contradictory results. A classic study on overeating was done by Miller, Mumford and Stock (1967). Eleven young adult men and women were overfed a nutritionally mixed diet for three weeks. Twenty-four hour oxygen consumption was measured in four of these subjects on one day of the third week. While BMR was not affected, the 24-hour VO_2 increased considerably to a level equivalent to their 24-hour food intake. The thermic effect, which peaked at approximately one hour after ingestion of the meal, was directly related to caloric intake, and was also substantially increased by a bout of exercise. Apfelbaum, Bostsarron and Lacatis (1971) observed a thermic response to 15 days of overeating in adult men and women. The overfed group consumed a total of 22,500 kcal above their normal intakes, but had an average weight gain of only 10,000 kcal. Thus, approximately 800 kcal per day were expended as excess heat.

Stirling and Stock (1968) examined the energy balance in rats that were overfed a normal diet supplemented with fat, sugar and starch. Though these rats were fed 920 kcal/day more than the control group for 20 days, they showed little or no weight gain. The authors concluded that the thermic effect of overfeeding caused the excess calories to be dissipated as heat, rather than being stored as fat. Rothwell and Stock (1979) found similar results. They measured VO_2 in adult male rats following three weeks of overfeeding. The overfed rats consumed 80% more energy than the controls did, but they weighed only 27% more than

the controls at the end of the study (groups were equal in weight at the beginning). There was also an increase in the size and metabolism of brown adipose tissue, suggesting that this tissue may have an effect on DIT. In further support is a study by LeBlanc, Dussault, Lupien and Richard (1982). Body weight was measured in two equal-weight groups of rats. One group was overfed for 10-weeks on a cafeteria diet, while the others were placed on a weight-maintenance diet. A thermic effect due to overeating was found in the cafeteria-fed rats, as evidenced by the increase in the size of brown adipose tissue and the heightened metabolic response to norepinephrine. Apfelbaum, Bostsarron and Lacatis (1971) observed a thermic response to 15 days of overeating in adult men and women. The overfed group consumed a total of 22,500 kcal above their normal intakes, but had an average weight gain of only 10,000 kcal. Thus, approximately 800 kcal/day were expended as excess heat.

In contrast, three studies using human subjects did not find evidence for increased thermogenesis induced by overeating. Hanson (1973) overfed four adult males for a period of 16 weeks until each had gained 19% of his original weight. A significant increase in VO_2 over basal levels was observed during treadmill walking, but this increase was, as predicted, strictly proportional to the weight gain. In addition, no such increase was detected during the non-weight-bearing bicycle exercise. It was concluded that no increase in energy expenditure beyond that which could be expected from a gain in weight was observed; therefore, no thermic effect of overeating. Bray et al., (1974) observed that the thermic effect of a meal at rest and during

exercise did not change significantly in four subjects who underwent four weeks of overeating.

Studies of the effects of short-term overfeeding on DIT have been less contradictory. Obarzanek and Levitsky (1983) measured DIT at rest and during treadmill exercise after one day of either complete fasting, normal eating or overeating. A significant DIT value was found for the overeaters, but only during postprandial exercise. In contrast, Dallosso and James (1981) observed no significant thermic response to a meal in subjects overfed a high-fat diet for one week. There was also no difference between DIT measured at rest and during cycle ergometer exercise. In another study (Glick et al., 1977), adult women were overfed at two separate times: for five days following a five-day weight-maintaining diet, and for two days after a four-week weight-loss diet. The authors found no evidence of DIT in response to either of the two overfeeding periods. Stock (1980) measured VO_2 at rest and during a 20 min step test, before and after a test meal, after one day of fasting followed by one day of overeating. Resting DIT values were similar for both test days. There were also no significant changes in metabolic rates due to the previous day's caloric intake. In a similar experiment (Hickson et al., 1986), VO_2 was measured in response to one-day diets of high or low energy. There was no difference between values obtained on either of the two test days. This was true for measurements taken at rest and during exercise. In light of this evidence, it may be suggested that DIT does not regulate energy balance when the period of overeating is short-term.

DIT and Obesity

There has been conflicting evidence as to whether DIT in the obese is lower than that in normal weight individuals (Thompson et al., 1982). However, several recent studies appear to have somewhat clarified the relationship between DIT and obesity (Segal & Gutin, 1983a, 1983b; Segal et al., 1984; Segal et al., 1985). Kaplan and Leveille (1976) measured DIT in four non-obese women and four women classified as obese since childhood. Energy expenditure following the test meal was significantly lower for the latter group than for the normal weight group. Pittet, Chappuis, Acheson, deTechtermann and Jequier (1976) examined the thermic effect of 50g of glucose in lean and obese women. They found an increase in VO_2 of 13% over preprandial values for the lean group, but only a 5% increase for the obese. In two additional studies, obese women showed a lower thermic response than lean women in response to noradrenalin infusion (Jung, Shetty & James, 1979) and to a standard liquid test meal (Shetty, Jung & James, 1979). In addition, Shetty, Jung, James, Barrand and Callingham (1981) observed that the thermic effect of a standard liquid meal was significantly lower in both obese and post-obese (those of normal weight who were previously obese) women than in lean women.

In contrast, Zahorska-Markiewicz (1980) found no difference in DIT at rest between obese and normally-weighted women. Both groups showed an equal increase in resting metabolism in response to the test meal; however, the control group showed a further significant increase during postprandial exercise on a cycle ergometer, while the obese did not.

Welle and Campbell (1983) tested the thermic effect of 100g of glucose at rest in 11 lean and 13 obese women. There was no difference between the two groups in the increase in either energy expenditure or in norepinephrine levels associated with the glucose intake. In addition, Sharief and MacDonald (1982) found no difference between resting DIT values for normal weight and obese subjects in response to both glucose and sucrose solutions. Cunningham, Levitt, Hendler, Nadel and Felig (1981) observed that DIT was relatively similar in lean and obese women, and that absolute energy expenditure was actually higher in the obese following the 800 kcal liquid meal. Neither Glick et al. (1977) nor Clough and Durnin (1970) observed significant differences between normal weight and slightly to moderately overweight groups in either resting or exercising DIT values.

Segal and Gutin (1983b) found that DIT measured at rest was similar in ten lean and ten moderately obese women However, the response to the 910 kcal mixed meal during cycle ergometer exercise more than doubled for the lean women, while the obese women showed no such increase. A similar study conducted with women (Segal & Gutin, 1983a) found that the same meal (i.e., 910 kcal, mixed) impaired the exercise efficiency of cycling (i.e., increased energy expenditure) in the lean subjects, but not in the obese. Another related study, again using the same test meal, was performed with men (Segal et al., 1984). DIT was compared in six normal weight and six obese men during graded cycle ergometer exercise. As was true for the women, a significant thermic response to the meal was evident in the normal weight men, but not in the obese. Segal et al. (1985) measured the thermic effect of a 750 kcal test meal

at rest, during cycle ergometry, and after the exercise in eight lean and eight obese men who were matched according to height, weight and degree of overweight. DIT was significantly lower for the obese than for the lean men under all three conditions. DIT and percent body fat were negatively correlated, and when the latter was controlled, the relationship between DIT and VO_2 max was nearly nonexistent. These results indicate that in obese and nonobese people of similar weight, the nonobese will show a significantly greater thermic response to a meal due to their greater LBM. This is true because muscle metabolism is greater than fat metabolism, and a greater LBM generally means more muscle, and thus, a higher rate of energy expenditure. Other studies have shown that higher RMR values in obese subjects could be attributed to their having a greater LBM than the normal weight controls (James, Bailes, Davies & Dauncey, 1978; Ravussin, Burnand, Schutz & Jequier, 1982).

Exercise Training and DIT

Another branch of research that has been more prevalent in recent years is that concerning the effect of exercise training on DIT, where again, the results have been conflicting. One study measured DIT, RMR, VO_2 max and percent body fat in adult men and women (Davis et al., 1983). A significant positive correlation between DIT and VO_2 max was found. Of the subjects in that study, three men and three women underwent a 12-16-week cycling or jogging program. An increase in DIT in direct proportion to the increase in VO_2 max was observed in all subjects who completed the program. In addition, Kertzer, Davis and

Tagliaferro (1981) found that DIT in subjects with higher VO_2 max values was 60% greater than that observed in subjects who had a lower aerobic capacity.

In contrast, Tremblay, Cote and LeBlanc (1983) observed that the thermic response to a 1636 kcal mixed meal was significantly lower in trained than in untrained men. The trained group consisted of competitive long-distance runners. It was suggested that this finding, combined with the lower observed RER values in the trained men, may indicate an adaptive response to vigorous exercise in which carbohydrates are spared. LeBlanc et al., (1984) found similarly in their experiment with seven men who were long-distance runners and seven untrained men. The runners showed a 50% smaller thermic response to the 755 kcal meal than the untrained men. They also oxidized 50% less glucose than the untrained men, as shown by their lower RER's. The authors concluded that exercise training diminishes the rise in both glucose oxidation and energy expenditure which normally follow the ingestion of a meal.

Related studies using rats as subjects have also produced conflicting results. Gleeson, Brown and Waring (1982) compared metabolic responses of adult male rats that received eight weeks of daily running exercise to sedentary rats of similar body weight. Energy expenditure increased by 20% in the trained rats. This was attributed mainly to significant increases in RMR and DIT. The trained rats also had higher resting values of DIT than the untrained rats. In direct contrast, LeBlanc et al. (1982) found that male rats that performed ten weeks of daily swimming showed a reduced thermic response to food. This

was evidenced by a lower response to norepinephrine injection and a lesser increase in brown adipose tissue size than that observed in the controls. The authors concluded that the exercise training prevented a waste of energy in the rats by reducing DIT.

Summary

The results regarding the four categories of DIT research reviewed in this paper have been somewhat contradictory. Several authors have reported that the thermic effect of food during exercise is less than that effect at rest (Clough & Durnin, 1970; Miller & Wise, 1975; Welle, 1984; Pacy et al., 1985). Others have documented just the opposite results (Bray et al., 1974; Zahorska-Markiewicz, 1980; Segal & Gutin, 1983a, 1983b; Segal et al., 1984).

There has been additional conflict regarding the thermic response to overfeeding. Findings in support of an increase in DIT due to long-term overeating have been observed in research with human subjects (Miller et al., 1967; Apfelbaum et al., 1971) and with rats (Stirling & Stock, 1968; Rothwell & Stock, 1979; LeBlanc et al., 1982). In contrast, two studies with human subjects found no support for this effect (Hanson, 1973; Bray et al., 1974). Most all of the studies on short-term overfeeding have found that it had no significant effect on the thermic response to a meal (Glick et al., 1977; Stock, 1980; Dallosso & James, 1981; Hickson et al., 1986).

Research on the possible relationship between DIT and obesity has also produced conflicting results. Several authors have observed a blunted thermic response to food in the obese at rest (Kaplan &

Leveille, 1976; Pittet et al., 1976; Jung et al., 1979; Shetty et al., 1979; Shetty et al., 1981; Segal et al., 1985) and during exercise (Zahorska-Markiewicz, 1980; Segal & Gutin, 1983a, 1983b; Segal et al., 1984; Segal et al., 1985). Others found no difference in DIT between obese and normal weight subjects at rest (Glick et al., 1977; Zahorska-Markiewicz, 1980; Cunningham et al., 1981; Sharief & MacDonald, 1982; Segal & Gutin, 1983b; Welle & Campbell, 1983) and during exercise (Clough & Durnin, 1970; Glick et al., 1977).

Finally, the effect of exercise training on DIT also appears uncertain. Of studies with human subjects, one reported a higher thermic effect of food in trained than in untrained adults (Davis et al., 1983), while others have found the opposite (Tremblay et al., 1983; LeBlanc et al., 1984). In studies using rats, DIT values were higher for the trained than for the untrained in one experiment (Gleeson et al., 1982), and vice-versa in another (LeBlanc et al., 1982).

CHAPTER III

METHODS

Introduction

The purpose of this study was to examine the possible difference in the metabolic response to food between trained distance runners and non-exercising adults of similar age. The following is a description of the methods and procedures used for the collection and analysis of the data obtained in this experiment.

Subjects

Forty-two adults from age 24-59 participated in the study. The experimental group (N = 19) consisted of 15 men and 4 women who regularly ran a minimum of 20 miles per week (range = 20-85). Three of these volunteers were members of the Adult Fitness Unit of the LaCrosse Exercise and Health Program, while others were runners who either ran on their own, or with one of the various running clubs in LaCrosse. The control group (N = 23) was comprised of members of the faculty and classified staff at UW-LaCrosse (13 men, 10 women). Several of the men from this group were randomly selected from a UW-L faculty directory, and a letter was sent to each man's campus address (see Appendix A). The respondents to the letter served as subjects in the control group. Others responded to the researcher's advertisement in the UW-L Faculty Newsletter (see Appendix A). All subjects signed a consent form before testing was initiated (see Appendix B).

Data from both men and women were included together in each group despite the obvious differences in body weight, lean body mass, percent fat and resting metabolic rate. This was justified by the fact that the major variable on which the two groups were compared (i.e, DIT) is expressed as the difference between preprandial and postprandial RMR. As previously discussed, RMR is a function of LBM. When RMR is expressed per unit of LBM, the inherent differences between men and women of similar body weight are eliminated, because in the average man, a higher percentage of total body weight is composed of lean mass (Katch & McArdle, 1977). The same is true of DIT, since DIT is a function of RMR. Even if RMR is not controlled for LBM, the difference between preprandial and postprandial RMR values may be the same for men and women. For example, if a woman has preprandial and postprandial RMR values of 3.0 and 3.5 ml/kg/min. respectively, and a man has values of 3.5 and 4.0, the DIT value is the same for each of them (i.e., 0.5 ml/kg/min).

In addition, several previous investigations regarding DIT have combined data from both male and female subjects (Clough & Durnin, 1970; Stock, 1980; Davis et al., 1983; Pacy et al., 1985).

Body Composition Analysis

The following procedure was used for all subjects. On the morning of the test date the subject reported to the laboratory at an hour prearranged with the researcher. At this time, the subject had not had anything to eat or drink during the previous twelve hours (i.e., the subject was in the fasting, or postabsorptive state). After reading and

signing the informed consent form, the subject's vital capacity was determined using a Collins 9-liter vitalometer (Warren E. Collins, Inc., MA). Next residual volume was determined via the oxygen dilution method (Wilmore, 1969) using the following instruments: (1) A Collins recording vitalometer (Collins, Inc., MA); (2) A Beckman MMC chart recorder (Beckman Instruments, Inc., CA); (3) A Nitrogen gas meter (Nitralyzer, Med Science, MO). Measurements of height and weight were then obtained with the subject wearing only a swimsuit. After rinsing off briefly in an adjacent shower room, the subject then entered the hydrostatic weighing tank. Underwater weight was determined as the heaviest reproducible weight among several trials. Values for body density, percent fat and lean body mass were obtained via a computer program (see Appendix C). The program used the Goldman and Buskirk (1961) formula to calculate body density, and the Brozek et al. (1963) equation to determine percent body fat:

$$\text{Body density} = MA/[(MA-MW/DW) - .1 \text{ liter} - RV]$$

where MA = mass in air (i.e., weight on land)
MW = mass in water
DW = density of water
RV = residual volume

$$\% \text{ fat} = [(457/\text{body density}) - 414.2]$$

All data was recorded on body composition data sheets used by the laboratory (see Appendix D).

Collection of Expired Air

After drying off and changing back into street clothes, the subject was seated in a comfortable chair for 5 min. The subject was then fitted with a Rudolf head support to which a Rudolf valve was attached (Hans Rudolf, Inc., Kansas City, MO). A noseclip was also worn.

Expired air was collected in the following way. The subject inhaled room air through the valve, while exhalations were channeled via a plastic hose into a Collins chain-compensated gasometer (Collins, Inc., MA) for 5 min. This initial 5 min. procedure allowed the introduction of an adequate sample of the subject's expired air into the tank, and also permitted the subject to become comfortable with breathing through the mouthpiece and valve. The tank was then flushed completely. Next a 10-min. sample of expired air was collected. The amount of air in the tank was determined by noting the initial and final numbers (in mm) on the meter stick attached to the side of the tank. The initial number was that observed just prior to the gas collection; the final was that observed immediately after collection was terminated. The difference between these two numbers was then multiplied by a constant (0.1332 liters/min) and divided by 10 (the number of min. air was collected) to yield a value for expired air (Ve) in liters/min. This and other relevant information was recorded on the data sheet in Appendix E. The expired air was then analyzed for percent oxygen and carbon dioxide using a Beckman Metabolic Measurement Cart (MMC, Beckman Instruments, CA). The OM-11 oxygen analyzer and the LB-2 carbon dioxide

analyzer were recalibrated after each measurement using room air and a gas mixture of approximately 16% O_2 and 4% CO_2.

Expired air collection using the method described above was repeated 40 min. following ingestion of the test meal, after which the experiment was terminated. In each case, the subject was given the choice of reading or sitting quietly during the gas collection process.

Test Meal

Immediately following removal of the headset, the subject was given a standard liquid formula meal consisting of two envelopes of Pillsbury Instant Breakfast (Pillsbury Company, Minneapolis, MN) mixed with two cups of whole milk. The test meal contained 580 kcal, and had a nutritional composition of 62% carbohydrate, 23% protein and 15% fat. This meal, which was provided by the researcher at no cost to the subjects, was chosen for the experiment because it was relatively inexpensive and easy to prepare. A time limit of approximately 5 min. was allowed for completion of the breakfast drink, after which the subject was permitted to read, sit quietly, and/or converse with the researcher until the next gas collection period.

Determination of RMR and DIT

RMR was calculated using a computer program (see Appendix F) which required certain values recorded on the RMR data sheets (see Appendix E). On these sheets, RMR was expressed first in ml/kg/min., and second, in ml/kg LBM/min. DIT was expressed as the difference between preprandial and postprandial RMR, in ml/kg/min. and in ml/kg LBM/min.

Statistical Treatment of Data

The data obtained in this experiment was analyzed using the SPSSx statistical analysis program. The Student's T-test for independent groups was used to compare the trained and untrained subjects with respect to age, body weight, LBM, RMR and DIT, and to determine the difference between preprandial and postprandial RMR within each group. Pearson Product Moment correlations were used to correlate the relationships of percent fat and LBM with RMR and DIT. For all such analyses of data, the .05 level was established as the criterion for statistical significance.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this experiment was to compare the experimental and control groups with respect to the thermic effect of food, and to determine whether lean body mass (LBM) plays a significant role in dietary-induced thermogenesis (DIT). In addition, the two groups were compared on a variety of descriptive characteristics, and the significance of each group's metabolic response to the test meal was also determined. For the statistical analysis of all data, the .05 level of significance was utilized. The following is a review of the findings followed by a discussion of their implications and comparisons with results from related studies.

Descriptive Characteristics

Results

A listing of the subjects' characteristics is presented in Table 1. Mean values are listed plus or minus the standard error of the mean for each variable except weekly mileage. The two groups were relatively similar in age, while they differed, but not significantly, with respect to the quantities of lean body mass and total body weight. The trained group (i.e., the runners) had a markedly lower percent body fat, a higher percent LBM (i.e., LBM/total body weight) and a higher preprandial resting metabolic rate (RMR) than the untrained group

(i.e., the non-exercisers). All three of these differences were statistically significant.

The relative similarity between trained and untrained subjects in age and total body weight concurs with descriptive data from other related research (Tremblay et al., 1983; LeBlanc et al., 1984; Segal et al., 1985). However, the mean age of subjects in the present study ($X > 40$ yrs.) was substantially higher than that of subjects in the related studies mentioned above (X = 20-30 yrs).

Table 1

Descriptive Characteristics of the Subjects:

	Trained	Untrained	Result
Age	39.9 ± 1.9	41.0 ± 2.2	NS
Weight (kg)	70.8 ± 1.9	75.8 ± 2.8	NS
Percent fat	16.5 ± 1.4	26.5 ± 1.5	$p \leq .05$
LBM (kg)	59.1 ± 2.0	55.4 ± 2.0	NS
Percent LBM	83.5 ± 1.4	73.5 ± 1.5	$p \leq .05$
RMR (ml/kg/min)	3.77 ± .10	3.36 ± .07	$p \leq .05$
(ml/kg LBM/min)	4.53 ± .14	4.59 ± .10	NS
PMR (ml/kg/min)	4.68 ± .09	4.08 ± .08	$p \leq .05$
(ml/kg LBM/min)	5.66 ± .14	5.57 ± .12	NS
DIT (ml/kg/min)	0.93 ± .09	0.71 ± .06	$p \leq .05$
(ml/kg LBM/min)	1.12 ± .12	0.98 ± .08	NS
Mileage (mi/week)	37.9 ± 4.0	----	

PMR = postprandial metabolic rate
DIT = PMR - RMR
NS = nonsignificant difference
$p \leq .05$ = significant difference

Thermic Effect of the Meal

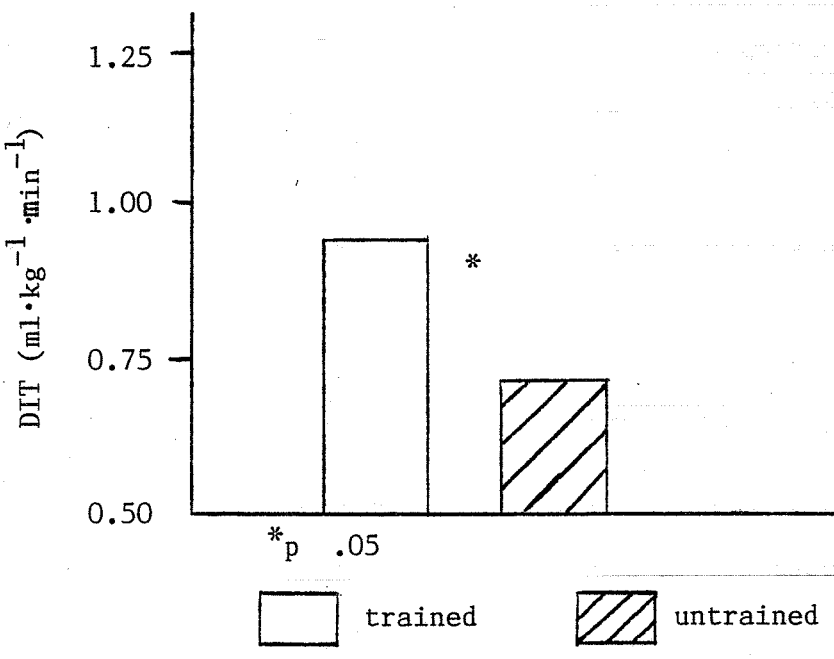
Results

Figure 1 represents the comparison of DIT between the two groups when DIT was expressed relative to total body weight (i.e., in ml/kg/min). The trained subjects had a significantly greater thermic

response to the test meal than their untrained counterparts. Therefore, the first research hypothesis is rejected.

FIGURE 1

Comparison of DIT Relative to Total Body Weight



Previous Investigations

The finding of a greater DIT value for the runners supports the results of studies by Davis et al. (1983) and Kertzer et al. (1981) with human subjects, and by Gleeson et al. (1982) using rats. In contrast, Tremblay et al. (1983) and LeBlanc et al. (1984) found DIT to be significantly lower in trained than in untrained human subjects; LeBlanc et al. (1982) found concurrent results using rats.

Discussion

Among the various studies of DIT in trained and untrained subjects,

perhaps the primary reason for contradictory results lies in the sample of runners which comprised the trained groups. The subjects in the experiments conducted by Kertzer et al. (1981) and Davis et al. (1983) were not divided into separate trained and untrained groups; rather, DIT was simply found to be greater in those subjects with higher max VO2 values. In fact, one of these studies found a significant positive correlation between max VO2 and DIT (Davis et al., 1983).

Tremblay et al. (1983) and LeBlanc et al. (1984) utilized men who ran between 100-160 kilometers per week (i.e., 60-100 miles/week). In the former study, these runners had a mean max VO2 of 69.2 ml/kg/min., while the untrained men had a mean max VO2 of 47.7; in the latter study, the corresponding values were somewhat similar. In contrast, most of the trained subjects in the experiment by Davis et al. (1983) had max VO2 values comparable to those of the untrained groups used in the two aforementioned studies. However, one subject in the former study, a marathon runner, had a much higher max VO2 (61.7 ml/kg/min.), and his thermic response to the test meal was similar to that of runners in the latter two studies.

While the present experiment did not measure the aerobic capacity of the trained subjects, average weekly mileage totals for these runners were recorded. The mean total for this group was 37.9 miles per week; this was substantially lower than the totals for corresponding groups in the studies which reported a lower thermic response to food in trained than in untrained subjects (Tremblay et al., 1983; LeBlanc et al., 1984). There were only three runners in the present study who averaged

over 60 miles per week, and their mean DIT value was similar to that for the rest of their group. Most of the other runners ranged from 20-35 miles/week. Through personal knowledge of the intensity and duration of training for these lower-mileage runners, it is likely that their mean max VO2 is also markedly lower than that of the subjects in the experiments conducted by Tremblay et al. (1983) and LeBlanc et al. (1984).

On the whole, the trained group in the present investigation more closely resembled the moderately trained subjects in the studies by Kertzer et al. (1981) and Davis et al. (1983). In light of this, it is not surprising that the results of the present study are concurrent with those of the latter two experiments.

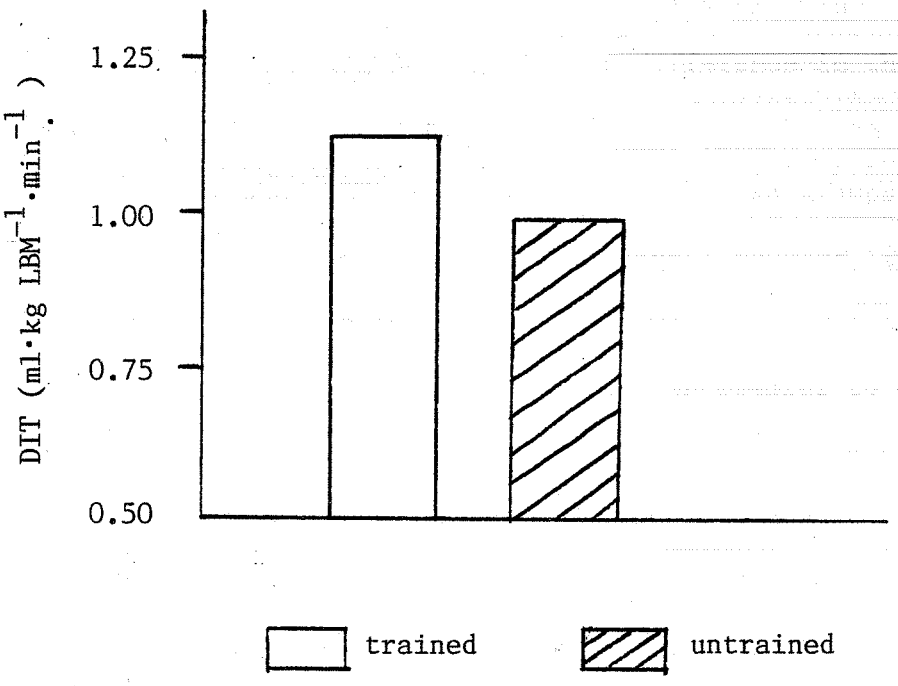
The Effect of Controlling for LBM

Results

As this researcher had hypothesized, there was no significant difference in mean DIT values between the trained and untrained groups when DIT was expressed per unit of LBM. Figure 2 represents the comparison of DIT between the two groups when DIT was expressed relative to lean body mass (i.e., in ml/kg LBM/min). In addition, there was no relationship between either percent body fat or LBM and DIT ($r = -.14$; $r = -.23$, respectively) as determined by a Pearson Product Moment correlation.

FIGURE 2

Comparison of DIT Relative to LBM



Previous Investigations

The finding of no significant difference between the two groups when DIT was controlled for LBM contrasts with that of Tremblay et al. (1983) in which the trained runners showed a significantly lower thermic response to the test meal. However, this finding supports the results obtained by Segal et al. (1985), who compared DIT and RMR in lean and obese men of similar age and weight. The lean men had significantly higher values for DIT and RMR, but when the latter was controlled for LBM, the difference between the two groups was not significant. Among the various body composition parameters measured in that study, percent body fat was found to be the best predictor of DIT at rest for all subjects ($r = -.55$). No such relationship existed in the present study.

Discussion

In the study conducted by Tremblay et al. (1983), the trained and untrained groups were similar in both total body weight and percent body fat. Thus, if there was no significant difference in the quantity of LBM, it seems logical that the runners would still have a significantly lower DIT value when LBM was controlled. The two groups in the present study were also similar in total body weight; however, they differed significantly in regard to percent fat. While the groups were not significantly different in LBM, they were in regards to percent LBM. Apparently, this discrepancy in body composition was enough to cancel out the difference in the metabolic response to the test meal in the runners, so that DIT, when expressed per kg LBM, was similar for both groups. This same equalization was true for RMR, which was also significantly higher for the runners when expressed per kg body weight, but not when controlled for LBM.

The lack of association between percent fat and DIT may be attributed to the fact that the two groups in this study did not differ as dramatically with respect to percent fat or LBM as did the groups tested by Segal et al. (1985). These authors suggested that since skeletal muscle may be one site for nonshivering thermogenesis (Newsholme, 1980), it is possible that the greater metabolic responses of the lean men might be due in part to their larger total muscle mass. This may be true of the trained subjects in the present study, who were significantly leaner than the controls, and had a greater average lean body mass.

The mean preprandial RMR for the trained group was also significantly greater than that for the untrained group, which seems logical given the greater mean LBM in the runners. As previously stated, RMR is mainly a function of LBM (Katch & McArdle, 1977). The trained group's higher preprandial RMR may be the result of their having a larger mean percent LBM than the untrained group. This is demonstrated in the significant positive relationship between percent LBM and RMR ($r = .55$, $p \leq .05$). However, the difference in LBM between the two groups was not significant. Since the relationships between DIT and both LBM and percent LBM ($r = -.23$ and .14, respectively) were not significant, the trained group's greater response to the test meal may not be attibuted primarily to either of these variables; hence, other factors may have been involved. The basis for the differences between the groups in both preprandial RMR and DIT may lie in more complex metabolic processes.

There is evidence that training enhances the lipolytic activity of fat cells (Costill, Sherman and Essig, 1981). This process is inefficient in terms of total energy cost, due to the increased reesterification of fatty acids (Stirling and Stock, 1968). In addition, there are other enzymatic pathways in the metabolism of carbohydrates which, as a consequence of aerobic exercise, may decrease the efficiency of energy expenditure (Newsholme, 1980). Kreisberg, Bowdoin and Meador (1970) have shown that skeletal muscle accounts for a large portion (i.e., as much as 40%) of total body tissue. Therefore, it is apparent that small adaptations in the efficiency of muscle

metabolism could significantly affect the body's expenditure of energy (Davis et al., 1983). In light of this evidence, it seems reasonable to suggest that LBM, a factor of central importance in determining RMR, may also be a significant determinant of dietary-induced thermogenesis in adults. However, further study of the thermogenic capacity of muscle tissue is needed before a definite relationship between LBM and DIT can be inferred (Segal et al., 1985).

DIT Within Each Group

Results

Tables 2 and 3 represent the comparisons within each group between preprandial and postprandial resting metabolic rates (i.e., RMR and PMR) expressed in ml/kg/min and ml/kg LBM/min. respectively. The tables contain the mean values for each variable along with their respective standard deviations and standard errors. Also included is the mean difference between RMR and PMR for each group, followed by the standard deviation and standard error of this difference. From these results, it was determined that the test meal used in this study produced a significant metabolic response (i.e., increase in VO2) in both the trained and the untrained groups.

Table 2

RMR vs. PMR (ml/kg/min.)

Trained

	N	X	SD	SE	X diff	SD	SE
RMR	19	3.77	0.456	0.105			
					-0.93	0.397	0.091
PMR	19	4.70*	0.386	0.088			

Untrained

	N	X	SD	SE	X diff	SD	SE
RMR	23	3.36	0.324	0.068			
					-0.71	0.283	0.059
PMR	23	4.07*	0.400	0.083			

Table 3

RMR vs. PMR (ml/kg LBM/min.)

Trained

	N	X	SD	SE	X diff	SD	SE
RMR	19	4.53	0.599	0.138			
					-1.12	0.516	0.116
PMR	19	5.65*	0.634	0.145			

Untrained

	N	X	SD	SE	X diff	SD	SE
RMR	23	4.59	0.459	0.096			
					-0.98	0.393	0.082
PMR	23	5.57*	0.560	0.117			

RMR = Preprandial resting metabolic rate
PMR = Postprandial resting metabolic rate
SD = Standard deviation
SE = Standard error
X diff = Mean difference between RMR and PMR (i.e., DIT)
* = $p \leq .05$

Previous Investigations

Tremblay et al: (1983) and LeBlanc et al. (1984) found the same significant response to the test meal utilized for the corresponding groups in their research, as did Zahorska-Markiewicz (1980) and Segal et al. (1985) in lean and obese adults; also, Clough and Durnin (1970) in both "slightly thinner" and "slightly fatter than average" groups of adults. The quantity of the test meals used in various related studies differed widely (750-1700 kcal). Most of the meals utilized in these experiments were nutritionally mixed (i.e., containing protein, fat and predominately carbohydrate calories). The test meal from the present study (Pillsbury Instant Breakfast, Pillsbury Co., MN) was similar to the others in that respect, but lower in calories (580 kcal).

Discussion

It does not appear that absolute quantity of the meal is a significant factor in determining the thermic response to food. For example, Tremblay et al. (1983) administered a test meal of more than twice as many calories as the meal given by LeBlanc et al. (1984) to the same type of subjects (i.e., highly-trained male distance runners); these experiments produced similar results. It is not certain just what minimum quantity of food is needed to elicit a significant increase in RMR, for this may vary among different individuals. Based on review of the related literature, it was decided that the test meal used in the present study would be sufficient to produce a significant thermic response in at least one group of subjects. The results show that this response was, in fact, significant for both groups.

CHAPTER V

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

The purpose of this study was to examine: (1) the difference in the metabolic response to food between a group of trained distance runners and a group of untrained adults of similar age, who were not regular exercisers at the time of the study; and (2) whether or not the quantity of lean body mass plays a significant role in determining the thermic effect of food. It was hypothesized that there would be no significant difference in the thermic effect of the test meal between the trained and the untrained groups when the thermic response (i.e., DIT) was controlled for total body weight and for LBM.

The experimental group consisted of fifteen male and four female runners, while the control group was comprised of thirteen male and ten female adults who were not engaging in any type of regular exercise at the time of their participation in the study. The two groups were similar in age, total body weight, and lean body mass; they differed significantly with respect to percent fat and preprandial resting metabolic rate.

The experimental testing process for all subjects was conducted at the Human Performance Laboratory at the University of Wisconsin-La Crosse. The procedures consisted of the following, in order of

occurrence: (1) hydrostatic weighing, (2) preprandial RMR measurement, (3) ingestion of the test meal, and (4) postprandial RMR measurement. The duration of the testing process was approximately two hours, with times scheduled during the morning so that subjects would be in the fasting state.

All experimental data was analyzed using the SPSSx statistical analysis program. T-tests for independent groups were used to compare the two groups with respect to age, weight, LBM, RMR and DIT, and to compare preprandial with postprandial RMR within each group. Pearson Product Moment correlations were used to examine relationships between some of the variables measured.

Conclusions

Based on the statistical analysis of the data, the following conclusions were drawn, given the scope and limitations of this study:

1. There was a significantly greater metabolic response to the test meal in the experimental (i.e., trained) group than in the control group. Consequently, the first research hypothesis is rejected.

2. When the metabolic response to the meal (i.e., DIT) was expressed per unit of lean body mass, the difference between the two groups was eliminated. This finding was concurrent with the second research hypothesis.

3. The metabolic response to the test meal was significant in each group. Thus, the test meal was of sufficient caloric content to produce a significant mean increase in oxygen consumption in both groups.

Recommendations for Further Study

The following are recommendations, as appropriate to the purpose and conclusions of this study:

1. To better measure the total thermic effect of food, it is recommended that the subjects' expired air be collected for 5 min. periods every 15 min. for two hours; once while in the fasting state, and once following the test meal. However, this protocol, which is similar to those used in several related studies discussed in this paper (Kertzer et al., 1981; Davis et al., 1983; Tremblay et al., 1983; LeBlanc et al., 1984; Segal et al., 1985), may be too time-consuming for the researcher and the subjects.

2. To better examine the effect of aerobic capacity on DIT, it is recommended that a group of highly trained runners that are more alike with respect to age, weight, percent fat and max VO_2 (e.g., the men's cross-country team) be compared to a control group of students similar in age and weight to the runners, who do not engage in regular aerobic exercise.

3. To better examine the effect of LBM on DIT, it is recommended that a group of heavily muscled men (e.g., football players or body builders) be compared to a control group of students similar in age and weight who are relatively inactive and who would likely have significantly less LBM.

4. To increase the calorie content of the test meal without appreciably affecting the amount, it is recommended that one more

package of the instant breakfast mix (Pillsbury Co., MN) be added to the test meal. This would result in a drink consisting of 710 kcal.

5. In order to minimize descriptive differences (i.e., weight, percent fat) between the experimental and control groups, and between members of the same group, it is recommended that the subject population be restricted to one sex (i.e., either all males or all females in both groups).

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APPENDIX A

LETTERS TO POTENTIAL SUBJECTS

Setting the pace since 1971

La Crosse Exercise and Health Program

College of Health, Physical Education and Recreation • University of Wisconsin-La Crosse • 1725 State Street, La Crosse, WI 54601-9959

Brian J. Dixon
2029 State St.
La Crosse, WI 54601

Dear Faculty Member,

I am currently looking for volunteers to participate as subjects in a study I am conducting for my Master's thesis. The study is designed to measure the body's metabolic response to ingesting food, and the relationship of this response to one's lean body mass. It is a relatively short experiment that consists of the following:

1. Hydrostatic (underwater) Weighing. This measurement will provide you with the opportunity to determine your body fat percentage, which is a much more accurate determinant of fitness than body weight alone. You will then be able see where you stand as compared to the national norms for men of your age.
2. Determining the metabolic response to food. This proce-dure will determine your basal metabolic rate, which in essence is the rate at which your body burns calories while at rest. This value is important in weight control. It will also determine if there is a significant increase in your metabolism immediately after eating a meal. This allows you to see just how your body adjusts to the intake of an average amount of food.

Subjects in the study must meet certain conditions. They must not:

-- have cardiovascular disease or diabetes;
-- have hypertension for which they are being treated;
-- be taking regular prescribed medication at the time of their test.
-- be following or planning to follow a weight-loss or weight-gain program of any kind at the time of their test.
-- be performing any type of regular exercise at the time of their test.

If you are interested in being a subject and can meet the above conditions, please call me at 782-5240 after 7 p.m. on weekdays, or after 11 a.m. on weekends. Feel free to ask any questions about the experimental procedures. If you would like to participate, please understand that you may withdraw from the experiment at any time, for any reason that you see fit. Your cooperation would be greatly appreciated.

Sincerely,

Brian J. Dixon

FREE UNDERWATER WEIGHING

Free Body Composition Analyses, normally costing $20-$30, will be offered this semester. In addition, participants must also undergo one measurement of resting metabolism before and after a light meal (free), which takes about 1 1/2 hours. Participation is limited to those who are not regularly exercising now. No further repeat measurements are necessary. Anyone wishing to begin exercising after his/her measurements are completed will be given information on starting an activity program along with an exercise prescription, plus a free follow-up weighing. If interested, please contact Brian Dixon through intra-campus mail at Rm. 225 Mitchell Hall.

APPENDIX B

INFORMED CONSENT

INFORMED CONSENT

I hereby give my willing consent to take part in this research study.

I am fully aware that I am expected to undergo one underwater weight measurement. During this procedure, I will be completely submerged several times, after expiring as much air as possible. I will be asked to remain still underwater for no more than five sec. at a time. There is a possibility of shortness of breath, choking due to inhalation of water, and--although extremely slim--drowning. These trials will be monitored very closely by the researcher and his assistants to assure for maximum safety.

All of my individual data obtained from the experimental tests are confidential. They will be revealed to no one without my expressed written consent.

I understand that I may withdraw from the experiment at any time and for any reason that I see fit.

I have read the information above. I understand it fully and agree to all stated conditions.

Signature _____ Date _____

Witness _____

APPENDIX C

COMPUTER PROGRAM FOR BODY COMPOSITION ANALYSIS

Appendix C

The program entitled "shortfat" (Tesch, UW-LaCrosse), is available in the VAX/VMS version V4.5 of the UW-LaCrosse computer network. The program determines body fat content from underwater weighing with two residual volume (RV) tests. Residual volume, body density and lean body mass are also calculated. The following values obtained via the RV tests and the underwater weighing were recorded for each subject on a body composition data sheet (see Appendix D) and used as input for the program:

1. Bag volume (Oxygen rebreathing bag) in liters.
2. Percent alveolar nitrogen (AN_2).
3. Percent impurity nitrogen (IN_2).
4. Percent equilibrium nitrogen (EN_2).
5. Percent final nitrogen (FN_2)
6. Body weight, dry in lbs.
7. Temperature of water in tank, in degrees Celsius.
8. Underwater weight of the scale apparatus with subject in tank (MY), in kg.
9. Underwater weight of scale apparatus plus subject (MX), in kg.

The following is an example of a printout from the "shortfat" program:

```
BODY FAT CONTENT FROM UNDERWATER WEIGHING WITH 2 RV TESTS
By Jeff Tesch, Technical Lab Director

This program assumes equipment deadspace = .05 liters
This program assumes BTPS correction factor = 1.1
Enter subject's name:
?
Enter values for first RV test:  Bag Vol., AN2, IN2, EN2, and FN2.
? 5.62, 79.5, 1.4, 18.5, 19.0
Enter values for second RV test:  Bag Vol., AN2, IN2, EN2, and FN2.
? 5.62, 79.5, .7, 18.0, 18.4
Enter weight (lbs), water temp. (degrees C), MY (kg), and MX (kg).
? 159, 36, 6.24, 9.7

RV =                1.69385
DB =                1.07161
% Fat =             12.2613
LBW (lb) =          139.505
LBM (kg) =          63.2673
```

When all of the values mentioned above are entered into the computer, the program calculates RV, % fat, LBM (kg) and LBW (same as LBM, but in lbs) based on this input.

APPENDIX D

BODY COMPOSITION DATA SHEET

Side 1

BODY COMPOSITION - HUMAN PERFORMANCE LAB (Revised: 12/8/86)

Subject's Name:_____ Age:___ Sex: (1=male, 2=female)
Tester's Name:_____ Date: (mo/day/yr):_____
Prior Tests ? (yes/no):____ Reason for Test:_____
Comments:_____

********** INFORMED CONSENT AGREEMENT **********

The procedures involved in underwater weighing, residual volume measurement, and anthropometric measurements (skinfolds, girths and diameters), have been explained clearly to me and I understand them. To my knowledge I have no physical handicaps or medical conditions that would prevent participation in these tests. I agree to hold harmless the University of Wisconsin-LaCrosse and its employees for any accidental injury that might occur as a result of these tests, which i have agreed to take.

Signed:_____ Date:_____

****

A. Vital Lung Capacity: #1____liters (to .1) #2_____liters (to .1)

B. RV Determinations:

	Trial 1	Trial 2
Bag Volume of Oxygen (BV)	_____l (to .01)	_____l (to .01)
Alveolar nitrogen (AN)	_____% (to .1)	_____% (to .1)
Impurity nitrogen (IN)	_____% (to .1)	_____% (to .1)
Equilibrium nitrogen (EN)	_____% (to .1)	_____% (to .1)
Final nitrogen (FN)	_____% (to .1)	_____% (to .1)

C. Direct subject to dressing room to put on swimsuit. NO SHOWER YET!

D. Anthropometry (mean of 3 readings):

Male subjects:

Skinfolds:
- Triceps _____mm
- Biceps _____mm
- Subscapular _____mm
- Suprailiac _____mm
- Thigh _____mm
- Pectoral _____mm
- Midaxillary _____mm
- Umbilical _____mm

Girth:
- Suprailiac _____cm

Diameter:
- Wrist _____cm

Female subjects:

Skinfolds:
- Triceps _____mm
- Biceps _____mm
- Subscapular _____mm
- Suprailiac _____mm
- Thigh _____mm

Girths:
- Forearm _____cm
- Abdominal _____cm
- Buttocks _____cm

Diameter:
- Wrist _____cm

Side 2

E. Direct subject to toilet to void any solid, liquid or gas possible.

F. Dry Weight_____lbs (to 1/4) Height_____inches (to 1/4)

G. Direct subject to shower to wash hair and shower completely. Jewelry and contact lenses should be removed before underwater weighing!

H. Denitometry:
Water Temp____degrees C. Immersed Weight of Apparatus (MY)____(to .1)

MX: (1)_____ (2)_____ (3)_____ (4)_____ (5)_____
(6)_____ (7)_____ (8)_____ (9)_____ (10)_____

Select the heaviest reproducible weight (MX) from the trials above:
Immersed weight of subject + apparatus (MX) _____kg (to .1).

I. Results:

J. Equations:

*RV = 1.1 x [BV X (EN - IN) - DS] / (AN - FN)

**BD = MA / ([(MA - MW) / DW] - RV - .1 liter)

***FAT % = (457 / BD) - 414.2

K. References:

*Wilmore, J.H. (1969). A simplified method for determination of residual lung volumes. JOURNAL OF APPLIED PHYSIOLOGY 27: 96-100.

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APPENDIX E

RMR DATA SHEET

RMR Data

Subject _____

Date _____

Preprandial		Postprandial	
Tissot tank final	_____mm	Tissot tank final	_____mm
Tissot tank initial	_____mm	Tissot tank initial	_____mm
Difference	_____mm	Difference	_____mm
Constant	.1332 l/min	Constant	.1332 l/min
Time	_____min	Time	_____min
Volume (ATPS)	_____l/min	Volume (ATPS)	_____l/min
Temp. (Ve)	_____C	Temp. (Ve)	_____C
Pressure (room)	_____mm Hg	Pressure (room)	_____mm Hg
P H2O	_____mm Hg	P H2O	_____mm Hg
FeO2 (STPD)	_____	FeO2 (STPD)	_____
FeCO2 (STPD)	_____	FeCO2 (STPD)	_____
RER	_____	RER	_____
VO2	_____ml/kg/min	VO2	_____ml/kg/min
	_____ml/kg LBM/ min		_____ml/kg LBM min
DIT	_____ml/kg/min	DIT	_____ml/kg/min
	_____ml/kg LBM/ min		_____ml/kg LBM min

APPENDIX F

COMPUTER PROGRAM FOR DETERMINATION OF VO2

Appendix F

The program entitled "ExpVO_2" (Tesch, UW-LaCrosse) is available in the VAX/VMS version V4.5 of the UW-LaCrosse computer network. The following values, obtained during expired air collection and recorded on the RMR data sheet shown in Appendix E, were employed to determine resting VO_2 (RMR).

1. Barometric pressure of the laboratory (Pb) in mm Hg.
2. Temperature of expired air (Tc) in degrees Celsius.
3. Body weight (WT) in kg.
4. Volume of air expired (VE) in liters/min.
5. Fractional equivalent of oxygen (FEO_2).
6. Fractional equivalent of carbon dioxide ($FECO_2$).

The following is an example of a printout from the "ExpVO_2" program:

```
Pb  (MMHG) =? 750
Tc  (CELSIUS) =? 22
WT  (KG) =? 69.2599
VE  (LITERS) =?8.7379
FEO2 =? .1685
FECO2 =? .0331

VE LITER/MIN 7.76887
Vo2/min = .333428     liter/min
VO2  (ml/kg x min) = 4.81416
VCO2/MIN = .25715     LITERS/MIN
RER  .77123
```

The top variables are values from the RMR data sheet which are entered into the computer. The bottom values are calculated by the program and expressed at STPD. Note that VO_2 is expressed in both liters/min. and ml/kg/min. In this experiment, the latter value was used.