ENERGY METABOLISM DURING EXERCISE AT DIFFERENT TIME INTERVALS FOLLOWING A MEAL

by

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INTRODUCTION

Several studies have shown that the thermic effect of food, or the increase in heat production following a meal, is affected by exercise. Miller et al (1) claimed that the thermic effect of a meal during exercise is twice that during rest. And in a similar study, Bray et al (2) noted an enhanced thermic effect of a meal during exercise with a meal size greater than 1000 kcal. More recently, Segal et al (3) reported that eating significantly increased energy expenditure during exercise in lean men. Other studies (4,5,6,7,8) have also provided evidence that the thermic effect of food is enhanced during exercise. On the other hand, some investigators (9,10,11,12) found that energy expenditure during exercise was not greater following a meal than in the fasted state.

Welle (9) examined the effects of intermittent exercise on metabolic responses to a meal. He found no difference between the thermic effect of the meal during exercise and at rest. Dallosso and James (10) studied normal weight men while the men occupied a whole-body indirect calorimeter and observed no interaction between the thermic effect of food and exercise.

Lack of agreement between studies might be attributed to the time interval following the meal at which the subjects began exercising. Karst et al (13) found that the thermic response to starch reached its maximum one hour after a meal and disappeared after 3 hours. Glickman et al (14) reported that a protein meal may cause an elevation in metabolism which lasts as long as 16 hours. Consequently, it might be important to compare the effects of exercise when begun at different time intervals following a standard meal.

The objective of this study was to compare energy expenditure during exercise in the fasted state and at 30, 60, and 90 minutes following a 940 kcal mixed meal. The data showed that the timing of exercise relative to a meal was an important factor determining the amount of fat oxidized for energy.

LITERATURE REVIEW

I. Thermic Effects of Food

Miller and Mumford (15) coined the term "dietary-induced thermogenesis" (DIT) to describe all increases in energy expenditure associated with diet. DIT includes specific dynamic action (SDA): SDA is also called the thermic effects of a meal. SDA is the short-term increase in heat production required for digestion, absorption, and metabolism of food. DIT also includes luxuskonsumption, a term created by Neumann (16) to represent the animal's ability to convert excess energy intake into heat such that body weight is maintained over long periods of time.

Fat

The SDA of fat is lower than that of carbohydrate or protein (13,17-21). Benedict and Carpenter (17), in one of the earlier experiments of its kind, found the SDA of fat to be 2% of the calories ingested. Wang et al (18) reported little, if any, evidence of a SDA associated with fat. The observed increase in heat production was attributed to the small amounts of carbohydrate and protein in the high fat test meal. Karst et al (13) determined that the SDA associated with fat was less than 7% of the net energy supplied by the food.

One of the proposed mechanisms for DIT is metabolism in brown adipose tissue (BAT). BAT, despite its very small mass, is the site of considerable increases in heat production in cold-adapted and cafeteria-fed rats (22). As much as 30% of cardiac output may flow through BAT (23). In newborn and cold-adapted rodents living in cold conditions, nonshivering thermogenesis in BAT may account for 40-50% of total energy expenditure (24). DIT in BAT accounts for less of the total energy expenditure than does nonshivering thermogenesis, however, due to the difficulty in measuring such a value, the exact amount is not known (24). BAT is also present and may be thermogenically active in humans (23). Some investigators believe that the relatively small SDA of fat may be linked to decreased metabolism in BAT. Glick (25) observed reduced respiration rates in the BAT tissue of rats fed a high fat diet, despite an increase in net energy consumption.

The type of fat consumed may affect the thermic response. In a review on the regulation of energy balance, Rothwell and Stock (26) cited studies by Bray et al (27) and Gurr et al (28) which suggested that long-chain triglycerides result in an increase in body fat and that medium-chain triglycerides lead to weight loss.

Carbohydrate

Benedict and Carpenter (17) found the SDA of carbohydrate to be 6% of the calories ingested as pure carbohydrate. Glickman et al (14) and Karst et al (13) estimated it to be 9.6% and 7%, respectively.

The type of carbohydrate ingested influences the thermic response. For instance, Sharief and MacDonald (29) stated that DIT is greater after sucrose ingestion than after glucose ingestion. Similarly, MacDonald (30) found the thermic response to sucrose to be greater than those of other carbohydrates except fructose.

The mechanism by which carbohydrate elicits extra heat production has been linked to BAT by many investigators (22,23,25,31,32). Glick et al (31) reported that the respiration rate and weight of BAT in rats increased after a single low protein, high carbohydrate meal. Another component in the mechanism of the SDA of carbohydrate is the sympathetic nervous system. Acheson et al (33) demonstrated that glucose ingestion stimulates the sympathetic nervous system to the extent that it may constitute from 30 to 50% of the total DIT. Welle et al (34), found that glucose ingestion caused a significant rise in plasma norepinephrine levels. Whereas, protein and fat did not cause such a rise. However, Welle and Campbell (35) later presented data which contradicted earlier findings. They found that the SDA of carbohydrate was not significantly influenced by activity of the sympathetic nervous system.

Rothwell and Stock (22) showed a significant increase in the temperature of the BAT area of rats who were injected with norepinephrine which indicated an increase in heat production and/or elevated blood flow to this area. A relationship between glucose ingestion, plasma norephinephrine levels, and BAT activity has been confirmed in the literature. But, the mechanism by which glucose causes a rise in plasma norepinephrine levels is still not known.

Protein

Extensive studies have been conducted on the SDA of protein and the consensus is that it is greater than that of fat or carbohydrate (13,14,17,20,21,34). Benedict and Carpenter (17) reported a SDA associated with protein of 12% of the calories ingested in protein-rich food. Glickman et al (14) and Karst et al (13) found the SDA of protein to be 17% and 15%, respectively. Welle et al (34) demonstrated a greater increase in energy expenditure after ingestion of 100 grams of protein than after ingestion of equal caloric amounts of fat or carbohydrate.

Mixed Diets

Although protein has the largest SDA of all nutrients when taken alone, many investigators have shown that mixed low protein diets allow increased caloric consumption for weight maintenance (36,37,38,39,40,41). For example, Dole et al (36) reported success after using a low protein diet to reduce weight in obese patients. Stirling and Stock (37) found that rats fed a low protein diet ate more and produced 690 more kcal of heat during 20 days. The rats fed the low protein diet also exhibited increased sensitivity to norepinephrine injections.

Swick and Gribskov (38) conducted an experiment similar to that of Stirling and Stock (37). They observed that rats fed a 5% protein diet consumed 19% more food than rats fed a 15% protein diet. However, the rats fed the 5% protein diet gained only 28% as much weight as the other rats. The rats fed the low protein diet had twice the thermic response and twice as much BAT. Rothwell et al (39) observed results similar to those of Swick and Gribskov (38). Their rats which were fed a low protein diet had more BAT with greater protein content and more mitochondria as compared to the control rats and their oxygen consumption (VO_2) was 15% greater.

Miller and Payne (40) found that protein-restricted pigs consumed five times as much energy as control pigs consumed. Yet, the protein-restricted pigs weighed the same as the controls. In a similar study conducted by Gurr et al (41), pigs fed a low protein diet consumed three times as many calories as pigs fed a high protein diet. And the pigs fed the low protein diet had a greater thermic response to norepinephrine.

Miller and Mumford (15) found that, during overeating periods, human subjects who were fed a low protein diet gained a mean of 1.0 kg against an expected gain of 4.7 kg and subjects who were fed a high protein diet gained 3.8 kg against an expected gain of 4.9 kg. The researchers attributed the discrepancy between actual and expected weight gains to excess heat production.

As exemplified in these experiments on mixed diets, dietary imbalance can cause increased DIT. As early as 1933, Forbes (42) wrote that nutrients cannot be evaluated individually and still have practical application and that the most metabolically efficient diet was a nutritively complete diet. A year later, Mitchell (43) stated that the SDA of the nutrients alone was considerably greater than that of a mixture of nutrients and the more balanced the combination of nutrients, the lower the SDA.

Length of the Effect

The length of time that the resting metabolic rate (RMR) is increased due to the consumption of food depends on the type of food consumed. In a review on energy metabolism, Dauncey (44) stated that the RMR can be significantly affected even 14 hours after a meal. And Glickman et al (14) found that a protein meal may cause a rise in metabolism which lasts as long as 16 hours.

In general, the effect of carbohydrate ingestion on metabolic rate has shorter duration than that of protein (13,14,20,21,34). Karst et al (13) reported that the thermic response to starch reached its maximum at one hour after the meal and disappeared after three hours. The thermic response that they observed after a casein ingestion peaked at two hours after the meal and lasted five hours. Glickman et al (14) noted that the effect of a sugar meal ended after three hours and that the accelerating phase of the metabolic rate after a 1000 kcal carbohydrate meal ended 1.5 hours after the meal, whereas it lasted 2.5 hours after a 1000 kcal protein meal. Welle et al (34) found that the difference in thermic responses to glucose and protein was only measurable 2-3 hours post-ingestion. And four hours was not sufficient to observe the full effect of the protein meal.

Meal Size

Several investigators found that the SDA of a meal was dependent on the number of calories the meal contained (11,13,15,25,33,45). Some found that after a larger meal the energy expenditure increased more, others found that it lasted longer, and some found both. Karst et al (13) observed a higher increase in energy expenditure, a longer duration of its maximum elevation, and a later return to the baseline value after a doubling of protein caloric intake. They also reported that to obtain a similar effect from a carbohydrate meal, four times as many calories were required. Hill et al (45) found that the thermic effect after 500, 1000, 1500 kcal meals increased systemically as the meal size increased. Swindells (11) reported a greater increment in energy expenditure after a meal providing one-half of the daily caloric allowance as compared to meals providing one-ninth and one-third of the daily allowance.

Some researchers observed no relationship between meal size and SDA (2,46). Bradfield and Jourdan (46) fed obese women meals of varying caloric content from 100% to 25% of the calories required for weight maintenance and found no significant difference in the SDA of the meals. Bray et al (2) fed men 1,000 and 3,000 kcal breakfasts and observed no greater SDA after the larger meal.

Long-term Effects of Overnutrition

There is considerable controversy in the literature as to whether or not *luxuskonsumption* exists. The studies which support its existence are in the minority (15,22,47,48,49). Sims et al (47) observed that long-term overeating leads to a large increase in energy expenditure. In their experiment, lean volunteers increased their food intake enough to increase their body weight by 20%. To maintain this weight, they had to consume 2700 kcal/sq m/day which is 900 kcal more than they consumed at their normal weight. In another overeating experiment, Apfelbaum et al (48) fed their subjects 22,500 extra kcal over a 15-day period, yet their gain in adipose tissue was only approximately 10,000 kcal. This discrepancy translated to a 30% rise over initial energy expenditure.

Some investigators have concluded that to observe *luxuskonsumption*, overeating must either occur for a given minimum length of time or constitute a given minimum number of calories (15,44,50). Dauncey (44) cited a study by Garrow (50) which demonstrated that to sufficiently increase heat production during overeating such that there is little or no weight gain, approximately 84,000 extra kJ must be consumed. And Miller and Mumford (15) suggested that experiments testing the theory of *luxuskonsumption* should last for at least two weeks.

Many other studies contradict the existence of *luxuskonsumption* (49,51,52,53,54). Wiley and Newburgh (51) tested the theory of *luxuskonsumption* in 1931 on one subject for 15 days and found no extra energy expenditure other than the increased SDA from the extra food consumed. Passmore et al (49) reported no excess food oxidation, apart from a small amount due to the SDA of the extra protein consumed, during a 10 to 14 day overfeeding experiment.

Long-term overfeeding seems to have no potentiating effect on the thermic effect of a single meal (2,6,35). After 30 days of overfeeding 4,000 kcal per day, Bray et al (2) observed no change in the thermic effect due to food ingestion. Stock (6) examined the effect of overeating one day on the thermic effect of a meal the next day. He found no difference between the thermic effect after a day of fasting and after a day of overeating.

The composition of the antecedent diet has been shown to have an effect on the thermic response to a meal. Acheson et al (53) found that subjects who consumed a high carbohydrate diet during 3-6 days before testing responded to a carbohydrate meal with a thermic effect of 8.6% of the calories ingested. Those subjects who consumed a high fat diet responded with a thermic effect of 5.2% and subjects who consumed a mixed diet responded with a thermic effect of 6.5%.

Individual Variation

Although studies on thermogenesis have elucidated the effects of different nutrients, different meal sizes, and long-term overnutrition, investigators have consistently noted large differences among individual responses. For instance, Swindells (11) noted greater individual variation in the thermic responses to meals than variation associated with different meal sizes. Those observed individual differences in thermogenesis have been followed up by studies examining a possible link between thermogenesis and obesity (18,55,56,57,58) and thermogenesis and level of fitness (11,59,60,61,62,63).

Schutz et al (55) found that the thermic response of obese women was blunted (8.7±0.8%) compared to that of non-obese women (14.8±1.1%). They also observed an inverse correlation between percentage body fat and SDA. Shetty et al (56) observed women with a family history of obesity who were either obese or of normal weight had a thermic response equal to half that of lean women.

Level of fitness has been suggested as another cause of individual variation in DIT. However, the researchers' conclusions seem to be equally divided as to the effect of training and fitness. Kertzer et al (59) found that both trained and untrained subjects had an increased metabolic rate after a meal, but the trained subjects with higher maximum oxygen consumption (VO_2max) showed DIT which was 60% greater in magnitude and duration than that of the untrained subjects. Similarly, Hill et al (60) observed that exercise training in rats led, not only to increased RMRs independent of diet, but also to increased thermic responses to cafeteria food. Hill et al (45) demonstrated that human subjects with high VO_2max responded with greater SDA to two different sized meals than subjects with low VO_2 max. Also, with a given increase in caloric load, the subjects with the higher VO_2max had a greater increase in SDA.

Different conclusions were arrived at by several other groups of investigators (4,61,62,63). Tremblay et al (61) examined elite trained subjects and found that their SDA after a 1,636 kcal meal was significantly lower than that of untrained subjects. The metabolic response to the meal in the untrained subjects was longer and greater in magnitude. Since the trained subjects' respiratory quotient (RQ) after the meal was lower than that of the untrained subjects, the researchers claimed that there was an increase in fat oxidation and a concomitant sparing of carbohydrate. LeBlanc et al (62) found that the SDA after feeding a 755 kcal meal to trained subjects was 50% less than the response of untrained subjects. The researchers suggested that this diminished response may have been due to reduced activity of the sympathetic nervous system or to a carbohydrate-sparing mechanism.

II. *Exercise and Metabolic Rate*

Oxygen consumption increases during exercise due to increased demands of the active muscles for oxygen. And most earlier studies indicated that oxygen consumption remains increased after exercise due to increased metabolic rate, aerobic removal of anaerobic metabolites, replenishing oxygen-depleted stores, and increased demand for oxygen by the heart and respiratory muscles. Increases in metabolic rate are caused by the rise in tissue temperature and possible increases in adrenalin output. The metabolic rate rises 13% per degree centigrade increase in tissue temperature (64).

Duration of the Effect

The increase in metabolic rate caused by exercise is the major reason for energy loss (65). DeVries (65) observed that after a vigorous workout, the RMR increased from 7.5% to 28% for four hours and this elevated metabolic rate lasted for at least six hours after exercise had ended. DeVries (65) cited Margaria et al (66) who also found that the elevated RMR lasted several hours after exercise. Recently Bielinski et al (67), found that moderate, prolonged exercise increased post-exercise energy expenditure for 4-5 hours and RMR for at least one day.

DeVries and Gray (68) tested the RMRs of two healthy middle-aged men during a six-week training program. They found a significant increase in metabolic rate for six hours after exercise which returned to pre-exercise level after eight hours. Although most studies support the theory of elevated metabolic rate after exercise, Freedman-Akabas et al (69) concluded that there is no sustained effect of moderate or intense exercise on VO_2 in fit or unfit individuals. And Pacy et al (70) observed no prolonged increase in metabolic rate after exercise in nonobese subjects.

Effect of Exercise Intensity and Duration

Simonson (71) cited Steinhaus (72) who observed a pronounced increase in metabolic rate only after maximum or near maximum intensity exercise performance. Hagberg et al (73) noted that exercise at 50% to 65% of VO_2max was not sufficient to increase the magnitude of the slow component of recovery oxygen consumption, but that exercise at 80% of VO_2max was sufficient. Segal and Brooks (74) also found that the slow component of recovery oxygen consumption was more prominent at higher work loads. In addition, Segal and Brooks (74) noted that exercise intensity was the predominant factor influencing the magnitude and kinetics of post-exercise oxygen consumption.

Hagberg et al (73) compared the effects of different durations of exercise and found that exercise at 80% VO_2max for 20 minutes resulted in a slow component of recovery oxygen consumption that was five times larger than after exercising at the same intensity for five minutes. However, at 50% and 65% VO_2max, this difference was not observed. The rapid component of oxygen recovery was not changed by different durations of exercise at the same intensity, but it was proportional to the exercise intensity.

III. Exercise and the Thermic Effect of Food

Fuel Source During Exercise in the Fasted State

At the very start of exercise, even at intensities lower than 60% VO_2max, some anaerobic metabolism occurs for 45-90 seconds until oxygen can reach the active muscles. Maximum work of short duration depends only on ATP and phosphocreatine muscles stores for fuel. During prolonged exercise, however, aerobic metabolism of glycogen and free fatty acids (FFA) provides the necessary ATP (75).

According to Brooks and Fahey (76), during hard exercise the respiratory quotient (RQ) approaches 1.0 and indicates predominant oxidation of carbohydrate. However, during prolonged exercise the RQ value is less than or equal to 0.9 and indicates increased fat oxidation. A possible reason for this difference is that, during hard exercise, oxygen is limited and use of carbohydrate predominates since 6.4% more energy is derived from carbohydrate than from fat per unit of oxygen consumed. During prolonged exercise, glycogen stores are limiting, so more fat is oxidized for energy (76).

Harris et al (77) found that during the first 5-15 minutes of mild exercise, the plasma FFA level was fairly low. During prolonged exercise, the level of FFA was greater or equal to the level at rest. Then, after exercise, the levels of FFA and glucose significantly increased for a considerable length of time. Ahlborg et al (78) studied substrate turnover during four hours of exercise at 30% VO_2 max. They found that exercising increased muscle uptake of FFA and glucose and that after 40 minutes of exercise, the relative contribution of FFA to total oxygen metabolism increased to 62%. From 90 to 240 minutes the contribution from glucose metabolism decreased from 40 to 30%. Pruett (79) studied FFA mobilization during exercise and observed increases in plasma FFA levels during exercise at intensities up to 70% VO_2max. However, at intensities greater than 85% VO_2max, the plasma FFA levels fell. After exercise at 85-90% VO_2max, the plasma FFA levels remained elevated for five hours or more. The author stated that the magnitude and duration of the increase in plasma FFA levels after exercise did not depend on the total energy expended but rather on the rate of energy expenditure during exercise. FFA mobilization was more pronounced and long lasting after exercise to exhaustion at 70-80% VO_2 max.

Effect of Diet on Fuel Source During Exercise

The source of calories in the diet affects the fuel source during exercise. Costill et al (80) examined the effects of different amounts and types of dietary carbohydrate on exercise. After feeding a low carbohydrate diet for 48 hours, the amount of fat burned during exercise was higher than after a mixed diet. After feeding a high carbohydrate diet, the amount of carbohydrate oxidized was greater than after a mixed diet. In an earlier study, Pruett (81) showed similar results. He put male subjects on three different diets for two weeks and then exercised them at a work load slightly less than 70% VO_2 max. The subjects who consumed a high carbohydrate diet burned a mean of 382 grams (1.98 grams/min) of carbohydrate. Those who had consumed a standard diet burned a mean of 324 grams (1.73 grams/min) and those on a high fat diet burned 268 grams (1.63 grams/min) during 2.5-4 hours of exercise.

Hurni et al (82) found contrary results at a different intensity of exercise. They fed subjects either a high carbohydrate, low fat diet (HCLFD) or a mixed diet for a week and found that the diets had no influence on the substrates oxidized during light exercise. However, when measured during an entire 24 hours, the fat and carbohydrate oxidation rates were different depending on the diet consumed. Subjects on the HCLFD oxidized twice as much carbohydrate and about half as much fat as when they were on the mixed diet.

The type of meal taken prior to exercise has been demonstrated to have an effect on the fuel source during exercise. Falecka-Wieczorek and Kaciuba-Uscildo (83) investigated the metabolic responses of dogs during exercise four hours after a high fat meal and four hours after a mixed meal. The plasma FFA levels were higher in the dogs fed the high fat meal than in the dogs fed the mixed meal. Their plasma glycerol levels also were higher, but their plasma triglyceride levels were lower. The researchers stated that these results indicate greater hydrolysis of triglycerides and increased fat oxidation during exercise in dogs fed a single high fat meal.

The Thermic Effect of Food During Exercise

In 1975 Miller and Wise (7) reviewed several studies on the effect of exercise on DIT. They found conflicting results. Some researchers found that energy expenditure during exercise was greater after a meal than before, some found that energy expenditure was lower after a meal and others found no change. Miller and Wise (7) themselves showed that the cost of exercise after a meal depended on the caloric intake of the previous day, but that the cost of exercise before a meal was unaffected by the previous day's intake. Stock (6) observed no significant changes in resting or exercise metabolic rates due to a previous day of fasting or overeating. However, postprandial exercise thermogenesis was greater on the day after overeating. Obarzanek and Levitsky (5) tested the hypothesis that exercise after a previous day of overeating resulted in an increased metabolic rate. They found that neither the RMR nor the thermic effect of food or exercise alone was changed by fasting or overeating on the previous day. But, the difference between preprandial and postprandial exercise after a day of overeating was twice as much as after a day of normal eating. They concluded that excess energy expenditure after overeating was apparent only during postprandial exercise.

As for the size of the meal, Bray et al (2) suggested that a test meal at least 1,000 kcal was necessary to elicit an increase in DIT during exercise. Other studies which support the potentiation of the thermic effect of food during exercise used test meals equal to or larger than 900 kcal (4,15,84).

Segal and Gutin (4) showed that the thermic effect of food increased as much as 30% during exercise compared to that at rest in lean women. In a later study, Segal et al (3) demonstrated a similar increase in the thermic effect of food during exercise in lean men. Miller and Mumford (15) reported that the thermic effect as a percentage of the basal metabolic rate rose from 28% after breakfast alone to 56% after breakfast with exercise. They stated that the thermic response to a 1,000 kcal meal was twice as high during mild exercise as it was at rest. Gleeson et al (8) conducted an experiment similar to that of Miller and Mumford (15) using rats. They found that the thermic effect of food was 7% of the fasting metabolic rate during rest and 11% of the fasting metabolic rate during exercise.

Dauncey (84) examined the effects of different 24 hour energy intakes on the metabolism of man. He showed that the increase in heat production during 30 minutes of cycling after a meal during a 3300±100 kcal diet was no greater than when the subjects consumed the same amount and rested after the meal. He concluded that overeating for one day did not significantly change the energy expenditure during the same day. In an earlier experiment, Durnin and Norgan (52) compared the metabolic rates of men when they were on a normal diet and after six weeks of overeating. They observed increases of 10-12% in the metabolic rate after overeating. The metabolic rate after overeating did not increase more during exercise than while at rest.

Garby and Lammert (12) found no significant effect of the preceding day's caloric intake on oxygen consumption during exercise before or after a test meal. But, they did find a significant difference in the respiratory exchange ratio (R) during exercise before and after a test meal after a day of high caloric intake and after a day of low caloric intake. The R during exercise was lower before and after the test meal after the day of low caloric intake than after the day of high caloric intake. These investigators concluded that their results did not support the theory that excess energy is burned during exercise after overeating.

A lack of interaction between thermic response to a meal and exercise was observed by Dalloso and James (10). They studied men during one week on a weight-maintenance diet and another week when the men were overfed by 50% with fat. An increase in thermic response to meals during the overeating week was demonstrated, but there was no potentiation of the thermic response to meals during exercise. Welle (9) fed subjects an 800 kcal meal and measured changes in metabolic rate during intermittent exercise. He found that the thermic effect of food during exercise was not different from the thermic effect without exercise.

Effects of Exercise Intensity

Segal and Gutin (4) used two different work loads, one subanaerobic threshold and one just slightly below the subjects' anaerobic thresholds. At both work loads, they reported a thermic effect of food during exercise. A later study by Segal et al (3) compared the difference in the thermic effects of food across submaximal power outputs. They found no significant difference. However, at maximum output, they found no thermic effect of food.

Duration of the Thermic Effect

Few of the studies examining the thermic effect of food during exercise have looked at the duration of the effect. Segal and Gutin (4) exercised subjects every half hour for five minutes after a meal. They observed an increase in exercise metabolic rate due to food for as long as four hours after the meal.

Individual Differences

Gleeson et al (8) compared differences in energy expenditure in trained and untrained rats. They observed increased exercise-induced dietary thermogenesis in the trained rats. Segal and Gutin (4) found that eating increased the exercise metabolic rate more for lean women than for obese women and Segal et al (3) found no evidence of a thermic effect of food during exercise in obese men. Segal and Gutin (4) also reported that the greatest potentiation of the thermic effect of food durng exercise at anaerobic and subanaerobic work loads was observed in lean subjects of low fitness levels. And the lowest potentiation of the thermic effect of food during exercise at anaerobic work loads was observed in obese subjects of higher fitness levels.

MATERIALS AND METHODS

Subjects

Eight fitness-oriented young college women (ages 21-27 years) volunteered to serve as subjects. Prior to the trial, they completed a self-report questionnaire in which their medical history and exercise, eating, and other health habits were determined (Appendix 1). Each reported that she had been exercising at least 5d/wk, for a minimum of 30 min/d for at least the previous 5 yrs. Running was the most popular form of exercise reported, but biking, swimming, and weight lifting were also cited. None of the subjects were smokers, diabetic, or were on special or unusual diets. Descriptive data of the subjects are shown in Table 1. All experimental procedures, risks, and benefits were explained to the women prior to the study and they signed an informed subject consent form as required by the Subcommittee on Research Involving Human Subjects, Kansas State University, Manhattan (Appendices 2, 3, and 4).

Procedures

Maximal oxygen uptake (VO_2 $ml \cdot kg^{-1} \cdot min^{-1}$) was assessed by a continuous treadmill protocol. The subjects began running at a slow speed (8.06 km/h) on a zero-grade treadmill. After 2 min, the speed was increased to 9.68 km/h, and held constant for 2 min. Thereafter, the treadmill grade was increased 2.5% every 2 min until the subject was exhausted, (usually 10-14 min). Each subject's VO_2 max was determined

TABLE 1

Subject characteristics

Subject	Age (yrs)	Weight (kg)	Height (m)	Body Fat (%)	LBM (kg)	VO_2 max (ml/min/kg)
1	27	64.20	1.70	24.9	48.2	53.0
2	24	60.51	1.64	17.1	50.1	50.2
3	27	54.77	1.63	19.0	44.4	48.0
4	23	58.95	1.68	19.5	47.4	50.5
5	25	54.54	1.63	16.3	45.6	50.5
6	21	54.88	1.63	20.9	43.4	51.9
7	22	63.00	1.70	23.7	48.1	49.8
8	21	55.90	1.68	15.0	47.5	57.6
Mean	23.7	58.3	1.66	19.5	46.9	51.4
±SD	2.4	3.9	0.03	3.5	2.2	2.9

to be the point at which her VO_2 reached a plateau and the respiratory exchange ratio (R) (VCO_2/VO_2) was greater than 1.15.

The subjects agreed to consume their habitual diet and to refrain from exhaustive exercise for 24 h prior to exercise trials. Each subject completed 4 exercise trials on separate mornings in a randomized order. For one trial, the subjects exercised at 07:30h after a 12-h overnight fast. For each of the other trials, the subjects consumed a test meal after a 12-h overnight fast and began exercising at 30, 60, or 90 min following the end of the meal. The 30, 60, and 90 min post-meal exercise trials began at 07:30h, 08:15h, and 09:00h, respectively. The 940 kcal test meal consisted of 3 Carnation chocolate chip breakfast bars (donated by Carnation Co., Los Angeles, CA) and 16 oz of 1.5% milkfat chocolate milk. The composition of the meal was 46.5% carbohydrate, 14.5% protein, and 39.0% fat. The subjects sat quietly before their exercise bout began. The exercise was 30 min of running on a Quinton treadmill at a workload that averaged 62% VO_2 max.

Oxygen consumption was determined by an open circuit technique. Subjects breathed through a 2-way Daniel's valve and exhaled air passed through a 4.0 l mixing chamber. A continuous gas sample of 500 ml/min was drawn from the mixing chamber and passed in series through CO_2 and O_2 gas analyzers (Beckman LB-2 and OM-11, respectively) which were calibrated before and after each exercise trial using a certified commercial gas preparation. The analog output of the gas analyzers was channeled through A/D converters (Action Instruments) which allowed the display of the gas concentrations of each minute on digital counters (Series 6100- DCI Inc.). Expired air volumes were measured with an Alpha Technologies ventilation meter. The data sheet used to collect indirect calorimetry data is shown in Appendix 5. Minute-by-minute oxygen consumption, carbon dioxide production, respiratory exchange ratio, caloric expenditure, and calories provided from fat were calculated for the last 23 min of each trial. Percentage kcal derived from carbohydrate and fat were calculated from respiratory exchange ratios as shown in Appendix 6.

Body density was determined by hydrostatic weighing using a Chatillon scale. Residual lung volume was assessed by the oxygen dilution technique using a nitrogen analyzer (Hewlett-Packard, Model 47302A). Lean body mass was calculated as the difference between total body weight and the product of percentage fat and body weight. The data sheet used to calculate body composition is shown in Appendix 7.

Data were analyzed using the Least Significant Differences Test following significant ($p<0.05$) analysis of variance procedures (85). The computer program used is shown in Appendix 8.

RESULTS

The mean caloric expenditures of the subjects during the last 23 min of the 30-min treadmill runs begun 30, 60, or 90 min after the meal, or in a fasted state, were not significantly different (range 215-219 kcal) (Fig 1). During the exercise trials 30, 60, and 90 min after the meal, the mean caloric expenditures were 0.6%, 1.8%, and 0.9% greater, respectively, than in the fasted condition.

The mean respiratory exchange ratio (R) was significantly higher in the subjects when they exercised 60 or 90 min after the meal than when they exercised in the fasted state ($p<0.05$) (Fig 2). The difference in R is also reflected in the subjects' calculated fat utilization. When exercised at 60 or 90 min after the meal, the subjects oxidized significantly ($p<0.05$) less fat than when exercised in the fasted state (Fig 3). Fat oxidation was 23% and 37% lower in the trials 60 and 90 min following the meal, respectively, than during the fasted trial. The data for each subject and the statistical analysis are presented in Appendices 9-12.

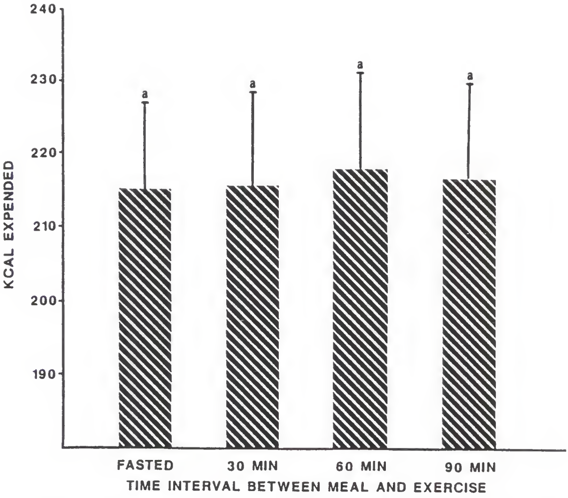

Figure 1. Caloric expenditure during exercise at different time intervals following a meal. (Groups sharing the same letter are not significantly different, $p<0.05$).

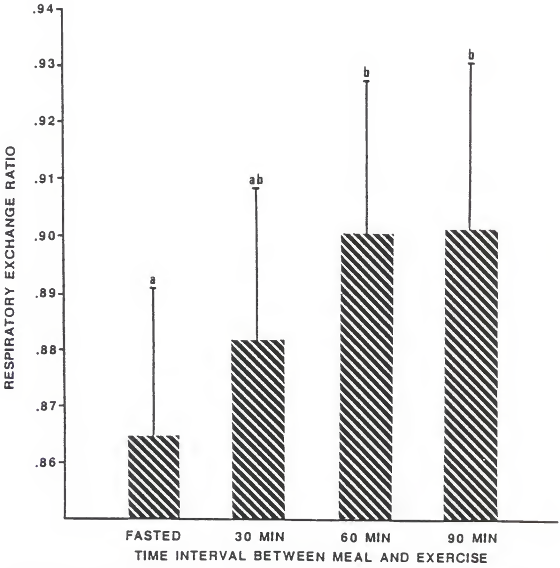

Figure 2. Respiratory exchange ratios during exercise at different time intervals following a meal. (Groups not sharing the same letter are significantly different, $p<0.05$).

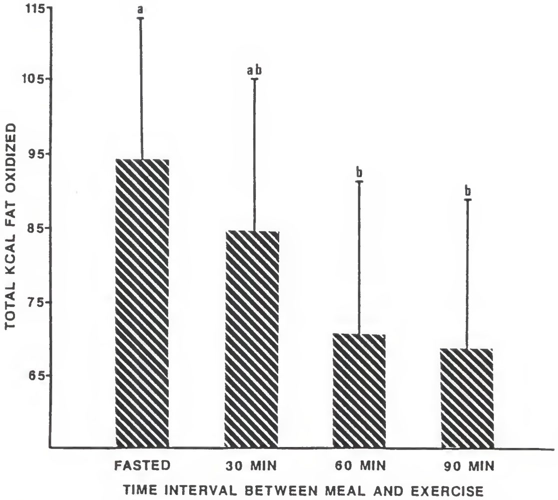

Figure 3. Fat utilization during exercise at different time intervals following a meal. (Groups not sharing the same letter are significantly different, $p<0.05$).

DISCUSSION

Previous research investigating a thermogenic effect of a meal during exercise is beset with inconsistancies. This study used subjects who were lean and physically-fit, consumed a meal of 940 kcal (46.5% carbohydrate, 39.0% fat, and 14.5% protein), and ran for a full 30 min at 62% VO_2 max at discrete intervals following a meal. All of these different factors may have influenced the outcome of this study and contribute to the agreement or disagreement with previous research. The leanness and/or fitness level of the subjects has been identified as an important variable, being associated with an enhanced thermogenic effect in lean (3,4,86) and fit (45,59,60) individuals and a blunted thermogenic effect in obese (3,4,55,56,86) and fit (3,4,61,62) individuals. Meal size has also been implicated, in that a 900 kcal meal appears to be the caloric threshold for a response (2,3,4,7), yet Swindells did not observe a thermogenic effect during exercise following a meal of 1200 kcal (11).

To date, this is the only investigation to use running as the mode of exercise. The cycle ergometer (2,3,4,9,10,70,86), the step test (6), and walking (5,11) have been employed previously. Additionally, in most cases the subjects worked at a common absolute workload (2,6,7,9,10,70) rather than at a common relative workload, as in this study and a few others (3,4,86). Finally, in the present investigation, subjects exercised for 30 min, a typical workout time, at varied time intervals (30, 60, 90 min) following the meal. Earlier studies did not truly investigate the effect of different time intervals between the meal and the exercise, since all the bouts of exercise (which were of only 5-15 min duration) followed the same meal (4,9). Considering the many features that differ among the many studies, it is not surprising that the results have been inconsistent. Obviously, the results of this study are limited to the conditions of the experiment. However, it is believed that the design incorporates more realistic levels and modes of exercise than previous investigations and adds insight into the time course for the influence of the meal on subsequent exercise.

Many studies have demonstrated that consumption of carbohydrate prior to exercise inhibits fat mobilization and creates a greater reliance on carbohydrate sources of energy, particularly, muscle glycogen (87,88,89). Few studies on the thermogenic effect of a meal during exercise have considered this inhibition on fat oxidation, evaluating only total caloric expenditure. Welle (9) reported a rise in respiratory exchange values from exercise in the fasted state to postprandial exercise without converting the these values to the amounts of fat oxidized. With or without additional caloric cost during exercise after a meal, it may be relevant to the goals of fat reduction whether fat oxidation is affected. The results demonstrated that significantly less fat was utilized during the sessions that began 60 and 90 min after the meal, as compared to the fasted condition. Approximately 110 g of carbohydrate was consumed in the meal, which probably led to an increase in blood glucose and insulin. Welle (9) observed increases in blood glucose and insulin during exercise after a meal which also contained 110 g of carbohydrate. Fat use during the session begun 30 min after the meal was intermediate between the fasted and 60 min post-meal conditions and not statistically different from either. The inhibitory effect of elevated insulin, thus, was not fully evident in the 30 min post-meal trial, but by 60 and 90 min post-meal, would most likely be responsible for the reduction in fat oxidation. The data from the respiratory exchange measures indicate that only 32.7% and 31.6% of the total caloric expenditure is provided by fat in the 60 and 90 min post-meal sessions, respectively, as compared to 43.1% during the fasted state.

Further research could help explain the mechanism leading to these results by measuring blood levels of insulin, glucose, and triglycerides, in addition to using indirect calorimetry. Also, investigation of the effects of meal composition, previous diet, and fitness level of the subjects is warranted.

In summary, there was no evidence that exercising shortly after a meal will capitalize on a thermogenic effect of the meal and enhance the caloric expenditure during the exercise. The meal affects substrate utilization during the exercise, however, causing a shift toward greater carbohydrate and reduced fat oxidation.

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APPENDIX

Appendix 1

EXERCISE, DIET, AND MEDICAL QUESTIONNAIRE

This information is strictly confidential and will be used only by the researchers.

Please fill out the following form as completely as possible.

Name:________________________________Age:__________Birthdate:____________

Campus Address:______________________________________Phone:________________

Home Address:_______________________________________Phone:________________

Height:______________ Weight:______________ Sex:_______________

Type(s) of exercise done regularly:____

Number of days you exercise per week:___________

Minutes per exercise bout:_______________

Mileage or intensity of each exercise bout:________________________

How long have you been a regular exerciser:____________________________

Why do you exercise?____

Do you have an health problems that might limit you when exercising?

Do you have any disease that might influence your food intake? (i.e. diabetes, hypoglycemia, etc.)

Do you take any regular medications? If so, list medications and give reason for taking them.

Check if you have any of the following:

__diabetes mellitus	__thyroid disorder	__high blood pressure
__chest pains	__heart murmur	__kidney disorder
__any type of infection	__chronic constipation or irregularity	__diarrhea
__gastric or duodenal ulcer	__frequent indigestion	__anemia
__recent weight change	__poor appetite	__congenital heart problems
__asthma		

How much did you weigh 1, 6, and 12 months ago?

Number of meals you usually eat per day:_______

Number of snacks you usually eat per day:_______

Are you on a special diet? If so, what kind and why?

Appendix 1 (cont'd)

Number of times per week you usually eat:the following and approximate serving sizes:

___ beef

___ pork

___ fish

___ fowl

___ eggs

___variety meats

___ cheese

___ milk

___ other dairy products - list items

___ bread

___ cereal

___ cakes, cookies, pastries

___ other desserts - list items

___ fruit or juices

___ vegetables

___ fats - oils, salad dressing, butter, margarine, etc.

___ legumes, beans, etc.

___ regular soft drinks

___ diet soft drinks

___ beer

___ other alcoholic beverages

List any additional food items that you regularly consume that are not listed.

Appendix 2

TITLE: METABOLIC EFFECTS OF EXERCISE DURING FASTED STATE AND AT 30, 60, OR 90 MINUTES AFTER A MEAL

INVESTIGATORS: Kathy Grunewald and Tony Wilcox, Project Directors
Kate Willcutts, Graduate Assistant

JUSTIFICATION: Reports of the effects of postprandial exercise are not in agreement. Nor has a study been published which compares the effect of exercising after an overnight fast and exercising at different times after a morning meal. In this study, young fitness-oriented women will be used to determine these effects by measuring oxygen consumption and carbon dioxide expired and determining the source of substrate utilization.

AGREEMENT AND RELEASE

1. I volunteer to participate in this study to be conducted during the end of July and the beginning of August, 1985 at Kansas State University. I am an asymptomatic, physically active person without coronary heart disease (CHD) or CHD risk factors. I have not experienced the following: pain in my chest or heart, episodes of rapid heart rates, difficulty in breathing, or a diagnosis of an abnormal electrocardiogram.

2. I will not eat considerably more or less than usual on the days before testing sessions and I will fast overnight and before testing time on the four exercise test mornings.

3. I will consume the test meal of 3 chocolate chip Carnation breakfast bars and 16 oz of low-fat chocolate milk on three mornings before exercise trials.

4. I will allow researchers to perform the following procedures to determine body composition, fitness level, and metabolic effects of exercise:

   a. Hydrostatic (underwater) weighing. This involves sitting submerged in a water tank, exhaling maximally, and staying under water a few seconds until the weight is read.

   b. Fitness level will be determined by measuring maximal oxygen consumption during exercise on a treadmill. The test starts at a slow speed and 0% elevation, then gradually increases elevation until the effort causes fatigue which occurs in 8 to 12 minutes. I will indicate to the investigator when I want the test ended. The effort is similar to the effort of competing in a half mile race.

   c. Oxygen consumption will be measure during 30 minutes of jogging on a treadmill on 4 mornings. One morning I will be fasted, the other 3 mornings I will be fed a test meal and exercised at 30, 60, or 90 minutes after the meal.

5. I have been completely informed as to and understand the nature and purpose of this research. The researchers have offered to answer any further questions that I may have. I understand that I will be able to withdraw from the study at any time of my own accord.

6. I realize that reports will be made of this study and I consent to publication of such if strict confidentiality is maintained by identifying my data only by a number and not by my name.

7. I have informed that this study should increase our knowledge of the optimal time, with respect to meals, to exercise for weight control. The benefits to me will include: gaining information about my 1) caloric cost of jogging at different times after a meal and after fasting, 2) body composition and 3) fitness level.

Date:________________________________ Signed:________________________________

College of Home Economics

APPLICATION FOR APPROVAL TO USE HUMAN SUBJECTS

1. ACTIVITY OR PROJECT TITLE: "Metabolic effects of exercise during fasted state and at 30, 60, or 90 minutes after a meal"

2. PROPOSED SPONSOR (IF ANY): (none)

3. Kathy Grunewald, Ph.D., R.D. — NAME (applicant must be faculty member) | Foods and Nutrition — DEPARTMENT | 532-5508 — PHONE

4. RISK

   A. Are there risks to human subjects? ____ yes __X__ no

   If yes, briefly describe. (See definition of risk, page 2 of the Handbook.)

   Treadmill exercise might present some risk for certain segments of the population, but our subjects will be fitness-oriented young women screened for medical problems. Therefore we believe the risks are minimal. (see page 5).

   B. Describe the benefits of the research

   a) to the subjects: Subjects will learn their calorie expenditure during treadmill exercise following a fast or meal; also will learn their body composition and fitness levels.

   b) to the discipline/profession: The main question that will be answered by this research is, "does exercise at specific time intervals following a meal enhance the thermic effect (caloric expenditure) of that meal?" The implications for weight control are obvious.

5. INFORMED CONSENT: General informed consent requirements are described on pages 3 and 4 of the Handbook. The written informed consent document must include the following: (1) a fair explanation of procedures to be followed, (2) description of discomforts and risks, (3) description of benefits, (4) disclosure of appropriate alternatives available, (5) an offer to answer inquiries, and (6) instructions that the subject is free to withdraw consent and participation at any time. Special informed consent policies relative to questionnaire/survey studies are described in the "Handbook Supplement" dated July, 1977.

   On what page(s) of the proposal are your informed consent procedure and/or forms described? (If not a part of your proposal, the procedures and informed consent document must accompany this application.)

   The procedures are on pages 2 and 3 attached. The informed consent document is on page 4 attached.

(OVER)

6. EMERGENCIES

A. Are any possible emergencies anticipated? _____ yes __x__ no

If yes, describe briefly or give the page of the proposal where these are described. (researchers will be well trained on use of equipment)

B. Describe procedures for dealing with emergencies, or give the page of the proposal on which these descriptions may be found.

7. PRIVACY: On what page of the proposal do you discuss procedures for keeping research data private? __page 4__ This should include procedures for maintaining anonymity of subjects. Supplemental information concerning privacy of data may be discussed below. (See page 3 of the Handbook on "Safeguarding Information.")

8. STATEMENT OF AGREEMENT: The below named individual certifies that he/she has read and is willing to conduct these activities in accordance with the Handbook for Research, Development, Demonstration, or Other Activities Involving Human Subjects. Further, the below named individual certifies that any changes in procedures from those outlined above or in the attached proposal will be cleared through Committee 8290, The Committee on Research Involving Human Subjects via the College of Home Economics Subcommittee.

Signed ______________________ (Applicant) Date May 17, 1985

Send applications to:

Appendix 4

KSU
KANSAS STATE UNIVERSITY

Department of Foods and Nutrition

Justin Hall
Manhattan, Kansas 66506
913-532-5508

May 30, 1985

TITLE: Metabolic Effects of Exercise During Fasted State and at 30, 60, or 90 Minutes After A Meal

PRINCIPAL INVESTIGATOR: Katharine Grunewald Ph.D.
Foods & Nutrition

Research activities involving no more than minimal risk and in which the only involvement of human subjects is within selected categories may be reviewed by the expedited review procedure authorized in 45CFR46:110 #3 & 8. The proposal is recommended for approval for a period of 12 months. If this proposal extends beyond 12 months from its date of approval, the proposal must again be reviewed by the subcommittee. Request for an extension of approval is the responsibility of the principal investigator. Any substantial revision in this study relative to human subjects should be reviewed again by the college subcommittee.

Robert D. Reeves, Ph.D.
Chairman
Subcommittee on Research Involving Human Subjects

Appendix 5

Name ______________________________ Date ______________

Time ______________________________ P_B ______________

Speed ______________________________ Time since last meal __________

min	Vol	O_2	CO_2	temp	min	Vol	O_2	CO_2	temp
1	___	___	___	___	16	___	___	___	___
2	___	___	___	___	17	___	___	___	___
3	___	___	___	___	18	___	___	___	___
4	___	___	___	___	19	___	___	___	___
5	___	___	___	___	20	___	___	___	___
6	___	___	___	___	21	___	___	___	___
7	___	___	___	___	22	___	___	___	___
8	___	___	___	___	23	___	___	___	___
9	___	___	___	___	24	___	___	___	___
10	___	___	___	___	25	___	___	___	___
11	___	___	___	___	26	___	___	___	___
12	___	___	___	___	27	___	___	___	___
13	___	___	___	___	28	___	___	___	___
14	___	___	___	___	29	___	___	___	___
15	___	___	___	___	30	___	___	___	___

Appendix 6

TABLE 8-1. *Thermal equivalent of oxygen for nonprotein respiratory quotient, including percent kcal and grams derived from carbohydrate and fat*

NONPROTEIN RQ	KCAL PER LITER OXYGEN CONSUMED	PERCENTAGE KCAL DERIVED FROM		GRAMS PER LITER O_2 CONSUMED	
		CARBOHYDRATE	FAT	CARBOHYDRATE	FAT
0.707	4.686	0	100	0.000	496
71	4.690	1.10	98.9	012	491
72	4.702	4.76	95.2	.051	476
.73	4.714	8.40	91.6	.090	460
.74	4.727	12.0	88.0	.130	.444
.75	4.739	15.6	84.4	.170	.428
76	4.751	19.2	80.8	.211	412
.77	4.764	22.8	77.2	.250	.396
78	4.776	26.3	73.7	.290	.380
.79	4.788	29.9	70.1	.330	.363
.80	4.801	33.4	66.6	.371	.347
81	4.813	36.9	63.1	413	.330
.82	4.825	40.3	59.7	454	.313
83	4 838	43.8	56.2	.496	.297
.84	4.850	47.2	52.8	.537	.280
.85	4.862	50.7	49.3	.579	263
.86	4.875	54.1	45.9	.621	.247
.87	4.887	57.5	42.5	663	.230
88	4.899	60.8	39.2	.705	213
89	4.911	64.2	35.8	.749	.195
.90	4.924	67.5	32.5	.791	.178
.91	4.936	70.8	29.2	.834	160
92	4.948	74.1	25.9	.877	.143
.93	4.961	77.4	22.6	.921	.125
94	4.973	80.7	19.3	.964	.108
.95	4.985	84.0	16.0	1.008	.090
.96	4.998	87.2	12.8	1.052	.072
.97	5.010	90.4	9.58	1.097	.054
98	5.022	93.6	6.37	1.142	.036
99	5.035	96.8	3.18	1.186	.018
1.00	5.047	100.0	0	1.231	.000

Appendix 7

Body Composition

Name: ______________________ Weight (kg): ______________________

Age: ______________________ Weight (lbs): ______________________

Date: ______________________ Height (inches): ______________________

Residual Volume

	Trial I	Trial II
Volume	____	____
N_2 (Initial)	____	____
N_2 (Equil)	____	____
N_2 (Final)	____	____
T^oC	____	____

	BTPS corr.
20^oC	1.102
21	1.096
22	1.091
23	1.085
24	1.080
25	1.075
26	1.068

Trial I

$$\frac{\text{Volume } \_\_\_\_ + 1.60 \times ({N_2}_{EQ} \_\_\_\_ - \text{Imp } O_2)}{N_{2(I)} \_\_\_\_ - N_{2(f)} \_\_\_\_} - .08 = \_\_\_\_ \times BTPS = \_\_\_\_$$

Trial II

Underwater Weighing

water weight (Kg)

____

____

____

____

____

____

____

____

Mw-tare ________

Tare Weight = ________

Water Temp = ________

Water density = .99

Residual Volume= ________

$$D_b = \frac{Ma}{\frac{Ma-Mw}{D_w} - RV} =$$

Fat (Kg) = ________

Fat (lbs)= ________

LBW (Kg) = ________

LBW (lbs)= ________

$$\% \text{ Fat} = (\frac{4.95}{Db} - 4.5) \times 100\%$$

Appendix 8

```
//WILLCUTT JOB                              ,'KATE',TIME=(,12)
/*REGION        300K
// EXEC SAS
//SYSIN DD *
OPTIONS LS=78;
DATA ONE;
INPUT (SUBJECT TRIAL TIME VEA1 VEA2 O2 CO2 STPD)
      (1. 2. 3. 2*7.2 2*6. 4.3);
IF SUBJECT=7 AND TRIAL=4 OR SUBJECT=8 AND TRIAL=3
 THEN VES=(VEA2-VEA1+.378)*STPD;
IF SUBJECT=8 AND TRIAL=1
 THEN VES=(VEA2-VEA1+.455)*STPD;
IF SUBJECT=8 AND TRIAL=4
 THEN VES=(VEA2-VEA1+.444)*STPD;
IF SUBJECT<7 OR SUBJECT=7 AND TRIAL<4
 THEN VES=(VEA2-VEA1+.5)*STPD;
IF SUBJECT=8 AND TRIAL=2
 THEN VES=(VEA2-VEA1+.5)*STPD;
VO2=VES*(((1-(O2/300000)-(CO2/600000))*.265)-O2/300000);
VCO2=VES*(CO2/600000-.0003);
RQ=VCO2/VO2;
KCALLO2=1.232*RQ+3.815;
KCALMIN=VO2*(1.232*RQ+3.815);
KCALFAT=KCALMIN*(402.4266-489.075*RQ+86.69*RQ*RQ)/100;
CARDS;
$ADD EXERCISE
PROC SORT; BY SUBJECT TRIAL;
PROC MEANS NOPRINT MEAN SUM;
BY SUBJECT TRIAL;
VAR VO2 RQ KCALMIN KCALFAT;
OUTPUT OUT=TWO
   SUM=SVO2 SRQ SKCALMIN SKCALFAT
   MEAN=MVO2 MRQ MKCALMIN MKCALFAT;
PROC PRINT DATA=TWO;
PROC ANOVA;
CLASSES SUBJECT TRIAL;
MODEL SVO2 MVO2 MKCALMIN MKCALFAT MRQ SKCALMIN SKCALFAT= SUBJECT TRIAL;
MEANS TRIAL/LSD;
/*
```

Appendix 9

Mean caloric expenditure during 23 minutes of exercise at different time intervals after a meal and in the fasted state

Subject	Condition			
	Fasted	30 min	60 min	90 min
1	241.8	246.8	259.6	236.4
2	243.0	255.5	248.2	236.6
3	192.5	166.6	215.4	208.4
4	209.9	221.8	205.2	208.3
5	186.2	188.1	195.2	191.1
6	232.7	217.7	209.3	237.4
7	207.0	216.0	215.0	212.6
8	209.0	219.8	206.0	207.1
	215.3±21.6*	216.6±28.7	219.2±22.5	217.3±17.4

*Mean±SEM.

Appendix 10

Mean respiratory exchange ratio during 23 minutes of exercise at different time intervals after a meal and in the fasted state

Subject	Condition			
	Fasted	30 min	60 min	90 min
1	0.858	0.825	0.860	0.884
2	0.880	0.878	0.906	0.874
3	0.825	0.894	0.873	0.869
4	0.869	0.896	0.936	0.879
5	0.841	0.899	0.896	0.950
6	0.924	0.894	0.927	0.910
7	0.843	0.900	0.924	0.940
8	0.879	0.871	0.885	0.928
	0.865±0.03*	0.882±0.03	0.901±0.03	0.904±0.03

*Mean±SEM.

Appendix 11

Mean calories expended from fat during 23 minutes of exercise at different time intervals after a meal and in the fasted state

Subject	Condition			
	Fasted	30 min	60 min	90 min
1	112.3	143.3	120.1	89.8
2	95.0	102.5	75.6	98.0
3	111.9	57.9	89.3	90.1
4	90.5	75.2	42.3	82.5
5	97.7	61.7	65.6	30.7
6	57.4	75.3	49.7	70.1
7	107.6	70.2	53.6	41.2
8	82.4	92.8	77.1	48.0
	94.3±18.3*	84.9±27.9	71.7±25.1	68.8±25.6

*Mean±SEM.

Appendix 12

SAS

GENERAL LINEAR MODELS PROCEDURE

LEAST SQUARES MEANS

TRIAL	MRQ LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3	4
1	0.86529728	0.01029541	0.0001	1	.	0.2562	0.0206	0.0126
2	0.88217216	0.01029541	0.0001	2	0.2562	.	0.2062	0.1429
3	0.90101588	0.01029541	0.0001	3	0.0206	0.2052	.	0.8325
4	0.90412150	0.01029541	0.0001	4	0.0126	0.1429	0.8326	.

TRIAL	SKCALMIN LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3	4
1	212.903078	8.255522	0.0001	1	.	0.7571	0.5921	0.7115
2	216.548933	8.255522	0.0001	2	0.7571	.	0.8200	0.9516
3	219.230706	8.255522	0.0001	3	0.5921	0.8200	.	0.8675
4	217.264454	8.255522	0.0001	4	0.7115	0.9516	0.8675	.

TRIAL	SKCALFAT LSMEAN	STD ERR LSMEAN	PROB > |T| HO:LSMEAN=0	PROB > |T| HO: LSMEAN(I)=LSMEAN(J) I/J	1	2	3	4
1	93.1913928	8.7342283	0.0001	1	.	0.5057	0.0923	0.0583
2	84.5628484	8.7342283	0.0001	2	0.5057	.	0.2944	0.2045
3	71.6635387	8.7342283	0.0001	3	0.0923	0.2944	.	0.8189
4	68.8090769	8.7342283	0.0001	4	0.0583	0.2043	0.8189	.

ENERGY METABOLISM DURING EXERCISE AT
DIFFERENT TIME INTERVALS FOLLOWING A MEAL

by

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B.A., Knox College, 1983

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

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1986

ABSTRACT

The objective of this study was to compare caloric expenditure and type of fuel used during exercise begun at different time intervals following a standard test meal or in the fasted state. Eight physically-fit young women (ages 21-27) participated in four separate exercise trials after fasting overnight. In three trials, the subjects consumed a 940 kcal breakfast and began exercising either 30, 60, or 90 minutes after the meal. In one trial the subjects did not consume any breakfast but exercised after an overnight fast. Energy expenditure and substrate utilization were determined by indirect calorimetry during the last 23 minutes of a 30-minute run on a treadmill at an average workload of 62% VO_2 max. There were no significant differences among trials when comparing the total caloric expenditures (range 215-219 kcal). However, subjects oxidized significantly more fat (94.3 kcal) when exercised on an empty stomach than they did when exercised 60 and 90 minutes after the meal (71.6 and 68.8 kcal, respectively).