THE COMPARATIVE EFFECTS OF LOW ERUCIC ACID RAPESEED OIL AND SOYBEAN OIL ON ENERGY METABOLISM IN YOUNG ADULT MEN

A Thesis

Presented to

The Faculty of Graduate Studies

University of Manitoba

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

DEPARTMENT OF FOODS AND NUTRITION

by

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September 1975

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ABSTRACT

The comparative effects of low erucic acid rapeseed oil (RSO) and soybean oil (SO) on energy metabolism were investigated in 8 male subjects. Energy metabolism was assessed by monitoring both respiratory (oxygen consumption, ventilation rate, heart rate and respiratory quotient) and blood parameters (serum glucose, plasma lactate and pyruvate, serum free fatty acids, serum glycerol and the calculated lactate/pyruvate ratio). The 32-day metabolic study consisted of four experimental periods of 8 days each. Experimental period I served as a stabilization period during which time a mixed fat diet was fed. During experimental periods II and III the diet contained either RSO or SO as the sole dietary fat. The diets were fed in a cross-over experimental design. During experimental period IV, the subjects again received a mixed fat diet. On the 7th day of each experimental period all subjects cycled at a uniform work load of 70% VO_2 max. On the 8th day of each experimental period subjects cycled at an adjusted work load of either 60 or 80% VO_2 max. Each 30 minute exercise protocol consisted of a 5 minute resting period, followed by a 15 minute exercise period and a 10 minute recovery period. Respiratory measurements were monitored continuously throughout the exercise sessions at both uniform and adjusted work loads. Blood samples were taken during exercise sessions at a uniform work load during rest, with 30 seconds following exercise and at the end of the recovery period. The diet consisted of ordinary foods with minimal fat content to ensure that the test fats comprised 95% of the total dietary fat. Diet had no significant effect on respiratory parameters at uniform or adjusted work loads, with the exception of heart rate. Mean heart rate for subjects fed the RSO diet was higher during exercise and recovery at adjusted work loads of 60 and 80% VO_2 max, than the mean heart rate for subjects fed the SO diet. There was significant interaction between the RSO and SO diets and adjusted work loads with respect to oxygen consumption, as well as significant interaction between the RSO and SO diets and rest and recovery, with respect to heart rate for subjects exercised at adjusted work loads. Diet had no significant effect on any of the blood parameters measured. The mean lactate/pyruvate ratios for subjects were comparable during rest, exercise and recovery irrespective of diet, suggesting that the oxidation: reduction potential of the muscular tissues was not altered by substitution of the SO or RSO diets for the mixed fat diet. Results indicated that the ingestion of a diet containing low erucic acid RSO as the sole source of dietary fat by 8 young adult men for 8 days had effects on energy metabolism which were similar to those when the diet contained SO.

ACKNOWLEDGEMENTS

The author would like to express her sincere appreciation to Dr. Vivian Bruce, Associate Professor, Department of Foods and Nutrition for her help in conducting the metabolic study and her guidance in the preparation of this manuscript; to Dr. B.E. McDonald, Professor, Department of Foods and Nutrition for his help in directing the research; to Dr. Bruce Johnston, Associate Professor, Department of Statistics, for his guidance in conducting the statistical analysis; to Dr. Victor Corroll, Associate Professor, School of Physical Education for help and advice in conducting the exercise protocol; and to Murray Ardies, School of Physical Education, for technical assistance in conducting the exercise protocol. Appreciation is also extended to the eight subjects who participated in the study, and to the laboratory and clerical staff of the Department of Foods and Nutrition. Special thanks is extended to my parents and to P.R.W., D.P., R.M., D.S. and K.F. for their encouragement and support during the preparation of this thesis. This research was funded by grants from the Defence Research Board and the Rapeseed Association of Canada.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

INTRODUCTION

Rapeseed was first grown commercially in Canada in 1943 as a war measure to supply oil for marine engines. Since then rapeseed has become Canada's major oilseed crop and third most important grain crop.

Prior to 1973 rapeseed produced in Canada was characterized by a high erucic acid content--approximately 38% of total fatty acid content. As of December 1, 1973 edible oil processors at the request of National Health and Welfare switched the production of rapeseed oil to the low erucic acid type. The shift to low erucic acid varieties stemmed from observations that long chain monoenoic acids, such as erucic acid, caused pathological changes in tissues, predominantly those dependent on fat for energy, namely the heart and skeletal muscle (Abdellatif and Vles, 1970; Beare-Rogers and Nera, 1972). Subsequently, low erucic acid rapeseed oil has been associated with necrosis and fibrosis in the myocardium of experimental animals (Rocquelin and Cluzan, 1968; Beare-Rogers et al., 1974).

There have been conflicting reports on the effects of rapeseed oil on energy production. Houtsmuller et al. (1970) reported decreased oxygen consumption and ATP synthesis for isolated heart mitochondria from rats fed high erucic acid rapeseed oil. Trémolières et al. (1971) reported decreased oxygen consumption during exercise for subjects fed a single dose of high erucic acid rapeseed oil, as compared to peanut

oil, as well as decreased respiratory quotients during rest, which were attributed to preferential oxidation of fatty acids. Lake (1975) reported that the ingestion of 126 grams of low erucic acid rapeseed oil daily for 10 days had no deleterious effect on energy metabolism of subjects at rest or during exercise.

The present study was designed to compare the effects of low erucic acid rapeseed oil (Brassica Napus cultivar Tower) and soybean oil on energy metabolism of adult male subjects both at rest and during exercise. Energy metabolism was assessed by monitoring both respiratory (oxygen consumption, ventilation rate, heart rate and respiratory quotient) and blood parameters (serum glucose, plasma lactate and pyruvate concentrations, lactate/pyruvate ratios, serum free fatty acids and serum glycerol).

REVIEW OF LITERATURE

Two varieties of the Brassica species of rapeseed are grown in Canada, Brassica Napus and Brassica Campestris. Oils from the Brassica seed are characterized by a significant content of the long chain monoenoic fatty acids, eicosenoic ($C_{20:1}$) and erucic ($C_{22:1}$), a relatively low level of linoleic acid and the saturated fatty acids, palmitic and stearic, and moderate amounts of linolenic acid. Rapeseed oil (RSO) differs from other vegetables oils, both in its significant content of long chain monoenoic acids, and its relatively low saturated fatty acid content (Downey et al.,1975).

Early varieties of RSO characterized by an erucic acid content as high as 45%, were associated with depressed growth and food intake in rats (Boer et al.,1947; Deuel et al., 1948; Beare et al.,1957) as well as severe myocardial abnormalities, including interstitial inflammatory changes, foci of histiocyte infiltration, lipidosis, necrosis and fibrosis (Roine et al.,1960; Craig and Beare, 1967; Rocquelin and Cluzan, 1968; Beare-Rogers et al.,1972). Maximum fat accumulation in the myocardium due, mainly to an increase of triglycerides containing large amounts of erucic acid, was reported to occur in 3 to 6 days, and to decrease to near normal levels after approximately 16 weeks (Beare-Rogers, 1970; Abdellatif and Vles, 1973). With the introduction of low erucic acid RSO with an erucic acid content of 5% or less, rats no longer showed depressed growth and food intake

(Craig and Beare, 1967; Rocquelin and Cluzan, 1968). However, studies on the effects of low erucic acid RSO on changes in the myocardium have produced conflicting results. Low erucic acid RSO is reported not to be associated with cardiac lipidosis (Craig and Beare, 1967; Beare-Rogers, 1970; Beare-Rogers et al.,1971; Rocquelin et al., 1973), but has been associated with necrosis and fibrosis of the myocardium (Rocquelin and Cluzan, 1968; Kramer et al.,1973; Beare-Rogers et al.,1974).

Metabolism of Erucic Acid

Evidence that rats fed RSO incorporated into tissues a relatively small proportion of dietary erucic acid, but produced an unusually high proportion of oleic acid suggested that erucic acid underwent B-oxidation (Craig et al.,1963 a,b; Beare et al.,1963) which was later verified by Craig and Beare (1967).

The accumulatiom of triglycerides in the myocardium of experimental animals fed high erucic acid RSO has been attributed to an inhibition of B-oxidation (Christophersen and Bremer, 1972), reduced activity of fatty acid oxidation enzymes (Kramer et al.,1973; Swarttouw, 1974), an increased uptake of fatty acids (Gumpen et al.,1973), and impaired respiratory activity (Houtsmuller et al.,1970).

Christophersen and Bremer (1972) have reported that the presence of erucylcarnitine caused a significant inhibition of the mitochondrial oxidation of palmitylcarnitine--

the inhibition being significantly more pronounced in the heart than in the liver mitochondria. The oxygen uptake of liver mitochondria however, was reported to be more inhibited by erucylcarnitine in the presence of malonate than malate, suggesting an inhibition of B-oxidation of palmitate. It is suggested that erucic acid inhibits the oxidation of other fatty acids, causing them to accumulate and be channelled into other pathways which are uninhibited or relatively less inhibited, such as triglyceride synthesis.

Erucic acid may undergo a relatively slow catabolism as compared to other fatty acids due to a reduced activity of the enzymes of fatty acid activation and B-oxidation for erucic acid. Swarttouw (1974) in a study on isolated rat heart mitochondria, reported a slower conversion rate for erucate than for palmitate in all enzymic reactions occurring in the oxidation of fatty acids. In addition to reduced activity of the enzymes of fatty acid activation and B-oxidation for erucic acid, Kramer et al. (1973) reported reduced levels of triglyceride lipase may be associated with the accumulation of fat in tissues of animals fed high erucic acid RSO.

Jaillard et al. (1973) have suggested that erucic acid may be more slowly catabolized than other fatty acids, because it must first undergo shortening of the chain in an extra-mitochondrial process before B-oxidation can occur in the mitochondria.

Swarttouw (1974) however, observed a decreased affinity of albumin for erucic acid, and has not ruled out the possibility that weaker binding to carrier proteins may result in differences in the transport of erucic acid to the site of B-oxidation.

RSO high in erucic acid has been reported to increase fatty acid uptake of fat utilizing tissues. Gumpen and Nörum et al. (1973) reported that the fractional amount of long chain acyl-carnitines of the rat heart remained unchanged after a RSO diet, while high levels of acyl-carnitines accumulated in the liver and brown adipose tissues. It was suggested that the latter reflected increased uptake of fatty acids and high oxidation rates, whereas the unchanged acyl-carnitines in the heart reflected unaltered myocardial fat oxidation, despite increased uptake of fatty acids, due to an inhibition of B-oxidation. A decrease in triglyceride content of the heart could then be attributed to decreased fatty acid uptake rather than to an increased ability of heart mitochondria to oxidize incoming fatty acids.

The rapid decrease in cardiac lipids after the first week of a RSO diet has been attributed to an enzymic adaptation at either the extra or intra-mitochondrial level (Jaillard et al., 1973). Struijk et al. (1973) have also reported a high erucic acid RSO diet increased postheparin lipoprotein lipase activity of the plasma after a feeding period of 3 to 6 days which would coincide with the rapid

decrease in triglyceride content of the heart in experimental animals fed RSO.

Houtsmuller et al. (1970) reported that isolated heart mitochondria of rats fed high erucic acid RSO oxidized glutamate and other substrates including α-oxoglutarate, caprinate and succinate at a reduced rate, and that there was an inverse relationship between the decrease in oxygen uptake and the erucic content of the heart. Other investigators (Kramer et al., 1973) have reported a decrease in palmitylcarnitine oxidation in heart mitochondria of rats fed high erucic acid RSO, but in contrast to Houtsmuller et al. (1970) observed no marked difference in oxygen uptake or energy production. The differences between these results may have been due to improper isolation of mitochondria (Kramer et al., 1973).

Studies on the utilization of RSO for energy production in the human are limited. Trémolières et al., (1971) investigated the effect of a single dose of a high erucic acid RSO in man at rest and during mild exercise at work loads of 120 and 240 kpm/min. They observed a decrease in respiratory quotient (RQ) followed by a rise during exercise. Peanut oil did not produce a similar decrease in RQ during rest, and produced a smaller increase in RQ during exercise. The decrease in RQ during rest was interpreted as preferential oxidation of fatty acids after the ingestion of RSO. No significant differences in plasma

concentrations of lactate and pyruvate were observed between the two diets, suggesting that mitochondrial function was not altered. However, decreased oxygen consumption was observed during exercise after the ingestion of RSO. No significant differences in serum free fatty acids were observed at rest or during exercise after the ingestion of either RSO or peanut oil.

Lake (1975) compared the effect of low erucic acid RSO and soybean oil on energy metabolism in 4 male subjects, both at rest and during exercise at a standardized work load of 950 kpm/min. In contrast to the work of Trémolières et al., (1971) on high erucic acid RSO, results did not indicate preferential oxidation of fatty acids. Respiratory measurements and blood samples were taken during exercise sessions both after a single meal and after prolonged feeding of the test fats. No significant differences were found in oxygen consumption, ventilation rate, or RQ during rest or exercise on either the soybean or low erucic acid RSO. Similarly, no significant differences in serum glucose, serum free glycerol, plasma lactate and pyruvate concentrations or the lactate/pyruvate ratio were observed between the test fats.

Whether the differences in metabolism of RSO are related to the erucic acid content or some other factor is not known at the present time. In order to further elucidate the effect of low erucic acid RSO on energy utilization in man, a study similar to the one reported by Lake (1975) was

conducted involving 8 subjects and graded work loads of 60, 70 and 80% VO_2 max.

Energy Metabolism

Energy requirements of the body are met by the breakdown of adenosine triphosphate (ATP)---a high energy phosphate compound to adenosine diphosphate (ADP) and phosphate (P). The supply of ATP is derived from energy produced by the oxidation of foodstuffs in a process called aerobic metabolism. When the energy requirements of the body are increased during exercise, there is an increased turnover rate of ATP.

During moderate exercise the restoration of ATP may continue to depend on energy derived from aerobic metabolism as reflected by an increased oxygen consumption. Carbohydrate in the form of a molecule of glucose or glycogen is metabolized to pyruvate with the formation of 2 moles of ATP. Pyruvate is then oxidized by way of the tricarboxylic acid cycle and respiratory chain to carbon dioxide and water.

If the maximal rate of oxygen consumption does not supply adequate oxygen to restore the ATP as rapidly as it is broken down, the energy needs are provided by anaerobic metabolism. Pyruvate is reduced to lactic acid instead of being oxidized to carbon dioxide and water. This results in the production of lactic acid and a low yield of ATP, only 2 moles of ATP per molecule of glucose, as compared to 38 moles of ATP produced during aerobic metabolism.

Oxygen Consumption

At the beginning of exercise there exists a greater need for oxygen than the cardiorespiratory processes can provide. During this transitional unsteady state, oxygen consumption will not reflect total energy needs. It is during this initial lag period, before the supply of oxygen has been increased by adjustments in ventilation and circulation, that anaerobic metabolism and the utilization of phosphagen stores (ATP and creatinine phosphate) of the muscle play an indispensable role in meeting energy requirements.

Oxygen uptake at the beginning of work is thought to depend on oxygen supply and perhaps ultimately on blood flow through the working muscles (Craig, 1972). Thereafter, oxygen consumption is reported to increase exponentially with time, the maximum level attained being unrelated to the intensity of exercise except in exercise of very high intensity and short duration (Margaria et al., 1963). However, the time to steady state has been reported to increase with the intensity of exercise. Wasserman et al. (1967) reported that oxygen consumption rose for a longer period of time when the subject exercised at heavy work rates as compared to more moderate work rates. Whipp and Wasserman (1972) reported that a steady state was progressively delayed at higher work rates, the difference between oxygen consumption at 3 and 6 minutes at each work level being increasingly greater, the higher the work rate. Di Prampero et al. (1970) however, reported

that the pattern of the rise in oxygen consumption to a steady state is the same regardless of work intensity, although this may have been due to the duration of exercise (Whipp and Wasserman, 1972). Bason et al. (1973) studied the time to steady state at work loads of 30, 60 and 80% VO_2 max at various altitudes. Data suggested that the rate of change in oxygen uptake is related only to the intensity of work, being more delayed the greater the intensity. A steady state was reached in 6 and 20 minutes at work loads of 30 and 60% VO_2 max, respectively. A steady state was not reached by any of the subjects exercising at 80% VO_2 max.

There are several reasons for the delayed return of oxygen uptake to resting levels following exercise. These include restoration of the oxygen stores of the body, aerobic removal of anaerobic metabolites, elevated metabolism due to an increase in tissue temperature and a possible increased output of adrenalin, and increased oxygen demands of the respiratory muscles and heart (Astrand and Rodahl, 1970).

Lactic Acid

The increase in lactic acid during exercise has been well documented since the early work of Hill and Lupton (1923) who reported that the higher the blood lactic acid level, the greater the oxygen debt. The latter was coined as an expression of the fact that the deficit in oxygen intake during strenuous exercise represented a debt that was repaid during recovery. Margaria et al. (1933) however,

introduced evidence of an alactacid oxygen debt mechanism to explain the consumption of excess oxygen during recovery, following moderate exercise without an increase in lactic acid. It is now well established that the oxygen debt payment is made up of two distinct processes to which the names alactacid and lactacid oxygen debt are given. The payment of the alactacid debt is a much slower process than that of the lactacid debt. The alacatacid portion of the debt is reported to be linearly related to the intensity of the exercise and oxygen uptake, while the lactacid oxygen debt is reported to accumulate only when the maximum oxygen consumption is approached (Margaria et al., 1963).

Since both lactic acid production and the oxidative reactions are known to be delayed at the start of exercise, the energy used during the first few seconds of exercise must be solely provided by the utilization of phosphagen (Margaria et al., 1967). During the initial minute of exercise before a steady state has been reached, the sum of the oxygen stored in the vicinity of the muscle mitochondria (oxymyoglobin, oxyhemoglobin, and oxygen dissolved in tissue fluids), and increased volume of oxygen extracted by the tissue from the increased blood flow may be adequate to allow exercise to be performed without anaerobic metabolism. The restoration of these oxidative sources presumably accounts for the major part of the alactic debt (Whipp et al., 1970).

If the work rate is excessive the total oxygen available may be inadequate during the early minutes of exercise. Additional energy is derived from anaerobic metabolism. As the oxygen stores are mainly used in the first minute of exercise (Astrand et al., 1960; Christensen et al., 1960), anaerobic metabolism would occur after the first minute and before steady state conditions have been reached (Whipp et al., 1970).

Peak blood lactate concentrations are generally reported to occur within the first 5 to 10 minutes of moderate exercise (Bang, 1936; Harris et al., 1962; De Coster et al., 1969), although blood lactate may continue to increase beyond this time especially during exhaustive exercise (De Coster et al., 1969).

Some uncertainty exists concerning the work intensity or oxygen requirements needed to initiate the accumulation of blood lactate. Margaria et al. (1933) reported that no extra lactic acid accumulated in the blood of a trained athlete during or after exercise when the oxygen requirement was less than 2.5 liters/minute. Knuttgen (1962) however, reported that in untrained subjects, lactic acid accumulated when oxygen consumption during exercise exceeded 1.5 liters/minute. When work intensity is expressed as a function of the percent VO_2 max, Costill (1970) reported that energy requirements of trained runners must exceed 70% VO_2 max before lactic acid begins to accumulate. Shepherd et al.

(1968) reported significant anaerobic metabolism in normally active men at 65% VO_2 max, although Costill (1970) has suggested that the blood lactate values of Shepherd et al. (1968) appeared to be above resting values at only 50% VO_2 max. This would support the conclusion of Margaria et al. (1933) that lactic acid accumulated at relatively lower work rates in untrained as compared to trained individuals.

Saiki et al. (1967) however, reported that no appreciable lactic acid production occurs at submaximal work levels once a steady state level of oxygen consumption is reached, and that lactic acid production is limited to the first phase of exercise during which the oxygen debt is contracted. During submaximal exercise at 70% VO_2 max, blood lactate tended to decrease slowly to resting values indicating that oxygen consumption at a steady state is sufficient not only to supply the energy for actual work performed, but also to provide energy necessary to reconvert lactic acid to glycogen.

During prolonged and moderate exercise a significant portion of the lactic acid produced is reported to be removed by hepatic-splanchnic tissues (Rowell et al., 1966). However, it is uncertain to what degree the lactic acid released from working muscles can replace the substrate ordinarily oxidized by non-working tissues (Issekutz et al., 1965; Gisolfi et al., 1966). Whipp et al. (1970) have reported a greater oxygen debt after exercise which lasts only two to three minutes

than that incurred by longer exercise periods. They have partially attributed these results to possible differences in the pathway of lactic acid utilization during the recovery period. Whereas glycogenesis is an endergonic process and would contribute to a large oxygen debt, the proportion of lactate used in place of the usual fuel, glucose, would not be reflected in an increased oxygen debt.

After severe exercise, arterial lactate may continue to increase because of a time lag between the diffusion of lactic acid from working muscles and redistribution within the body (Astrand and Rodahl, 1970). When effort is not exhaustive, the decrease in lactic acid is apparent within 30 seconds following exercise (De Coster et al., 1969).

Pyruvate

Harris et al. (1962) reported that the pyruvate concentration of the blood began to rise at the beginning of exercise simultaneously with that of lactate. This would suggest that the increased production of pyruvate was not simply due to the oxidation of lactate, but rather that the production of lactate itself was partly dependent on an increased rate of formation of pyruvate. The increase in blood pyruvate concentration is not a linear function of time, but tends to level off at a maximum value which appears to be related to the intensity of exercise (Margaria et al., 1963). A transient increase in the concentration of pyruvate following exercise has been reported (Asmussen, 1950;

Harris et al., 1968) which could be due to the transformation of lactic acid and its reintroduction into aerobic metabolism (De Coster et al., 1969). Harris et al. (1968), however, have also reported an uninterrupted decline in pyruvate blood levels following exercise.

Lactate/Pyruvate Ratio

Pyruvate is reduced to lactate in the presence of lactic dehydrogenase while nicotinamide adenine dinucleotide (NADH) is simultaneously converted from the reduced to the oxidized form. Lactate and pyruvate are normally in a ratio of about 10:1 in the blood depending on the pH and on the redox potential. Why the lactate/pyruvate ratio changes and its biochemical significance are not clear. Huckabee (1958) assumed that the ratio of NAD+ to NADH in muscle cells remained unchanged; the amount of blood lactate over and above that required to maintain a normal ratio in respect to pyruvate was called excess lactate. Excess lactate was thought to be related to tissue anoxia, namely the oxygen debt. However, the relation between oxygen debt and excess lactate has not been supported by evidence (Harris et al., 1962; Margaria et al., 1963; Thomas et al., 1965; Harris, 1969).

Harris et al. (1962) observed that the concentration of excess lactate as calculated by Huckabee (1958) is dependent on both the change in the lactate/pyruvate ratio and the change in pyruvate. The ratio of the concentrations

of lactate to pyruvate is, in the presence of a constant concentration of hydrogen ions, proportional to the ratio of reduced to oxidized NAD. The change in the lactate/pyruvate ratio of the blood is more closely related to the ratio of NADH/NAD+ than to excess lactate, and may indirectly reflect changes in the state of oxidation:reduction of the tissues (Harris et al., 1962).

Olson (1963) suggested that the failure of the lactate/pyruvate ratio to provide a consistent index of tissue anoxia may be a lack of free communication between the NAD+ in the cytoplasm and that in the mitochondria. There are two, possibly more, pools of NADH/NAD+ in the cell, one in the cytoplasm and the other in the mitochondria. External NAD is poorly utilized by intact mitochondria. Therefore, the lactate/pyruvate ratio in the blood which is determined by the cytoplasmic lactic dehydrogenase does not necessarily reflect the state of oxidation:reduction of mitochondrial NADH.

Glucose

In contrast to the brain which is dependent upon glucose as its energy source, the peripheral musculature of the resting human uses relatively little glucose. The amount of glucose used by working muscles is regulated by a decrease in plasma insulin concentration during heavy exercise, and the inhibition of at least one phosphorylating enzyme, hexokinase, by products of the breakdown of glycogen.

Therefore, glycogen is more readily available as a source of energy for working muscles than exogenous glucose (Astrand and Rodahl, 1970).

There is however, indirect evidence of an accelerated whole body glucose turnover during exercise. Reichard et al. (1961) reported that although blood glucose levels did not change markedly, there was evidence of an increased turnover of glucose which began some time after the commencement of work and continued into the recovery period. The increased rate of decline of blood glucose specific activity which occurredsome time after work began was presumed due to a rapid out pouring of hepatic glucose. Since the blood glucose concentration did not increase, it was assumed that the removal of glucose by exercising muscle had similarly increased. Hultman (1967) reported that the release of glucose from the splanchnic region increased during exercise, and that glucose production increased with time. The proportion of carbohydrate utilization sustained by glucose has been reported to be as low as 12% (Costill et al., 1973) to as high as 60% and 80% in heavy and light exercise, respectively (Wahren et al., 1971). Some of these differences in results may have been due to variations in the intensity and duration of exercise as well as in the type of exercise performed.

A drop in blood glucose generally occurs only during prolonged exercise (Keppler et al., 1969), and usually

coincides with a subjective feeling of fatigue (Christensen and Hansen, 1939; Rodahl et al., 1964) and emptying of the glycogen depots in working muscles (Hultman, 1967).

Free Fatty Acids and Glycerol

Resting muscles utilize fat almost exclusively. Free fatty acids are also known to be an important fuel for muscular work (Issekutz et al., 1960; Havel et al., 1963; Carlson, 1967). It is estimated that during long sustained work between 40 and 50% of energy expenditure is derived from the direct oxidation of free fatty acids (Havel et al., 1963; Young et al., 1967). The relatively moderate role played by free fatty acids in energy metabolism with increasing work loads can be partly attributed to an inhibiting effect of lactic acid (Issekutz and Miller, 1962).

During short exercise periods, arterial concentration of free fatty acids has been reported to fall (Harris et al., 1964; Harris et al., 1965). During more prolonged exercise, the concentration of free fatty acids rises after the first 10 to 15 minutes (Carlson et al., 1961; Havel et al., 1963). Whatever the length of exercise, a transient increase in the concentration of fatty acids has been found during the recovery period (Havel et al., 1963; Harris et al., 1964; Carlson et al., 1961).

Harris et al. (1965) reported that glycerol concentrations in arterial blood fell slightly at the beginning of exercise, then rose to the initial resting level

during exercise, and continued to rise to a maximum during recovery. When the concentrations of glycerol and free fatty acids are compared, the ratio is significantly less than three to one (Harris et al., 1965). A large proportion of free fatty acids liberated by lipolysis is utilized in the resynthesis of triglycerides while free glycerol cannot be phosphorylated in adipose tissue (Shafrir and Gorin, 1963). Rather, glycerol passes into the blood stream unchanged, but may be metabolized either in the liver or intestine (Harris et al., 1965).

Havel et al. (1963) reported an increased turnover and oxidation of free fatty acids during exercise. An increase occurred both in the influx and efflux of free fatty acids during exercise, the changes in the efflux occurring more rapidly than those in the influx. This would account for the transient fall in the concentration of free fatty acids at the beginning of exercise and the transient rise at the beginning of recovery. The increased efflux of free fatty acids is presumably due to the increased utilization by the exercising muscles while the increased influx is due to a rise in the rate of lipolysis. Such a rise in the rate of lipolysis would also account for the rise in glycerol concentrations following exercise. The slight decrease in glycerol concentrations during exercise would suggest that there was little increase in the rate of utilization of glycerol during exercise (Havel et al., 1963; Harris et al., 1965).

Objectives

The study was designed to determine whether there were any differences in the utilization of low erucic acid rapeseed oil (B. Napus cultivar Tower) and soybean oil in energy metabolism. Adult male subjects were monitored during rest, exercise and recovery periods at a uniform work load of 70% maximal oxygen uptake (VO_2 max) and at adjusted work loads of either 60 or 80% VO_2 max.

Experimental design

Study I

Eight male subjects participated in a 32-day study which consisted of four experimental periods of 8 days each. Experimental period I (days 1-8) served as a stabilization period during which time the subjects received a mixture of fats which simulated the typical North American diet. During experimental periods II (days 9-16) and III (days 17-24), the diet contained either rapeseed or soybean oil as the sole source of dietary fat. The diets were fed in a cross-over design; four of the eight subjects received either the rapeseed oil diet or the soybean oil diet in experimental period II. In experimental period III the same four subjects received the alternate diet. During experimental period IV, (days 25-32), the subjects were again fed the mixed fat diet.

On the 7th day of each experimental period the subjects cycled on a bicycle ergometer at a

uniform work load of 70% VO_2 max. On the 8th day of each experimental period subjects cycled at adjusted work loads of either 60 or 80% VO_2 max. The adjusted work loads remained the same for each subject throughout the study.

Blood samples were taken during exercise sessions at a work load of 70% VO_2 max during the resting period, within 30 seconds following exercise and at the end of the recovery period.

Study II

During study I laboratory facilities could only handle analysis of blood samples taken during exercise at a uniform work load of 70% VO_2 max. One week following termination of study I, seven of the original eight subjects participated in a four day metabolic study during which time a mixed fat diet was fed. The fourth day of the study the subjects participated in an exercise protocol identical to that in study I. Each subject cycled at the adjusted work load assigned in study I, either 60 or 80% VO_2 max. Blood samples were taken during rest, within 30 seconds following exercise, and during recovery.

Subjects

The subjects who participated in the study were eight young adult men, either students or employees of the University of Manitoba. The subjects ranged in age

from 21-29 years. Subjects replied to posted advertisements on campus. They were chosen on the basis of a personal interview with the supervisor of the study, a medical examiniation, and expressed interest in the study. During the study, the subjects resided at home and maintained their normal pattern of physical activity. Vital statistics for the subjects are given in Table 1.

Exercise

The subjects were familiarized with the exercise equipment prior to the experiment during initial tests to determine individual VO_2 max. All tests were conducted in an air conditioned laboratory of the Faculty of Physical Education, University of Manitoba, using an electronically braked bicycle ergometer (Monark Ideal Ergometer 870).[1]

On the 8th day of each experimental period all subjects cycled at an adjusted work load of either 60 or 80% VO_2 max. Maximum oxygen uptake of each subject was determined from heart rate and work load using a nomogram by Astrand (1960). The work loads for each subject are given in Table 2.

The exercise protocol consisted of a 5 minute resting period, followed by a fifteen minute exercise period and a 10 minute recovery period. During the resting period the subjects remained in a sitting position.

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[1] Quinton Instruments, 390 Progress Ave., Unit I, Scarborough, Ontario.

TABLE 1

VITAL STATISTICS FOR SUBJECTS

Subjects	Age	Height (cm)	Fat Mix (Initial)	Mean Weight Diet (kg) Soy	Rapeseed	Fat Mix (Final)
1	21	187.5	81.8	81.2	80.7	81.1
2	25	181.2	72.9	72.3	72.6	71.4
3	29	175.5	78.4	77.1	77.6	76.7
4	24	181.2	61.4	60.8	61.1	60.9
5	23	183.4	66.7	66.7	66.8	66.8
6	27	189.7	94.2	93.5	93.3	92.3
7	22	177.6	74.7	73.9	73.0	73.3
8	26	174.7	74.8	74.9	74.7	74.8

TABLE 2

WORK LOAD INTENSITIES (kpm*/min)

Subject	70% VO_2	60% VO_2	Subject	70% VO_2	80% VO_2
2	870	720	1	756	864
5	651	558	3	658	752
7	742	636	4	752	860
8	770	660	6	721	824

*Kilopondmeter: 1 kp is the force acting on the mass of 1 kg at normal acceleration of gravity.

Immediately following exercise, subjects again rested in a sitting position. Respiratory measurements were monitored continuously throughout the resting, exercise and recovery periods.

Heart rate was monitored by an electrocardiograph (Cambridge VS 4 portable electrocardiograph)[1] using a 3 electrode system during the last 20 seconds of the 4, 8, 11, 14, 17, 20, 23, 26 and 29th minutes of the exercise protocol.

Oxygen consumption (VO_2) was measured by the open circuit technique. Expired gas was measured for oxygen using a paramagnetic oxygen analyzer (Servomex DCL 101)[2] and for carbon dioxide using an infra-red gas analyzer (200 series).[3]

All expired gases during the exercise protocol were channelled through a low resistance breathing valve[4] to a Kafronyi-Michaelis Gas Meter[5] for determination of minute volume (VE), and collection of gas samples for analysis by

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[1]Kent Cambridge Instrument Co., 73 Spring St., Ossining, N.Y. 10562.

[2]Servomex Controls Ltd., Crowborough, Sussex, England

[3]Quinton Instruments, 390 Progress Ave., Unit I, Scarborough, Ontario.

[4]Modified Otis-McKerrow Value. W.E. Collins, Inc., 220 Wood Road, Braintree, Mass.

[5]Gottingen, Germany.

means of the micro-Scholander method using Scholander equipment.[1] Gas samples were collected in non-diffusible polyethylene bags.[2] Readings were taken from the gas analyzers for percentage oxygen and carbon dioxide every 20 seconds throughout the resting, exercise and recovery periods. The gas analyzers were calibrated immediately before and after each subject, using bottled commercial calibration gases[3] which had been previously calibrated with micro-Scholander equipment.

Diet

The diet consisted of ordinary foods with minimal fat content to ensure that the test fats comprised 95% of the total dietary fat. Textured soy protein,[4] soy isolate (Bontrae),[5] spray-dried egg albumin,[6] and fluid skim milk were the primary protein sources.

The fat sources for the mixed fat diet were butter, beef tallow, lard, corn oil and vegetable shortening.

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[1]Scientific Instruments, 80 Swarthmore Ave., Rutledge, Penn.

[2]Calibration Instruments, Inc., 731 Saw Mill River Road, Ardsely, N.Y., 10502.

[3]Gas Dynamics, Division of Liquid Carbonic Canada Ltd., Wpg.

[4]British Canadian Importers, Vancouver, B.C.

[5]General Mills, Minneapolis, Minn.

[6]Export Packers, Winnipeg (Cham Foods Ltd., Jarvis St., Wpg.).

Fatty acid composition for the fat mix and corn oil are given in Table 3. The proportions of the various fat sources in the mixed fat diet were determined from estimations of fat consumption of the Canadian population.[1]

The fat source in the rapeseed diet was a low erucic acid rapeseed oil derived from the Brassica Napus cultivar Tower. A margarine specially prepared from Tower oil[2] was utilized. The fat source in the soybean oil diet was soybean oil purchased on the commercial market and a specially prepared soybean oil margarine.[2] Fatty acid composition of rapeseed oil and rapeseed margarine, and of soybean oil and soybean margarine are given in Tables 4 and 5, respectively.

The experimental diets are described in detail by Masniuk (1976). The diets were designed to include all food groups and to meet the recommended daily intake of all nutrients. Calories were adjusted in order to maintain normal body weight. Body weights of the subjects were recorded each morning before breakfast. Normal body weight was maintained for each subject by adjusting the carbohydrate and fat content of the diet. Fat intake was maintained at

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[1]Personal Communication, Paul Sims, Food Research Institute, Ottawa, 1974.

[2]Canada Packers Research Laboratory, Toronto.

TABLE 3

FATTY ACID COMPOSITION OF FAT MIX[1] AND CORN OIL

Fatty Acid	% of Total Fatty Acids	
	Fat Mix	Corn Oil
Decanoic C10:0[2]	0.13	-
Lauric C12:0	0.11	-
Myristic C14:0	1.46	0.11
Palmitic C16:0	20.88	10.99
Palmitoleic C16:1	1.96	-
Stearic C18:0	15.74	1.79
Oleic C18:1	43.48	26.25
Linoleic C18:2	13.88	58.82
Linolenic[3] C18:3	0.84	1.69
Eicosenoic C20:1	0.26	-

[1]Fat mix contained lard: tallow: shortening in the ratio of 4:5:6 (W:W:W). Fatty acid composition for butter not available.

[2]Carbon number: number of double bonds.

[3]Not distinguished from C20:0 with the column used to resolve fatty acids.

TABLE 4

FATTY ACID COMPOSITION OF LOW ERUCIC ACID RAPESEED OIL AND MARGARINE[1]

Fatty Acid	% of Total Fatty Acid	
	Oil	Margarine
Lauric C12:0[2]	-	0.34
Myristic C14:0	-	0.09
Palmitic C16:0	4.64	4.93
Palmitoleic C16:1	tr	tr
Stearic C18:0	1.73	12.28
Oleic C18:1	58.25	76.28
Linoleic C18:2	22.23	3.67
Linolenic[3] C18:3	9.70	0.64
Eicosenoic C20:1	2.42	1.14
Behenic C22:0	tr	tr
Erucic C22:1	0.79	0.59

[1]Oil from B. Napus cultivar Tower, Agro Industries, Nipawin, Saskatchewan. Margarine specially prepared from Tower Oil, Canada Packers, Research Laboratory, Toronto.

[2]Carbon number: number of double bonds.

[3]Not distinguished from C20:0 with the column used to resolve fatty acids.

TABLE 5

FATTY ACID COMPOSITION OF SOYBEAN OIL AND MARGARINE[1]

Fatty Acid	% of Total Fatty Acid	
	Oil	Margarine
Lauric C12:0[2]	0.03	2.33
Myristic C14:0	0.06	1.54
Palmitic C16:0	9.27	11.66
Palmitoleic C16:1	-	tr
Stearic C18:0	3.80	7.95
Oleic C18:1	46.81	35.29
Linoleic C18:2	36.35	36.15
Linolenic[3] C18:3	3.37	4.92
Eicosenoic C20:1	0.08	-
Behenic C22:0	0.04	-

[1]Crisco Oil, Proctor and Gamble, Toronto, Ontario. Margarine prepared by Canada Packers, Research Laboratory, Toronto.

[2]Carbon number: number of double bonds.

[3]Not distinguished from C20:0 with the columns used to resolve fatty acids.

40% of the total daily caloric intake throughout the study.

Respiratory Gas Analysis

Ventilation Rate: The volume of expired gas was monitored by the Kafronyi-Michaelis gas meter. The total volume of expired air was divided by the unit time (minutes) to give the average ventilation rate per period (liters/minute).

Oxygen Consumption: VO_2 and VE are the minute volumes, standard temperature and pressure, dry (STPD), of oxygen consumed and of air expired, respectively. Oxygen consumption was computed from the product of VE (STPD) and True Oxygen.

$$VO_2 = VE \times \frac{\text{True Oxygen}}{100}$$

where True Oxygen (%) is:

$$\frac{(\%N_2 \text{ exhaled air} \times [O_{2\,(\text{atmospheric air})} - \%O_{2\,(\text{exhaled air})}]}{N_{2\,(\text{atmospheric air})}}$$

and where VE is:

$$\frac{\text{Volume of expired air (liters) STPD}}{\text{minute}}$$

Respiratory Quotient: Respiratory quotient (RQ) was calculated using the formula:

$$RQ = \frac{\%CO_2 \text{ exhaled air} - 0.03}{\%N_2 \text{ exhaled air} \times 0.265 - \%O_2 \text{ exhaled air}}$$

where 0.03 is $\%CO_2$ in atmospheric air and 0.265 is the ratio of O_2 to N_2 in atmospheric air. Percentage CO_2 and O_2 were determined from readings taken on the infra-red CO_2 analyzer

and Servomex (DCL 101) O_2 analyzer, respectively. Per cent N_2 was determined by subtraction, i.e. $\%N_2 = 100 - \%CO_2 - \%O_2$.

Blood Collection Procedure and Analysis

Blood samples during the exercise period were drawn from the antecubital vein four times during Study I on days 7, 15, 23 and 31, and on day 4 of Study II by a medical technician. One 15 ml BD Vacutainer Tube (No. 4796)[1] of blood was obtained from each subject one minute before the end of the resting period, within 30 seconds following exercise, and at the end of the recovery period. Fasting blood samples were taken on days 1, 9, 17 and 25 following eight hours of fasting. All the blood samples were analyzed for glucose, glycerol, lactate, pyruvate and free fatty acids.

Chemical Analyses of Blood

Lactate and Pyruvate

Two ml of whole blood were removed with a pipette from each 15 ml sample within thirty seconds of collection and added to 5 ml 8% perchloric acid. The mixture was shaken and put on an ice bath for five minutes. The sample was then centrifuged at 1,400 X g. for ten minutes. The protein - free filtrate obtained was used for lactate and pyruvate determinations. The samples were stored at refrigerator temperature overnight and chemical analyses were carried out the following day. The lactate and

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[1]Canlab Laboratory Equipment, Winnipeg.

pyruvate content of the whole blood samples was determined as described in Sigma Technical Bulletin 726/826-UV-10-68.[1]

Glycerol

The remaining 13 ml of whole blood were divided into two centrifuge tubes. The blood samples were allowed to clot for approximately fifteen minutes and then centrifuged at 1,400 X g. for ten minutes. The serum was removed from each tube and stored in vials for glucose and glycerol determinations. The glycerol determination was done immediately, using the method of Pinter et al. (1957). The enzymic assay of serum glycerol was determined in duplicate as described in the Triglyceride Reagent set from Worthington Biochemical Corporation.[2]

Glucose

The serum for glucose determination was stored at refrigerator temperature overnight and chemical analysis was carried out the following day. Serum glucose determinations were carried out as described in Sigma Technical Bulletin 510-5-69.[3] The procedure described in the bulletin is a modification of the method of Raabo and Terkildsen (1960).

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[1]Sigma Chemical Co., P.O. Box 14508, St. Louis, Missouri, 63178.

[2]Worthington Biochemical Corp., Freehold, New Jersey, 17728.

[3]Sigma Chemical Co., 3500 Dekaib St., St. Louis, Missouri, 63118.

Free Fatty Acids

Two ml samples of serum were taken for determination of free fatty acids. Total lipids were extracted from the serum by the method of Folch et al. (1957). Prior to the extraction 0.1 mg of heptadecanoic acid, dissolved in chloroform, was added to serve as an internal standard. The extracted lipid was separated on glass plates coated with silica gel H. The solvent system of Schlierf and Woods (1965) was modified from 82:18:1 petroleum ether (B.P. 30-60° C)--diethyl ethyl-glacial acetic acid (V/V/V) to 82:25:2. The free fatty acid band was transferred to a 25 ml vial, and 5 ml of chloroform were added, and shaken. After separation the chloroform layer was filtered through previously fat extracted Whatman #1 filter paper. The procedure was repeated with two additional 5 ml aliquots and the chloroform filtered into the same vial. The chloroform was evaporated under nitrogen and the free fatty acids methylated by a slight modification of the procedure by Barnes and Holaday (1972). The methylation was carried out in a small vial at a temperature of 80C for two minutes using one and one-half ml of boron trifluoride (10% in methanol). The methyl esters were extracted with petroleum ether and resolved on 2.7m X 3.2mm O.D. stainless steel columns packed with 10% EGSS-Y on 100/120 Gas Chrom Q.[1] The gas chromatograph used was a

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[1]Applied Science Laboratories, State College, Pennsylvania.

Varian Aerograph model 1740 equipped with dual flame detectors and a model 477 Digital Integrator.[1] Column temperature, injector temperature and detector temperature were 195 C, 230 C and 250 C, respectively.

Statistical Analysis

Analysis of variance was completed for both respiratory and blood parameters, with the exception of fasting blood. The sources in the analysis were subjects, diet, work load, time and their interactions. Fasting blood was analyzed using the student's t-test. All statistical tests were carried out at the $P < 0.05$ level.

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[1] Varian Aerograph, 6358 Viscount Road, Malton, Ontario.

RESULTS AND DISCUSSION

Study I

All subjects remained in good physical health throughout the study. Body weights remained constant (Table 1) and the diets were well accepted.

Discussion of respiratory and blood data for subjects fed a mixed fat diet is restricted to observations recorded during the post experimental period, since exercise procedures were not properly standardized during experimental period I.

EFFECTS OF DIET ON RESPIRATORY PARAMETERS

Oxygen Consumption

Individual oxygen consumption and mean oxygen consumption for subjects fed the mixed fat, SO and RSO diets and exercised at a uniform work load of 70% VO_2 max, and at adjusted work loads of 60 and 80% VO_2 max are given in Tables 6, 7 and 8, respectively.

Oxygen consumption for subjects fed the SO and RSO diets did not differ significantly (α=0.05) during rest, exercise and recovery at a uniform work load of 70% VO_2 max, or at adjusted work loads of 60 and 80% VO_2 max (Appendix, Tables 1, 3, 4 and 5).

Mean oxygen consumption increased markedly from rest to exercise for subjects fed the SO and RSO diets and exercised at a uniform work load of 70% VO_2 max; from 0.25 to 1.83 l/min, and from 0.23 to 1.88 l/min, respectively.

TABLE 6

EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

Subject	Work Load % VO_2 max		Mixed Fat	Soybean Oil Liters/Min	Rapeseed Oil
1	70	rest	0.21	0.24	0.23
		ex	2.10	2.28	2.19
		rec	0.31	0.26	0.34
2	70	rest	0.21	0.21	0.18
		ex	1.58	2.14	1.94
		rec	0.26	0.23	0.25
3	70	rest	0.21	0.35	0.26
		ex	1.46	1.34	1.50
		rec	0.26	0.28	0.27
4	70	rest	0.18	0.19	0.18
		ex	1.56	1.61	1.66
		rec	0.20	0.31	0.17
5	70	rest	0.26	0.24	0.28
		ex	1.45	1.87	1.91
		rec	0.28	0.25	0.36
6	70	rest	0.23	0.28	0.27
		ex	1.71	1.87	1.87
		rec	0.28	0.37	0.35
7	70	rest	0.21	0.25	0.21
		ex	1.84	1.63	2.28
		rec	0.19	0.18	0.23
8	70	rest	0.17	0.24	0.25
		ex	1.83	1.86	1.66
		rec	0.25	0.30	0.25
Group Means and SD:		rest	0.21 ± 0.03	0.25 ± 0.05	0.23 ± 0.04
		ex	1.69 ± 0.22	1.83 ± 0.30	1.88 ± 0.27
		rec	0.25 ± 0.04	0.27 ± 0.06	0.28 ± 0.07

[1]Mean oxygen consumption during rest, ex & rec at work loads of 60, 70 and 80% VO_2 max based on minutes 4 and 5, 9 to 20, and 29 and 30, respectively.

TABLE 7

EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 60% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil Liters/Min	Rapeseed Oil
2	60	rest	0.16	0.20	0.16
		ex	1.66	1.57	1.67
		rec	0.15	0.18	0.20
5	60	rest	0.20	0.18	0.21
		ex	1.37	1.12	1.75
		rec	0.19	0.23[1]	0.25
7	60	rest	0.18	0.22	0.24
		ex	1.83	1.69	2.02
		rec	0.19	0.19	0.21
8	60	rest	0.19	0.21	0.22
		ex	1.78	1.60	1.79
		rec	0.28	0.24	0.19
Group Means and SD:		rest	0.18 ± 0.02	0.20 ± 0.02	0.21 ± 0.03
		ex	1.66 ± 0.21	1.49 ± 0.26	1.79 ± 0.17
		rec	0.20 ± 0.05	0.21 ± 0.03	0.21 ± 0.03

[1]Calculated value according to Snedecor, G.W. and Cochran, W.G., 1967. Statistical Methods, 6th edition. Iowa State University Press, Ames, Iowa. P. 317.

TABLE 8

EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 80% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil Liters/Min	Rapeseed Oil
1	80	rest	0.20	0.22	0.22
		ex	2.25	2.33	2.46
		rec	0.33	0.37	0.37
3	80	rest	0.22	0.32	0.23
		ex	1.53	1.59	1.44
		rec	0.24	0.29	0.26
4	80	rest	0.15	0.12	0.14
		ex	1.83	2.09	1.61
		rec	0.22	0.19	0.23
6	80	rest	0.24	0.33	0.17
		ex	2.12	2.48	2.55[1]
		rec	0.30	0.40	0.36[2]
Group Means and SD:		rest	0.21 ± 0.03	0.25 ± 0.09	0.19 ± 0.04
		ex	1.93 ± 0.32	2.12 ± 0.39	2.02 ± 0.57
		rec	0.27 ± 0.05	0.31 ± 0.09	0.31 ± 0.07

[1] Calculated Value (Contribution to sum of squares for error (SSE) = 0)

[2] Calculated value according to Snedecor, G.W. and Cochran, W.G., 1967. Statistical Methods, 6th edition. Iowa State University Press, Ames, Iowa. P. 317.

Mean oxygen consumption also increased markedly from rest to exercise for subjects fed the SO and RSO diets and exercised at an adjusted work load of 60% VO_2 max; from 0.20 to 1.49 l/min, and from 0.21 to 1.79 l/min, respectively, and at an adjusted work load of 80% VO_2 max from 0.25 to 2.12 l/min, and from 0.19 to 2.02 l/min, respectively. Similarly, mean oxygen consumption for subjects fed the mixed fat diet increased markedly from rest to exercise at all work loads (Tables 6, 7 and 8).

Work load had no significant effect on oxygen consumption (Appendix, Table 4), although the mean oxygen consumption was greater for subjects exercised at a work load of 80% VO_2 max as compared to a work load of 60% VO_2 max, irrespective of diet (Tables 7 and 8).

Oxygen uptake has been found to increase slowly during the first few minutes of exercise to a steady state in which oxygen uptake corresponds to the demands of the tissues. The attainment of a steady state is delayed until circulatory and respiratory adjustments have been made, and coincides with the adaptation of heart rate and ventilation. The greater increase in oxygen consumption from rest to exercise at a work load of 80% VO_2 max as compared to a work load of 60% VO_2 max was not unexpected since a linear relationship between oxygen consumption and increased work loads is well established (Astrand and Rodahl, 1970).

During exercise at adjusted work loads of 60 and

80% VO_2 max, there was also a significant interaction between work load and the SO and RSO diets (Appendix, Table 4). Mean oxygen consumption was somewhat higher for subjects fed the RSO diet and exercised at a work load of 60% VO_2 max, 1.79 l/min, as compared to mean oxygen consumption for subjects fed the SO diet, 1.49 l/min. However, during exercise at a work load of 80% VO_2 max, the pattern was reversed. Mean oxygen consumption was slightly lower for subjects fed the RSO diet, 2.02 l/min (Figure 1). Trémolières et al. (1971) reported a significant decrease in oxygen consumption during exercise after the ingestion of a single dose (0.5 gm/kg) of high erucic acid RSO at work loads less than one-half as intense as the lowest work load used in this study. The mean oxygen consumption observed in this study for subjects fed the RSO diet was only slightly lower than the mean oxygen consumption for subjects fed the SO diet, and occurred only at a work load of 80% VO_2 max. At a work load of 60% VO_2 max, mean oxygen consumption was higher for subjects fed the RSO diet as compared to the SO diet, conflicting with the results reported by Trémolières et al. (1971). Similarly, Lake (1975) reported that dietary fat had no significant effect on oxygen consumption for subjects exercised at a standardized work load of 950 kpm/min.

Mean oxygen consumption was significantly different between the rest and recovery periods for subjects fed all diets both at a uniform work load of 70% VO_2 max and at adjusted work loads of 60 and 80% VO_2 max (Appendix,

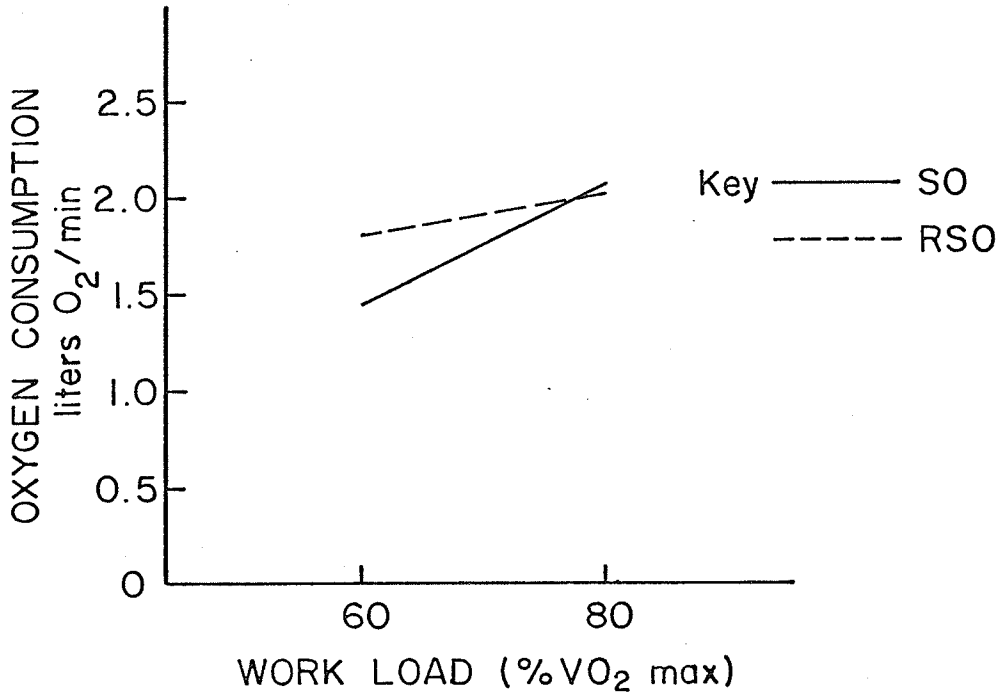

FIGURE 1

MEAN OXYGEN CONSUMPTION FOR SUBJECTS FED SO AND RSO DIETS AND EXERCISED AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

Tables 2 and 6, respectively).

The mean oxygen consumption during recovery at a work load of 70% VO_2 max remained elevated for subjects fed both the SO and RSO diets, 0.27 and 0.28 l/min, respectively, as compared to mean oxygen consumption during rest, 0.25 and 0.23 l/min, respectively. Mean oxygen consumption for subjects fed the mixed fat diet also remained elevated during recovery, 0.25 l/min, as compared to mean oxygen consumption during rest, 0.21 l/min, (Table 6).

The mean oxygen consumption during rest and recovery at a work load of 60% VO_2 max was comparable for subjects fed the SO and RSO diets. Mean oxygen consumption for subjects fed the mixed fat diet was slightly higher during recovery than during rest. Mean oxygen consumption at a work load of 80% VO_2 max remained elevated during recovery for subjects fed the SO and RSO diets, 0.31 l/min, as compared to mean oxygen consumption during rest, 0.25 and 0.19 l/min, respectively. Mean oxygen consumption for subjects fed the mixed fat diet also remained elevated during recovery, 0.27 l/min., as compared to mean oxygen consumption during rest, 0.21 l/min (Table 8). Mean oxygen consumption for subjects fed the mixed fat diet and exercised at work loads of 60 and 80% VO_2 max did not differ significantly from mean oxygen consumption for subjects fed the SO and RSO diets during either rest or recovery (Appendix, Tables 3 and 5, respectively).

Since in this study diet had no significant effect on oxygen consumption (α=0.05) the delay in the return of oxygen consumption to resting levels following exercise must be due to some factor(s) other than dietary fat. The delay in the return of oxygen consumption to resting values has been attributed to restoration of the oxygen stores of the body, increased metabolism due to an increase in tissue temperature, aerobic removal of anaerobic metabolites, and increased oxygen demands of the activated respiratory muscles and heart (Astrand and Rodahl, 1970).

Ventilation

Individual ventilation rates and mean ventilation rates for subjects fed the mixed fat, SO and RSO diets, and exercised at a uniform work load of 70% VO_2 max, and at adjusted work loads of 60 and 80% VO_2 max are given in Tables 9, 10 and 11, respectively.

Ventilation rates for the subjects fed the SO and RSO diets did not differ significantly (α =0.05) during rest, exercise or recovery at a uniform work load of 70% VO_2 max or at adjusted work loads of 60 and 80% VO_2 max, (Appendix, Tables 7, 9, 10 and 11).

Mean ventilation rates for the subjects fed the SO and RSO diets increased markedly from rest to exercise at a uniform work load of 70% VO_2 max, from 7.0 to 41.8 l/min, and from 6.6 to 44.8 l/min, respectively. Mean ventilation rates also increased markedly from rest to

TABLE 9

EFFECT OF DIETARY FAT ON THE VENTILATION RATE OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil Liters/Min	Rapeseed Oil
1	70	rest	5.0	4.5	5.8
		ex	64.8	55.7	59.2
		rec	9.8	7.0	8.9
2	70	rest	6.4	5.4	6.4
		ex	38.5	48.9	40.7
		rec	5.9	6.0	6.6
3	70	rest	10.3	10.6	7.2
		ex	36.8	30.8	34.7
		rec	7.9	8.9	10.7
4	70	rest	6.5	5.8	4.1
		ex	43.3	37.6	39.7
		rest	5.1	12.9	4.7
5	70	rest	7.8	6.3	6.6
		ex	36.6	48.5	57.9
		rec	7.4	6.9	10.1
6	70	rest	7.9	9.5	8.1
		ex	34.2	34.4	37.1
		rec	9.9	13.2	13.2
7	70	rest	5.7	7.4	6.9
		ex	41.4	33.7	47.5
		rec	4.2	3.5	4.5
8	70	rest	5.1	6.4	7.6
		ex	47.8	45.1	41.2
		rec	6.9	7.9	7.4
Group Means and SD:		rest	6.8 ± 1.8	7.0 ± 2.1	6.6 ± 1.2
		ex	42.9 ± 9.8	41.8 ± 8.9	44.8 ± 9.3
		rec	7.1 ± 2.1	8.3 ± 3.3	8.3 ± 3.0

[1]Mean ventilation rate during rest, ex and rec at work loads of 60, 70 and 80% VO_2 max based on minutes 4 and 5, 9 to 20, and 29 and 30, respectively.

TABLE 10

EFFECT OF DIETARY FAT ON THE VENTILATION RATE OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 60% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil Liters/Min	Rapeseed Oil
2	60	rest	4.2	5.3	4.5
		ex	37.8	35.2	32.3
		rec	4.1	5.4	9.6
5	60	rest	5.7	4.4	4.9
		ex	37.6	25.7	44.4
		rec	5.2	5.2	6.4
7	60	rest	4.9	7.2	4.7
		ex	40.8	33.5	46.0
		rec	3.9	3.6	4.2
8	60	rest	5.9	5.9	5.9
		ex	47.5	44.3	37.9
		rec	7.1	5.7	4.9
Group Means and SD:		rest	5.2 ± 0.8	5.7 ± 1.2	5.0 ± 0.6
		ex	40.9 ± 4.6	34.7 ± 7.6	40.2 ± 6.3
		rec	5.1 ± 1.5	5.0 ± 0.9	6.3 ± 2.4

TABLE 11

EFFECT OF DIETARY FAT ON THE VENTILATION RATE OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 80% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil Liters/Min	Rapeseed Oil
1	80	rest	5.8	4.9	5.1
		ex	70.2	68.5	76.1
		rec	10.0	11.1	10.9
3	80	rest	7.5	8.3	6.3
		ex	37.6	33.9	37.4
		rec	6.6	10.0	7.6
4	80	rest	4.1	3.1	3.3
		ex	57.1	36.6	57.2
		rec	7.1	5.5	7.6
6	80	rest	8.9	13.2	6.6
		ex	44.4	51.9	38.0
		rec	12.2	12.2	10.9
Group Means and SD:		rest	6.6 ± 2.1	7.4 ± 4.4	5.3 ± 1.5
		ex	52.3 ± 14.4	47.7 ± 15.9	52.2 ± 18.4
		rec	8.9 ± 2.6	9.7 ± 2.9	9.3 ± 1.9

exercise for subjects fed the SO and RSO diets, and exercised at adjusted work loads of 60% VO_2 max, from 5.7 to 34.7 l/min and from 5.0 to 40.2 l/min, respectively, and 80% VO_2 max, from 7.4 to 47.7 l/min and from 5.3 to 52.2 l/min, respectively. A similar increase in mean ventilation rates from rest to exercise was observed for subjects fed the mixed fat diet and exercised at a uniform work load of 70% VO_2 max, and at adjusted work loads of 60 and 80% VO_2 max (Tables 9, 10 and 11, respectively).

Work load had no significant effect on ventilation rates although mean ventilation rateswere higher for subjects exercised at a work load of 80% VO_2 max than for subjects exercised at a work load of 60% VO_2 max (Appendix, Table 10).

Pulmonary ventilation is mainly regulated to provide gaseous exchange required for aerobic metabolism. The observed increase in mean ventilation rates with increasing work loads was not unexpected, and is in accordance with the well established relationship between ventilation rates and work loads. At the beginning of exercise there exists a semilinear relationship between the increase in ventilation rate and work loads, with a relatively greater increase in ventilation rates at heavier work loads (Saltin and Astrand, 1967).

Ventilation rates were significantly different between the rest and recovery periods for subjects fed the SO and RSO diets, as well as for subjects fed the mixed

fat diet, both at a uniform work load of 70% VO_2 max and at adjusted work loads of 60 and 80% VO_2 max (Appendix, Tables 8 and 12, respectively). Although the mean ventilation rates were significantly different between the rest and recovery periods, for subjects fed all three diets and exercised at adjusted work loads of 60 and 80% VO_2 max, this appeared to be mainly due to subjects exercised at a work load of 80% VO_2 max. The mean ventilation rate at a work load of 70% VO_2 max remained elevated during the recovery period, 8.3 l/min for the subjects fed both the SO and RSO diets, as compared to the mean ventilation rate during rest, 7.0 and 6.6 l/min for the respective diets (Table 9). The mean ventilation rate for the subjects fed the mixed fat diet remained only slightly elevated during recovery as compared to rest. However, the mean ventilation rate for subjects fed the mixed fat diet or the SO and RSO diets did not differ significantly during rest or recovery, (Appendix, Table 8).

The mean ventilation rate during recovery at a work load of 60% VO_2 max was lower for subjects fed the SO diet, 5.0 l/min, than the RSO diet, 6.3 l/min. The higher mean ventilation rate observed for the subjects fed the RSO diet may have been due to subject 2, whose ventilation rate during recovery remained elevated, 9.6 l/min in comparison to that of all other subjects. Mean ventilation rates during rest for subjects fed the SO and RSO diet were 5.7 and 5.0 l/min, respectively (Table 10). The mean ventilation rates during recovery at a work load of 80% VO_2 max were 9.7 and 9.3 l/min for the subjects fed the SO and RSO diets, respectively,

and remained elevated in comparison to the mean ventilation rates during rest for subjects fed the SO, 7.4 l/min, or RSO diets, 5.3 l/min (Table 11). The mean ventilation rate during recovery for subjects fed the mixed fat diet and exercised at work loads of 60 and 80% VO_2 max did not differ significantly from mean ventilation rates for subjects fed the SO and RSO diets (Appendix, Table 12).

The time for ventilation rates to return to resting values following exercise is dependent upon the intensity and duration of exercise and the physical condition of the subject (Morehouse and Miller et al., 1971). In the present study, ventilation rates did not differ significantly between the SO and RSO diets, or the mixed fat diet at work loads of 60, 70 and 80% VO_2 max. Therefore, the difference in ventilation rates between rest and recovery must be related to the intensity and duration of exercise, and/or physical condition of the subjects, rather than to an effect of dietary fat. Lake (1975) reported similar results in ventilation rates for the same diets at a standardized work load of 950 kpm/min, a higher work load than used in this study. It should be noted that Lake (1975) calculated mean oxygen consumption, ventilation rate and respiratory quotient during rest, exercise and recovery over the entire period. In this study, means for the respiratory data during rest, exercise and recovery were based on selected minutes during each period.

Heart Rate

Individual heart rates and mean heart rates for subjects fed the mixed fat, SO and RSO diets, and exercised

at a uniform work load of 70% VO_2 max, and at adjusted work loads of 60 and 80% VO_2 max are given in Tables 12, 13 and 14, respectively.

Heart rate did not differ significantly (α=0.05) between the SO and RSO diets during rest, exercise or recovery at a work load of 70% VO_2 max (Appendix, Table 13). However, there was a significant difference in mean heart rate for subjects fed the SO and RSO diets when exercised at adjusted work loads of 60 and 80% VO_2 max (Appendix, Table 16). The mean heart rate for subjects fed the RSO diet was higher during exercise and recovery at adjusted work loads of 60 and 80% VO_2 max than the mean heart rate for subjects fed the SO diet. However, the mean heart rate for subjects fed the SO and RSO diets did not differ significantly from the mean heart rate for subjects fed the mixed fat diet (Appendix, Table 16). During rest and recovery, mean heart rate for subjects fed the SO and RSO diets did not differ significantly at work loads of 60 and 80% VO_2 max (Appendix, Tables 15 and 17).

Mean heart rate for the subjects increased markedly from rest to exercise at a uniform work load of 70% VO_2 max, from 89 to 170 beats/min for the SO diet, and from 86 to 172 beats/min for the RSO diet. At a work load of 60% VO_2 max, mean heart rate increased from 78 to 157 beats/min for the SO diet and from 76 to 166 beats/min for the RSO diet, while at a work load of 80% VO_2 max mean heart rate increased from 96 to 168 beats/min for the SO

TABLE 12

EFFECT OF DIETARY FAT ON HEART RATE OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
			Beats/Min		
1	70	rest	105	95	90
		ex	190	180	161
		rec	128	130	126[1]
3	70	rest	115	110	95
		ex	180	165	167
		rec	118	127	132
4	70	rest	75	75	70
		ex	190	154	172[1]
		rec	100	82	90
5	70	rest	90	90	88
		ex	160	170	183
		rec	120	120[1]	110
7	70	rest	110	80	85
		ex	182	175	183
		rec	90	122	112
2	70	rest	98	85	90
		ex	159	175	167[1]
		rec	112	110	116[1]
Group Means & SD:		rest	99 ± 15	89 ± 12	86 ± 9
		ex	177 ± 14	170 ± 9	172 ± 9
		rec	111 ± 14	115 ± 18	114 ± 15

[1]Calculated value (contribution to SSE = 0)

TABLE 13

EFFECT OF DIETARY FAT ON HEART RATE OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 60% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil Beats/Min	Rapeseed Oil
5	60	rest	97	95	75
		ex	150	138	146
		rec	90	88	91
7	60	rest	78	70	75
		ex	180	165	179
		rec	85	80	112
8	60	rest	69	70	78
		ex	172	169	172
		rec	99	92	102
Group Means & SD:		rest	81 ± 14	78 ± 14	76 ± 2
		ex	167 ± 16	157 ± 17	166 ± 17
		rec	91 ± 7	90 ± 9	102 ± 11

TABLE 14

EFFECT OF DIETARY FAT ON HEART RATE OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 80% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil Beats/Min	Rapeseed Oil
1	80	rest	92	95	92
		ex	192	190	185
		rec	130	122	110
3	80	rest	104	125	95
		ex	170	169	175
		rec	125	122	112
4	80	rest	78	68	72
		ex	180	145	180
		rec	97	75	98
Group Means & SD:		rest	91 ± 13	96.0 ± 29	86 ± 13
		ex	181 ± 11	168 ± 23	180 ± 5
		rec	117 ± 18	106 ± 27	107 ± 8

diet, and from 86 to 180 beats/min for the RSO diet. A similar increase in mean heart rate from rest to exercise was observed for subjects fed the mixed fat diet (Tables 12, 13 and 14).

Work load had no significant effect on heart rate although the mean heart rate for subjects was higher during exercise at a work load of 80% VO_2 max, as compared to a work load of 60% VO_2 max, irrespective of diet (Appendix, Table 16).

Individual variation in heart rate response to the same work load is pronounced, and may be observed at times among the same individual (Maxfield, 1971). The rise in heart rate with increasing work loads was expected since there is a well established linear relationship between heart rate and either work load or oxygen uptake (Astrand and Rodahl, 1970). The maximal heart rate reached during exercise and the rapidity with which the maximal value is attained, vary with the intensity and duration of exercise, and physical condition of the subject. The preliminary rise in heart rate at the beginning of exercise usually shows a tendency to level off after a few seconds, and is followed by a more gradual rise to the final maximal level (Morehouse and Miller et al., 1971).

Mean heart rate of subjects differed significantly between the rest and recovery periods, irrespective of diet or work load. At a uniform work load of 70% VO_2 max the

mean heart rate of subjects was elevated during recovery as compared to rest. During rest mean heart rates were 89 and 86 beats/min for the SO and RSO diets, respectively, as compared to 115 and 114 beats/min, respectively during recovery. Although the mean heart rates for subjects fed the SO and RSO diets were comparable during recovery, the mean heart rate for subjects fed the mixed fat diet was slightly lower than that for the SO or RSO diets (Table 12). However, mean heart rates for subjects fed the mixed fat diet did not differ significantly from mean heart rates for the subjects fed the SO and RSO diets during rest or recovery (Appendix, Table 14).

Mean heart rates also remained elevated during recovery as compared to rest when the work load was adjusted to 60 and 80% VO_2 max. Subjects exercised at a work load of 60 VO_2 max had mean heart rates of 78 and 76 beats/min during rest for the SO and RSO diets, respectively, as compared to 90 and 102 beats/min, respectively, during recovery. Subjects exercised at a work load of 80% VO_2 max had mean heart rates of 96 and 86 beats/min during rest for the SO and RSO diets, respectively, as compared to 106 and 107 beats/min, respectively during recovery. During rest, mean heart rates for subjects fed the mixed fat diet were similar to mean heart rates for the subjects fed the SO and RSO diets. During recovery mean heart rates for subjects fed the mixed fat diet and exercised at an adjusted work load of 80% VO_2 max were somewhat higher than the mean heart rates for subjects fed the SO and RSO diets (Table 14). Mean heart rates for subjects fed the mixed fat diet and exercised at an adjusted work load of 60% VO_2 max

were similar to mean heart rates for subjects fed the SO diet, but were somewhat lower than mean heart rates for subjects fed the RSO diet (Table 13). However, the mean heart rate for subjects fed the mixed fat diet did not differ significantly from the mean heart rate for subjects fed the SO and RSO diets during rest or recovery (Appendix, Table 18).

The delay in the return of heart rate to resting values following exercise was not unexpected. For the first two or three minutes following exercise, the heart rate decreases almost as rapidly as it increased at the beginning of exercise. After this initial decrease, further decline in heart rate occurs at a rate related to intensity and duration of exercise (Morehouse and Miller, 1971).

In the combined statistical analysis for mean heart rate during rest and recovery at adjusted work loads of 60 and 80% VO_2 max a significant interaction was observed between the SO and RSO diets and rest and recovery. Mean heart rates for subjects fed the SO diet were 81 and 97 beats/min during rest and recovery, respectively, while mean heart rates for subjects fed the RSO diet were 81 and 104 beats/min during rest and recovery, respectively (Figure 2). A significant interaction was also observed between the SO and RSO diets and work loads during rest and recovery (Appendix, Table 18). During rest, mean heart rates for subjects fed the SO diet and assigned to adjusted work loads of 60 and 80% VO_2 max were 78 and 96 beats/min, respectively, as compared to 76 and 86 beats/min, respectively, for subjects fed the RSO diet (Figure 3a). During recovery, mean heart rates for subjects fed the SO diet and exercised

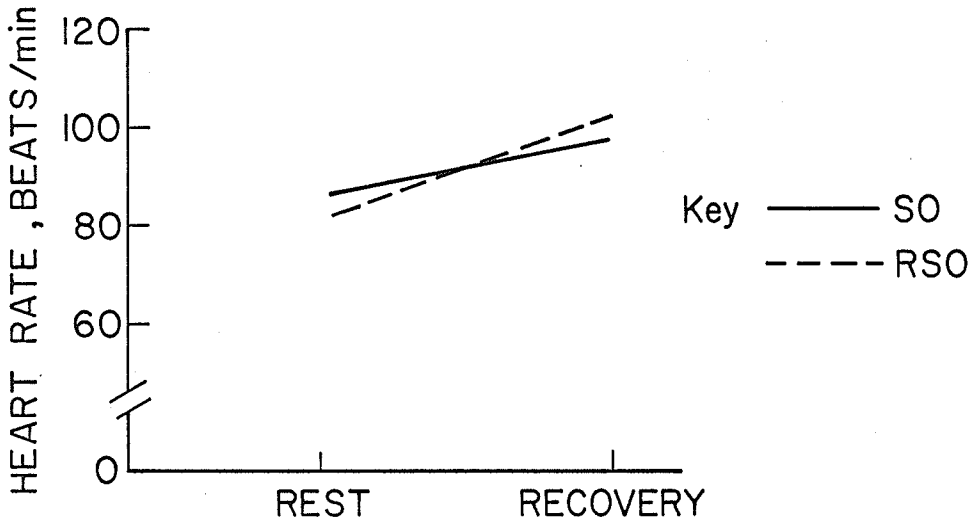

FIGURE 2

MEAN HEART RATE DURING REST AND RECOVERY FOR SUBJECTS FED SO AND RSO DIETS (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

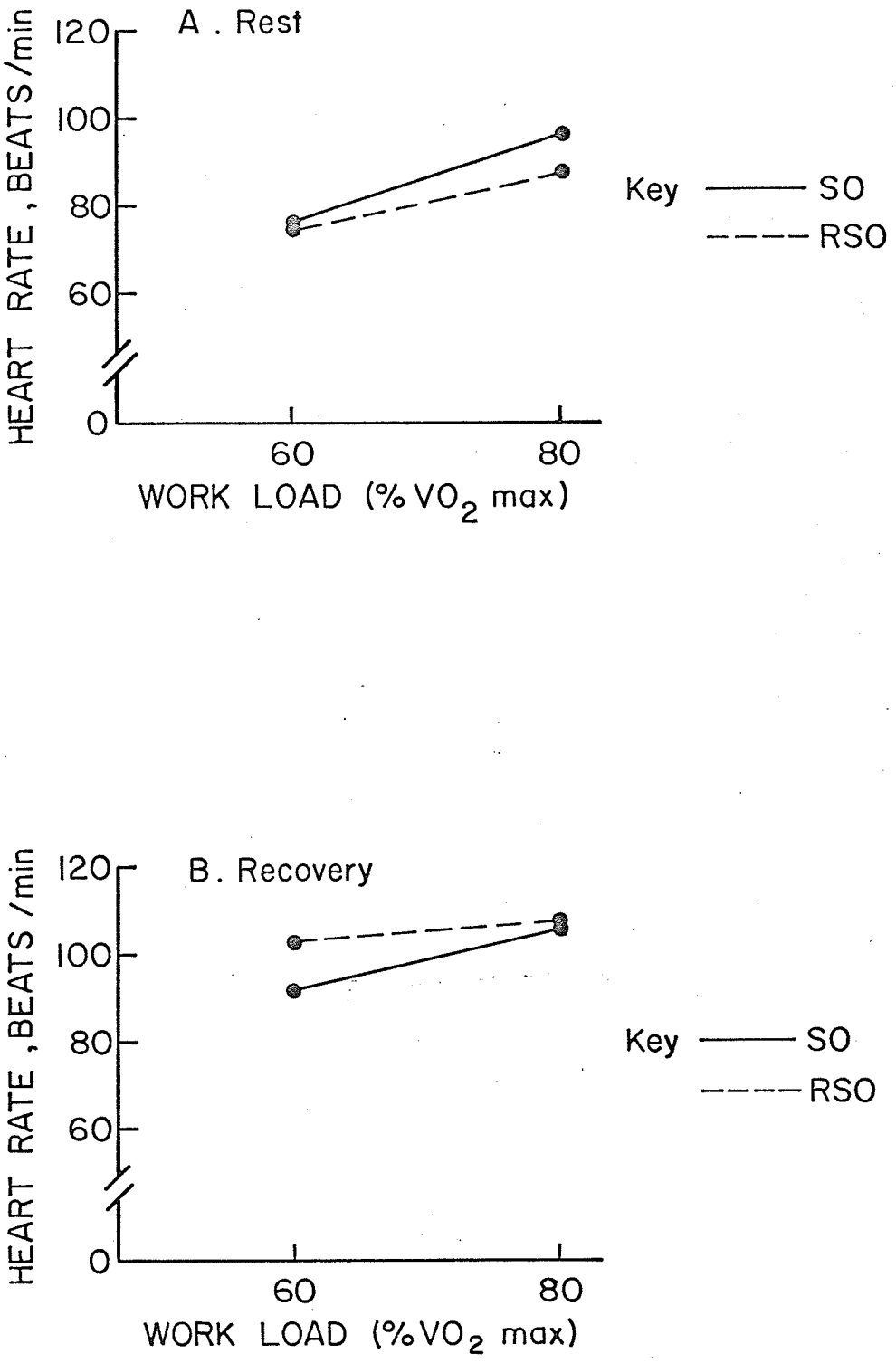

FIGURE 3

MEAN HEART RATE DURING REST AND RECOVERY FOR SUBJECTS FED SO AND RSO DIETS AND EXERCISED AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

at work loads of 60 and 80% VO_2 max, were 90 and 106 beats/min, respectively while mean heart rates for subjects fed the RSO diet were 102 and 107 beats/min, respectively (Figure 3b). Since in this study, heart rate was the only parameter which appeared to be affected by diet, it is difficult to attribute the changes in heart rate solely to diet.

Respiratory Quotient

Individual respiratory quotients (RQ) and mean RQs for subjects fed the mixed fat, SO and RSO diets and exercised at a uniform work load of 70% VO_2 max, and at adjusted work loads of 60 and 80% VO_2 max are given in Tables 15, 16 and 17, respectively.

It is well established that fat is an important fuel for both resting and working muscles (Havel et al.,1963; Carlson, 1967). The participation of fat and carbohydrate as fuels for working muscles is a function of the intensity and duration of exercise (Astrand, 1967), diet (Issekutz et al., 1963), and physical fitness (Issekutz et al., 1965). During long periods of sustained work between 40 and 50% of energy expenditure is reported to be from the direct oxidation of fat (Havel et al., 1963; Young et al., 1967). Christensen and Hansen (1939) reported that in prolonged aerobic work up to three hours in duration, an increasing participation of fat was observed, supplying up to 70% of total energy. In heavy work involving anaerobic metabolism,

TABLE 15

EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
1	70	rest	0.89	0.89	1.09
		ex	1.15	1.04	1.20
		rec	0.92	0.86	0.95
2	70	rest	0.99	0.98	0.85
		ex	1.04	1.00	0.99
		rec	1.01	0.81	0.92
3	70	rest	1.44	0.99	0.95
		ex	1.04	0.95	1.03
		rec	0.92	0.92	1.04
4	70	rest	1.11	1.06	0.89
		ex	1.09	0.98	1.05
		rec	0.76	0.91	0.94
5	70	rest	1.01	1.00	1.07
		ex	1.03	1.11	1.11
		rec	0.86	0.79	0.80
6	70	rest	0.97	1.04	1.02
		ex	0.92	0.93	0.93
		rec	0.95	0.97	0.97
7	70	rest	0.91	0.91	0.87
		ex	0.98	1.05	0.90
		rec	0.80	0.83	0.67
8	70	rest	0.99	0.91	0.92
		ex	1.10	1.05	1.07
		rec	0.85	0.83	0.85
Group Means and SD:		rest	1.04 ± 0.17	0.97 ± 0.06	0.96 ± 0.09
		ex	1.04 ± 0.07	1.01 ± 0.06	1.04 ± 0.09
		rec	0.88 ± 0.08	0.81 ± 0.06	0.89 ± 0.12

[1] Mean respiratory quotients during rest, ex and rec at work loads of 60, 70 and 80% VO_2 max based on minutes 4 and 5, 10 to 16 and 29 and 30, respectively.

TABLE 16

EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 60% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
2	60	rest	0.87	0.95	0.88
		ex	1.04	1.04	0.92
		rec	0.90	1.01	0.84
5	60	rest	0.96	0.95	0.86
		ex	1.06	1.05	1.01
		rec	0.86	0.86	0.81
7	60	rest	0.81	1.03	0.63
		ex	0.95	0.93	0.89
		rec	0.72	0.66	0.66
8	60	rest	0.97	0.86	0.91
		ex	1.07	0.98	1.08
		rec	0.74	0.70	0.88
Group Means and SD:		rest	0.90 ± 0.08	0.95 ± 0.07	0.82 ± 0.13
		ex	1.03 ± 0.05	1.00 ± 0.06	0.98 ± 0.09
		rec	0.81 ± 0.09	0.81 ± 0.16	0.80 ± 0.10

TABLE 17

EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS OF SUBJECTS EXERCISED AT AN ADJUSTED WORK LOAD OF 80% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
1	80	rest	1.03	0.94	0.94
		ex	1.15	1.17	1.11
		rec	0.92	0.88	0.92
3	80	rest	1.05	0.80	0.91
		ex	1.03	0.90	1.00
		rec	0.85	0.95	0.86
4	80	rest	0.91	0.85	0.88
		ex	1.10	0.93	1.10
		rec	0.87	0.83	0.92
6	80	rest	1.01	1.32	1.17
		ex	0.99	1.01	0.92
		rec	0.91	0.84	0.81
Group Means and SD:		rest	1.00 ± 0.06	0.98 ± 0.24	0.98 ± 0.13
		ex	1.07 ± 0.07	1.00 ± 0.12	1.03 ± 0.09
		rec	0.89 ± 0.03	0.88 ± 0.05	0.88 ± 0.05

carbohydrate metabolism increases. The relatively moderate role played by the metabolism of fat with increasing work loads can be partly attributed to an inhibitory effect of lactic acid (Issekutz et al., 1962).

RQ, the ratio of carbon dioxide to oxygen uptake can be used to estimate the relative rates of carbohydrate and fat metabolism. Theoretically, the RQs for the metabolism of carbohydrate, fat, and protein are approximately 1.00, 0.71, and 0.80, respectively. Rarely, if ever, however, does the body metabolize only one kind of fuel. Rather a mixture of carbohydrate, fat and protein is metabolized giving rise to resting RQs ranging from about 0.80 to 0.85. There is little, if any change, in RQ during moderate work, but after one minute of severe exercise, the RQ may rise as high as 1.50 because of hyperventilation and the buffering of lactic acid by sodium bicarbonate (Consolazia et al., 1963).

Mean RQs for subjects fed the SO and RSO diets did not differ significantly (α=0.05) during rest, exercise and recovery at a uniform work load of 70% VO_2 max or at adjusted work loads of 60 and 80% VO_2 max (Appendix, Tables 19,21,22 and 23).

Mean RQs increased from rest to exercise for subjects fed the SO and RSO diets and exercised at a uniform work load of 70% VO_2 max, from 0.97 to 1.01, and from 0.96 to 1.04, respectively. Mean RQs also increased from rest to exercise for subjects fed the SO and RSO diets and

exercised at an adjusted work load of 60% VO_2 max, from 0.95 to 1.00, and from 0.82 to 0.98, respectively, and at an adjusted work load of 80% VO_2 max, from 0.98 to 1.00, and from 0.98 to 1.03, respectively. A similar increase in mean RQs from rest to exercise was observed for subjects fed the mixed fat diet and exercised at adjusted work loads of 60 and 80% VO_2 max. Mean RQs for subjects fed the mixed fat diet and exercised at a work load of 70% VO_2 max did not change from rest to exercise (Tables 15, 16 and 17).

Work load had no significant effect on RQ although there was a greater increase in RQ for subjects exercised at a work load of 80% VO_2 max as compared to subjects exercised at a work load of 60% VO_2 max, irrespective of diet (Appendix, Table 22).

Trémolières et al. (1971) observed a significant decrease in the resting RQs of subjects fed RSO as compared to peanut oil which was attributed to preferential oxidation of fatty acids. Results in this study conflict with those of Trémolières et al. No significant difference was observed between the resting RQs for subjects fed the RSO as compared to subjects fed either the SO or mixed fat diets. The increase in RQs for subjects from rest to exercise was not unexpected and may be attributed to a general increase in carbohydrate metabolism as well as some hyperventilation in a few subjects.

Mean RQs differed significantly between the rest

and recovery periods for subjects exercised at adjusted work loads of 60 and 80% VO_2 max (Appendix, Table 24). Mean RQs for subjects fed the SO and RSO diets and exercised at work loads of 60% VO_2 max were 0.95 and 0.82 respectively, during rest and 0.81 and 0.80, respectively, during recovery. Mean RQs for subjects fed the SO and RSO diets and exercised at a work load of 80% VO_2 max decreased from 0.98 during rest to 0.88 during recovery. Mean RQs for subjects fed the mixed fat diet and exercised at adjusted work loads of 60 and 80% VO_2 max showed a similar decrease from rest to recovery (Table 16 and 17, respectively). The decrease in RQs following exercise was not unexpected since fat is an important fuel for resting muscles (Carlson, 1967).

During rest, the RQ can be considered a reliable indicator of the nature of foodstuffs being oxidized. In this study there was no evidence of preferential oxidation of fatty acids for subjects fed the RSO diet. Similar results were reported by Lake (1975) for the same dietary fats as reported here. It should be noted that subjects in these studies were not in a fasting state. RQ values in excess of 1.00 during exercise make interpretation of the RQ difficult. Elevated RQs have been attributed to various factors, among them, hyperventilation, and a disproportionate rise in pulmonary ventilation as compared to oxygen uptake (Consolazio et al., 1963).

The logs (common) of the RQs during rest

exercise and recovery at a uniform work load of 70% VO_2 max were used for the statistical analysis, since the variances were proportional to the means, suggesting that the variances were not constant within the data (Appendix, Table 20).

EFFECT OF DIETARY FAT ON CERTAIN BLOOD PARAMETERS

Glucose

Individual serum glucose concentrations and mean serum glucose concentrations for subjects fed the mixed fat, SO and RSO diets and exercised at a uniform work load of 70% VO_2 max are given in Table 18.

Serum glucose remained within normal psysiological limits throughout the study, and did not differ significantly (α=0.05) between subjects fed the SO and RSO diets during rest, exercise or recovery at a work load of 70% VO_2 max (Appendix, Table 25). Mean serum glucose decreased during exercise to comparable levels for subjects fed the SO and RSO diets,80.0 and 77.9 mg/100 ml, respectively. A similar decrease in mean serum glucose was observed in subjects fed the mixed fat diet.

Mean serum glucose during rest was somewhat lower for subjects fed the SO and RSO diets, 85.4 and 83.1 mg/100 ml, respectively, as compared to mean serum glucose for subjects fed the mixed fat diet, 90.8 mg/100 ml. However, this difference was not statistically significant (Appendix, Table 25a). Similarly, Lake (1975) reported that serum glucose during rest was substantially higher for subjects fed the mixed fat diet, as compared to either the SO or RSO diets.

Mean serum glucose was comparable duringexercise and recovery for subjects fed the SO and RSO diets, while mean serum

TABLE 18

EFFECT OF DIETARY FAT ON SERUM GLUCOSE CONCENTRATIONS IN SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
			mg glucose/ 100 ml		
1	70	rest	83.9	90.0	72.8
		ex	78.2	81.2	77.0
		rec	87.5	83.8	69.3
2	70	rest	83.1	75.1	66.5
		ex	74.2	75.5	63.5
		rec	83.1	78.2	70.4
3	70	rest	92.7	77.4	90.8
		ex	89.1	82.1	82.4
		rec	89.9	82.9	82.8
4	70	rest	89.1	79.8	76.7
		ex	86.3	67.3	80.5
		rec	89.9	79.0	83.6
5	70	rest	96.0	92.7	93.0
		ex	71.3	72.7	72.8
		rec	70.6	76.5	67.3
6	70	rest	97.2	85.5	90.7
		ex	85.9	87.4	81.3
		rec	95.2	84.4	82.5
7	70	rest	94.4	92.0	89.5
		ex	88.3	94.2	75.5
		rec	85.5	90.0	79.8
8	70	rest	89.9	90.7	85.0
		ex	79.9	79.3	90.0
		rec	77.0	75.9	81.5
Group Means and SD:		rest	90.8 ± 5.3	85.4 ± 7.0	83.1 ± 9.9
		ex	81.7 ± 6.7	80.0 ± 8.4	77.9 ± 7.8
		rec	84.8 ± 7.9	81.3 ± 4.8	77.2 ± 6.9

glucose for subjects fed the mixed fat diet increased slightly during recovery (Table 18). However, during recovery, mean serum glucose for subjects fed the mixed fat diet did not differ significantly from mean serum glucose for subjects fed the SO and RSO diets (Appendix, Table 25c).

The results in this study indicate that dietary fat had no effect on glucose metabolism at rest or during exercise and recovery. The increase in glucose metabolism indicated by a slight decrease in serum glucose levels during exercise was attributed to an effect of exercise rather than dietary fat. Similarly, Lake (1975) reported that dietary fat had no effect on serum glucose of subjects at rest or during exercise for short periods at a standardized work load of 950 kpm/min. A pronounced decrease in serum glucose generally occurs only during prolonged exercise (Keppler et al., 1969).

Lactate, Pyruvate and the Lactate/Pyruvate Ratio

Individual plasma lactate and pyruvate concentrations and lactate/pyruvate ratios, and mean plasma lactate and pyruvate concentrations and lactate/pyruvate ratios for subjects fed the mixed fat, SO and RSO diets and exercised at a uniform work load of 70% VO_2 max are given in Tables 19, 20 and 21.

Plasma lactate did not differ significantly (α=0.05) for subjects fed the SO or RSO diets during rest, exercise or recovery at a uniform work load of 70% VO_2 max

TABLE 19

EFFECT OF DIETARY FAT ON PLASMA LACTATE CONCENTRATIONS IN SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
			mg lactate/100 ml whole blood		
1	70	rest	7.71	6.07	7.52
		ex	77.81	78.29	80.96
		rec	53.0	38.77	52.34
2	70	rest	15.03	7.88	6.71
		ex	22.81	52.12	20.35
		rec	12.37	25.70	11.65
3	70	rest	7.45	5.57[1]	6.07
		ex	36.31	25.11	30.93
		rec	28.13	7.45	22.07
4	70	rest	6.58	9.34	7.46
		ex	54.80	30.30	38.72
		rec	36.77	22.34	21.91
5	70	rest	6.45	5.96	7.45
		ex	30.59	54.88	75.19
		rec	19.68	41.67	45.33
6	70	rest	6.05	7.57	5.33
		ex	33.52	38.40	37.60
		rec	19.02	21.32	19.13
7	70	rest	7.45	6.07	5.04
		ex	23.54	24.17	28.32
		rec	13.30	13.10	11.97
8	70	rest	10.57	5.62	10.42
		ex	68.56	59.28	41.03
		rec	59.58	52.20	32.70
Group Means and SD:		rest	8.41 ± 3.01	6.76 ± 1.36	7.00 ± 1.69
		ex	43.5 ± 20.97	45.32 ± 19.08	44.14 ± 22.01
		rec	30.23 ± 18.01	27.82 ± 15.19	27.14 ± 15.04

[1] Calculated value (Contribution to SSE = 0)

TABLE 20

EFFECT OF DIETARY FAT ON PLASMA PYRUVATE CONCENTRATIONS IN SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
			mg pyruvate/100 ml whole blood		
1	70	rest	0.60	0.60	0.49
		ex	2.14	2.52	1.70
		rec	2.37	2.45	2.19
2	70	rest	1.13	0.58	0.77
		ex	1.06	1.57	1.35
		rec	0.90	1.26	0.88
3	70	rest	0.54	0.41[1]	0.85
		ex	1.71	1.18	1.77
		rec	1.52	1.09	1.44
4	70	rest	0.55	0.70	0.88
		ex	1.56	1.37	1.88
		rec	2.00	1.08	1.56
5	70	rest	0.74	0.59	0.48
		ex	1.13	1.74	1.59
		rec	1.00	2.38	1.66
6	70	rest	0.44	0.57	0.33
		ex	1.27	1.46	1.10
		rec	0.95	1.27	0.91
7	70	rest	0.47	0.57	0.38
		ex	1.02	1.48	1.21
		rec	0.83	1.16	0.81
8	70	rest	0.91	0.48	1.02
		ex	1.80	1.67	1.88
		rec	2.73	2.57	2.89
Group Means and SD:		rest	0.67 ± 0.24	0.56 ± 0.09	0.65 ± 0.26
		ex	1.46 ± 0.41	1.62 ± 0.40	1.56 ± 0.30
		rec	1.54 ± 0.74	1.66 ± 0.68	1.54 ± 0.72

[1]Calculated value (Contribution to SSE = 0)

TABLE 21

EFFECT OF DIETARY FAT ON THE LACTATE/PYRUVATE RATIO IN SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
1	70	rest	12.85	10.12	15.35
		ex	36.36	31.07	47.62
		rec	22.36	15.82	23.90
2	70	rest	13.30	13.59	8.71
		ex	21.52	33.20	15.07
		rec	13.74	20.40	13.24
3	70	rest	13.80	13.35[1]	7.14
		ex	21.23	21.28	17.47
		rec	18.51	6.83	15.33
4	70	rest	11.96	13.34	8.48
		ex	35.13	22.17	20.60
		rec	18.39	20.69	14.04
5	70	rest	8.72	10.10	15.52
		ex	27.07	31.54	47.29
		rec	19.68	17.51	27.31
6	70	rest	13.75	13.28	16.15
		ex	26.39	26.30	34.18
		rec	20.02	16.79	21.02
7	70	rest	15.85	10.65	13.26
		ex	23.08	16.33	23.40
		rec	16.02	11.29	14.78
8	70	rest	11.62	11.75	10.22
		ex	38.09	35.50	21.82
		rec	21.82	20.31	11.31
Group Means and SD:		rest	12.73 ± 2.08	12.02 ± 1.55	11.85 ± 3.63
		ex	28.61 ± 6.92	27.17 ± 6.74	28.43 ± 13.02
		rec	18.82 ± 2.87	16.21 ± 4.91	17.62 ± 5.73

[1]Calculated value (Contribution to SSE = 0)

(Appendix, Table 27). During exercise the mean plasma lactate rose to comparable levels for subjects fed the SO and RSO diets, 45.32 and 44.14 mg/100 ml, respectively (Table 19). Mean plasma lactate for subjects fed the mixed fat diet rose to a similar level during exercise, and did not differ significantly from mean plasma lactate for subjects fed the SO and RSO diets (Appendix, Table 27b).

Mean plasma lactate for subjects fed the SO and RSO diets decreased during recovery to 27.82 and 27.14 mg/100 ml, respectively, but remained elevated in comparison to mean resting levels of 6.76 and 7.00 mg/100 ml, respectively (Table 19). During rest and recovery, the mean plasma lactate concentrations were greater for subjects fed the mixed fat diet than for either the SO or RSO diets, but the mean plasma lactate concentrations for subjects fed the mixed fat diet did not differ significantly from those for subjects fed the SO and RSO diets (Appendix, Table 27a and b).

Plasma pyruvate did not differ significantly (α=0.05) for subjects fed the SO and RSO diets during exercise at a work load of 70% VO_2 max, (Appendix, Table 28), although there was a greater increase in mean plasma pyruvate for the SO diet, 1.62 mg/100 ml, than for the RSO diet, 1.56 mg/100 ml (Table 20). Plasma pyruvate did not differ significantly between the SO and RSO diets during rest, although the mean plasma pyruvate was lower for subjects

fed the SO diet, 0.56 mg/100 ml than for subjects fed the RSO diet, 0.65 mg/100 ml (Appendix, Table 28a). Also, plasma pyruvate did not differ significantly during recovery, although subjects fed the SO diet had a slightly elevated plasma pyruvate, 1.66 mg/100 ml, as compared to 1.54 mg/100 ml for subjects fed the RSO diet (Appendix, Table 28c).

The lactate/pyruvate ratios did not differ significantly (α=0.05) for subjects fed the SO or RSO diets during rest, exercise or recovery at a work load of 70% VO_2 max (Appendix, Table 29). During exercise the mean lactate/pyruvate ratio rose to a similar level for subjects fed the mixed fat diet. During rest the mean lactate/pyruvate ratio was comparable for subjects fed the SO and RSO diets, 12.02 and 11.85, respectively, but was slightly higher for subjects fed the mixed fat diet, 12.73. During recovery the mean lactate/pyruvate ratio was also similar for subjects fed the SO and RSO diets, but was slightly higher for subjects fed the mixed fat diet.

The mean lactate/pyruvate ratio during rest, exercise and recovery was comparable for subjects fed the mixed fat, SO and RSO diets, suggesting that the oxidation: reduction potential of the muscular tissues was not altered by substitution of the SO or RSO diets for the mixed fat diet. Lake (1975) reported similar results for the same dietary fats as reported here, although the work load used, 950 kpm/min, was higher than any of the work loads in this

study (Table 2). Trémolières et al. (1971) reported that the lactate/pyruvate ratio did not rise significantly after the ingestion of a single dose (0.5 gm/kg) of high erucic acid RSO, and concluded that mitochondrial function was not altered. The biochemical significance of the lactate/pyruvate ratio has not been clearly defined (De Coster et al., 1969), therefore it should be interpreted with caution. The blood lactate/pyruvate ratio does not necessarily reflect the state of oxidation: reduction of cytoplasmic NADH (Olson, 1963; Harris, 1969). Therefore, it may not be possible to assess mitochondrial function on the basis of changes in the lactate/pyruvate ratio. Houtsmuller et al. (1970) in a study related to the ability of mitochondria to oxidize various substrates reported that high erucic acid RSO had a deleterious effect at the mitochondrial level, reducing oxygen consumption and synthesis of ATP. It would be of interest to repeat the work of Houtsmuller et al. (1970) since these results have been attributed to improper isolation of mitochondria (Kramer et al., 1973).

The logs (common) of the data were used for the statistical analysis since the variances for the plasma lactate and pyruvate concentrations, and the lactate/pyruvate ratios were proportional to the means, suggesting that the variances were not constant within the data (Appendix, Tables 30, 31 and 32).

Free Fatty Acids and Glycerol

Individual serum free fatty acids and mean serum free fatty acids for subjects fed the mixed fat, SO and RSO diets and exercised at a uniform work load of 70% VO_2 max are given in Table 22.

Serum free fatty acids did not differ significantly (α=0.05) for subjects fed the SO and RSO diets during rest, exercise or recovery at a uniform work load of 70% VO_2 max (Appendix, Table 33). During exercise the mean serum free acids for subjects fed the SO and RSO diets were comparable, 133.67 and 113.13 ug/ml, respectively, but were somewhat lower for subjects fed the mixed fat diet, 71.79 ug/ml. However, serum free fatty acids for subjects fed the mixed fat diet did not differ significantly from mean serum free fatty acids for subjects fed the SO and RSO diets (Appendix, Table 33b).

Mean serum free fatty acids during rest for subjects fed the SO and RSO diets were 100.99 and 127.95 ug/ml, respectively (Table 22). Mean serum free fatty acids for subjects fed the mixed fat diet did not differ significantly from mean serum free fatty acids for subjects fed the SO and RSO diets (Appendix, Table 33a).

Mean serum free fatty acids for the subjects fed the RSO diet rose from 113.13 ug/ml during exercise to 135.15 ug/ml during recovery while serum free fatty acids for subjects fed the SO diet decreased from 133.67 ug/ml

TABLE 22

EFFECT OF DIETARY FAT ON SERUM FREE FATTY ACID CONCENTRATIONS OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
			ug/ml		
1	70	rest	29.69	57.57	48.55
		ex	34.46	82.76	29.35
		rec	42.42	55.04	81.65
2	70	rest	85.38	56.43	124.75[1]
		ex	56.64	40.37	51.50
		rec	69.04	65.14	77.03
3	70	rest	187.37	82.63	178.12
		ex	132.32	72.74	103.57
		rec	210.34	120.92	176.98
4	70	rest	63.19	54.17	46.85
		ex	83.54	133.67	47.47
		rec	17.99	73.41	119.89
5	70	rest	99.62	66.84	58.74
		ex	13.75[1]	53.33	29.83
		rec	78.05	71.01	30.26
6	70	rest	130.17	209.58	122.21
		ex	125.46	147.10	116.42
		rec	238.70	246.72	128.67
7	70	rest	150.24	91.82	331.78
		ex	100.29	89.62	400.87
		rec	187.00	102.47	307.19
8	70	rest	89.65	188.85	112.63
		ex	91.20	195.92	126.03
		rec	112.25	156.58	159.52
Group Means & SD:		rest	104.41±50.04	100.99±62.29	127.95±122.55
		ex	79.71±42.02	133.67±22.15	113.13±122.55
		rec	119.47±82.44	111.41±64.27	135.15±84.06

[1]Calculated value (Contribution to SSE = 0)

during exercise to 111.41 ug/ml during recovery (Table 22). The mean serum free fatty acids for subjects fed the mixed fat diet increased from 79.71 ug/ml during exercise to 119.47 ug/ml during recovery. However, during recovery, mean serum free fatty acids for subjects fed the mixed fat diet did not differ significantly from mean serum free fatty acids for subjects fed the SO and RSO diets (Appendix, Table 33c).

Individual serum glycerol levels and mean serum glycerol levels for subjects fed the mixed fat, SO and RSO diets and exercised at a uniform work load of 70% VO_2 max are given in Table 23.

Serum free glycerol did not differ significantly (α=0.05) for subjects fed the SO and RSO diets during rest, exercise or recovery at a work load of 70% VO_2 max (Appendix, Table 35). During exercise mean serum glycerol rose to 7.10 mg/100 ml for subjects fed the RSO diet but remained lower for subjects fed the SO diet, 5.91 mg/100 ml. (Table 23). Mean serum glycerol for subjects fed the mixed fat diet rose to a level similar to that for subjects fed the RSO diet, but remained somewhat higher than that for subjects fed the SO diet. However, during exercise, mean serum glycerol for subjects fed the mixed fat diet did not differ significantly from mean serum glycerol for subjects fed the SO and RSO diets (Appendix, Table 35b).

During rest, mean serum glycerol was comparable

TABLE 23

EFFECT OF DIETARY FAT ON SERUM FREE GLYCEROL CONCENTRATIONS IN SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil mg/100 ml	Rapeseed Oil
1	70	rest	3.48	1.55	2.10
		ex	6.66	4.78	5.38
		rec	9.80	7.82	7.18
2	70	rest	7.14	3.87	2.54
		ex	5.76	4.26	3.53
		rec	4.39	4.22	3.14
3	70	rest	7.52	4.82	7.43
		ex	10.40	6.80	10.80
		rec	11.61	5.28	9.68
4	70	rest	3.96	4.08	2.28
		ex	5.68	4.04	3.53
		rec	4.98	3.36	3.31
5	70	rest	5.64	3.10	2.49
		ex	4.95	3.35	3.18
		rec	5.24	4.61	3.18
6	70	rest	7.48	8.06	5.07
		ex	11.79	11.04	7.65
		rec	10.88	10.45	11.85[1]
7	70	rest	7.91	3.44	12.21
		ex	8.09	4.56	17.68
		rec	8.43	3.48	13.42
8	70	rest	2.71	5.80	3.40
		ex	7.96	8.43	5.03
		rec	6.75	9.93	5.59
Group Mean and SD:		rest	5.73 ± 2.08	4.34 ± 1.95	4.69 ± 3.54
		ex	7.66 ± 2.41	5.91 ± 2.66	7.10 ± 4.99
		rec	7.76 ± 2.82	6.14 ± 2.86	7.17 ± 4.09

[1]Calculated value (Contribution to SSE = 0)

for subjects fed the SO and RSO diets, 4.34 and 4.69 mg/100 ml, respectively. Mean serum glycerol for subjects fed the mixed fat diet was higher than that for subjects fed either the SO or RSO diets. However, during rest, mean serum glycerol for subjects fed the mixed fat diet did not differ significantly from mean serum glycerol for subjects fed the SO and RSO diets (Appendix, Table 35a).

During recovery mean serum glycerol increased above exercise levels for subjects fed the SO and RSO diets to 6.14 and 7.17 mg/100 ml, respectively (Table 23). There was a similar increase in mean serum glycerol for subjects fed the mixed fat diet. Mean serum glycerol for subjects fed the mixed fat diet did not differ significantly from mean serum glycerol for subjects fed the SO and RSO diets (Appendix, Table 35c).

Since there were no significant differences in free fatty acids for subjects fed the mixed fat or SO and RSO diets, changes in free fatty acids were attributed to an effect of exercise, specifically an increased hydrolysis of triglycerides. The increase in serum glycerol during exercise and recovery for all three dietary fats, is in accordance with an augmented hydrolysis of triglycerides during exercise (Astrand and Rodahl, 1970). In contrast, Lake (1975) reported no consistent change in serum glycerol during exercise or recovery, but similarly reported no significant differences in serum glycerol for subjects fed

the same dietary fats as reported here.

Arterial concentration of free fatty acids has been reported to fall after short exercise periods (Harris et al., 1964; Harris et al., 1965), but rise during more prolonged exercise after the first 10 or 15 minutes (Havel et al., 1963). Whatever the length of exercise a transient increase in the concentration of free fatty acids is reported to occur during recovery (Havel et al., 1963; Harris et al., 1964). In this study, the mean free fatty acids for subjects fed the SO diet, in contrast to subjects fed the mixed fat or RSO diets, increased during exercise and decreased during recovery, although a transient increase was expected following exercise. This may have been due to the nature of the data, since a decrease in free fatty acids from exercise to recovery was observed for three subjects fed the SO diet.

CHANGES IN RESPIRATORY AND BLOOD PARAMETERS DURING EXERCISE

Statistical analysis for both respiratory and blood parameters showed some significant interactions which were not related to diet. These results are presented for information only, since this study was not designed to investigate these particular effects.

During exercise at adjusted work loads of 60 and 80% VO_2 max, mean oxygen consumption differed significantly (α=0.05) over time i.e. between experimental periods (Appendix, Table 4). Mean oxygen consumption for subjects decreased from 1.76 l/min in experimental period II, to 1.64 l/min in experimental period III, but increased to 1.79 l/min in experimental period IV. Mean oxygen consumption differed significantly between experimental periods II and III.

The combined statistical analysis for oxygen consumption during rest and recovery at a work load of 70% VO_2 max showed a significant difference over time i.e. between experimental periods (Appendix, Table 2). The mean oxygen consumption for subjects in experimental period IV was lower during both rest and recovery than the mean oxygen consumption for subjects in experimental periods II and III (Figure 4). During recovery, mean oxygen consumption returned to resting levels, 0.25 l/min in experimental period II, but remained elevated in experimental periods III and IV, 0.29 and 0.24 l/min, respectively, in comparison to mean resting values of 0.25 and 0.21 l/min, respectively.

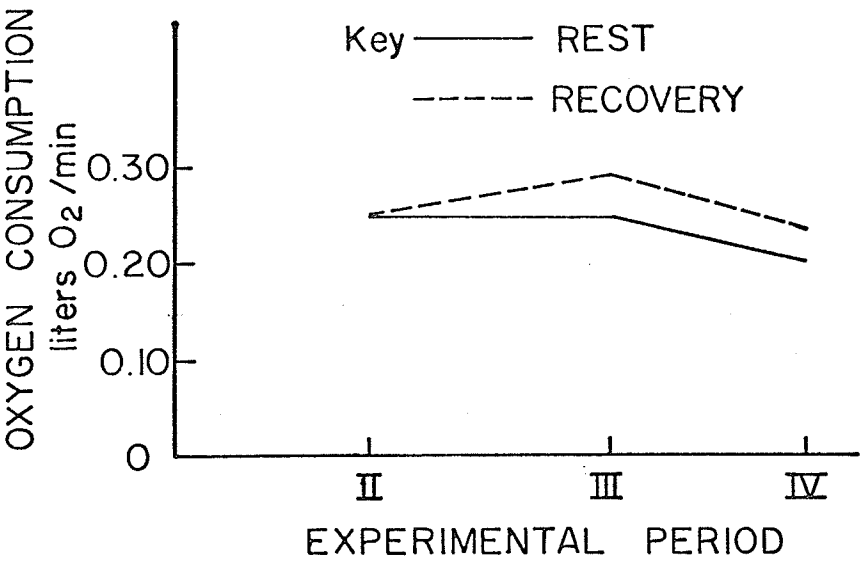

FIGURE 4

CHANGES IN MEAN OXYGEN CONSUMPTION FOR SUBJECTS DURING REST AND RECOVERY (UNIFORM WORK LOAD OF 70% VO_2 MAX)

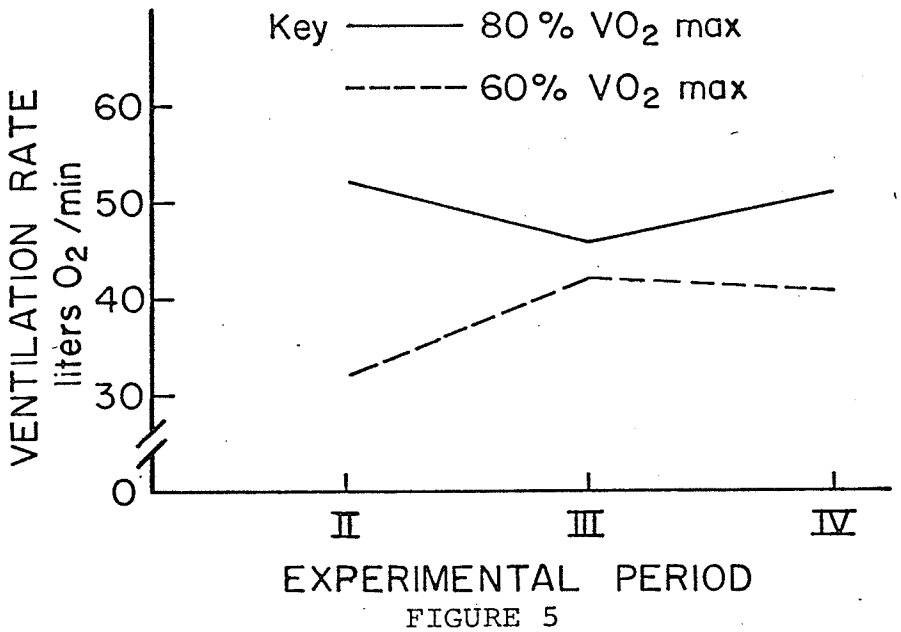

FIGURE 5

CHANGES IN MEAN VENTILATION RATE FOR SUBJECTS DURING EXERCISE AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

The statistical analysis for ventilation rate during exercise at adjusted work loads of 60 and 80% VO_2 max showed a significant interaction between work load and time, i.e. between experimental periods (Appendix, Table 10). Work load had no significant effect on mean ventilation rates for subjects in experimental period IV, as compared to mean ventilation rates for subjects in experimental periods II and III. However, work load did have a significant effect on mean ventilation rates for subjects in experimental periods II and III. Mean ventilation rates for subjects exercised at a work load of 60% VO_2 max increased from 32.3 l/min in experimental period II, to 42.5 l/min in experimental period II, and remained relatively constant during experimental period IV at 40.9 l/min. In contrast, the mean ventilation rate for subjects exercised at a work load of 80% VO_2 max decreased from 53.8 l/min in experimental period II, to 46.2 l/min in experimental period III, but increased slightly in experimental period IV to 52.3 l/min (Figure 5).

During exercise at adjusted work loads of 60 and 80% VO_2 max, mean RQs differed significantly over time, i.e. between experimental periods (Appendix, Table 22). Mean RQs for subjects differed significantly between experimental periods II and III. The elevation in mean RQs in experimental periods II and IV may have been due to subjects 2 in whom RQs increased to 1.15 and 1.17 in experimental periods II and IV, respectively.

The statistical analysis for heart rate during exercise at adjusted work loads of 60 and 80% VO_2 max, showed a significant interaction between work load and time, i.e. between experimental periods (Appendix,Table 16). Mean heart rate for subjects exercised at a work load of 60% VO_2 max increased from 158 beats/min in experimental period II, to 165 and 167 beats/min in experimental periods III and IV, respectively. Mean heart rate for subjects exercised at a work load of 80% VO_2 max decreased from 182 beats/min in experimental period II, to 166 beats/min in experimental period III, but increased again to 181 beats/min in experimental period IV. There was no significant interaction between work load and experimental period II as compared to experimental period III (Figure 6).

Although the combined statistical analysis for heart rate during rest and recovery at adjusted work loads of 60 and 80% VO_2 max showed a significant interaction between rest and recovery, work loads and experimental periods (Appendix,Table 18), the changes in heart rate were small. During rest, mean heart rate for subjects exercised at a work load of 60% VO_2 max decreased from 81 beats/min in experimental period II, to 73 beats/min in experimental period III, but returned to 81 beats/min in experimental period IV. Mean heart rate for subjects exercised at a work load of 80% VO_2 max increased from 87 in experimental period II, to 95 beats/min in experimental period III, but decreased to 91 beats/min in experimental period IV (Figure 7A).

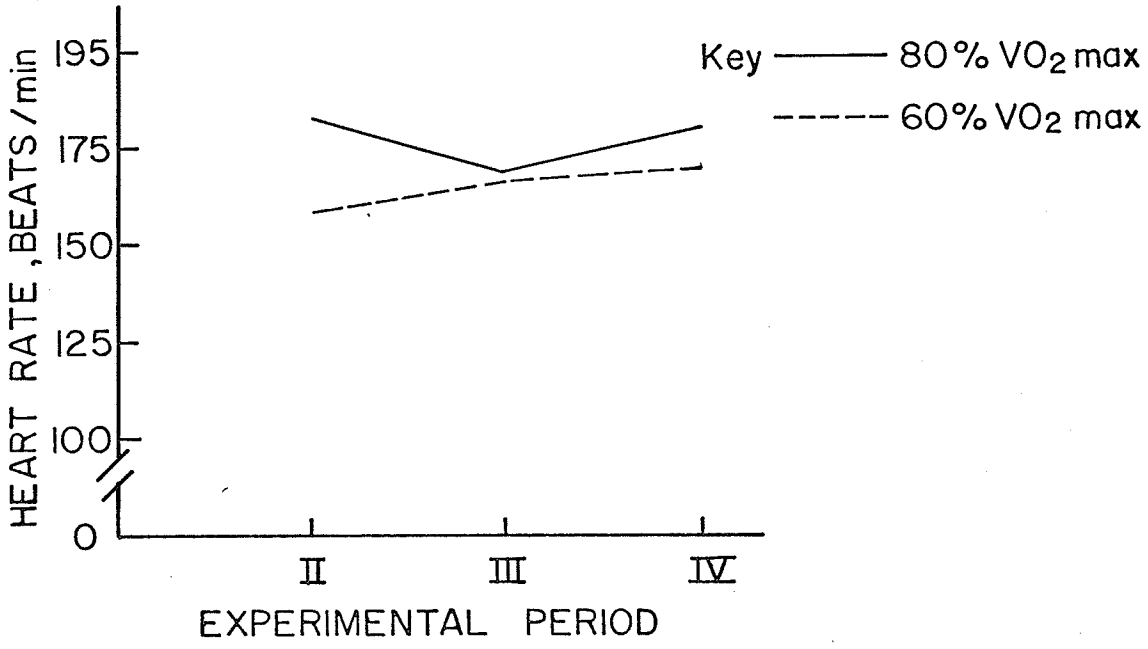

FIGURE 6

CHANGES IN MEAN HEART RATE FOR SUBJECTS DURING EXERCISE AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

During recovery, mean heart rate for subjects exercised at a work load of 60% VO_2 max increased from 90 beats/min in experimental period II, to 98 beats/min in experimental period III, but decreased to 91 beats/min in experimental period IV. Mean heart rate for subjects exercised at a work load of 80% VO_2 max decreased from 111 beats/min in experimental period II, to 102 beats/min in experimental period III, but increased to 117 beats/min in experimental period IV (Figure 7B).

The combined statistical analysis for heart rate during rest and recovery at a work load of 70% VO_2 max showed a significant interaction between rest, recovery and time, i.e. between experimental periods (Appendix, Table 14). During rest, mean heart rate increased over time. Mean heart rates were 87, 89 and 99 beats/min in experimental periods II, III and IV, respectively. During recovery, mean heart rate decreased from 118 beats/min in experimental period II to 111 beats/min in experimental periods III and IV (Figure 8).

The statistical analysis for serum glucose during rest and recovery showed a significant difference over time, i.e. between experimental periods (Appendix, Table 25). During rest, mean serum glucose levels were relatively constant in experimental periods II and III, 84.9 and 83.6 mg/100 ml, respectively, but increased slightly to 90.8 mg/100 ml in experimental period IV. Similarly, during recovery, mean serum glucose levels decreased from 81.6 mg/100 ml in

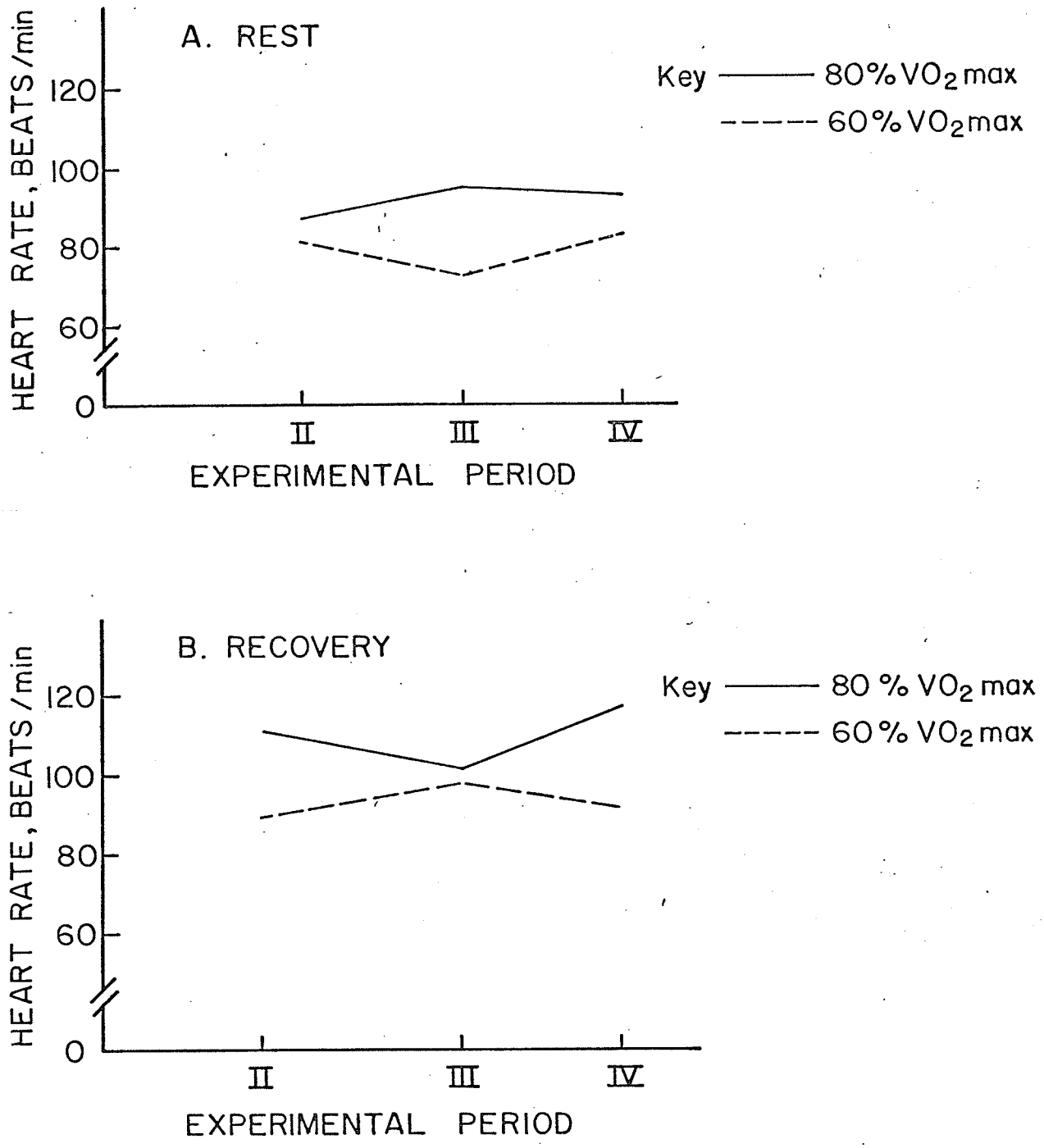

FIGURE 7

CHANGES IN MEAN HEART RATE FOR SUBJECTS
DURING REST AND RECOVERY
(ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

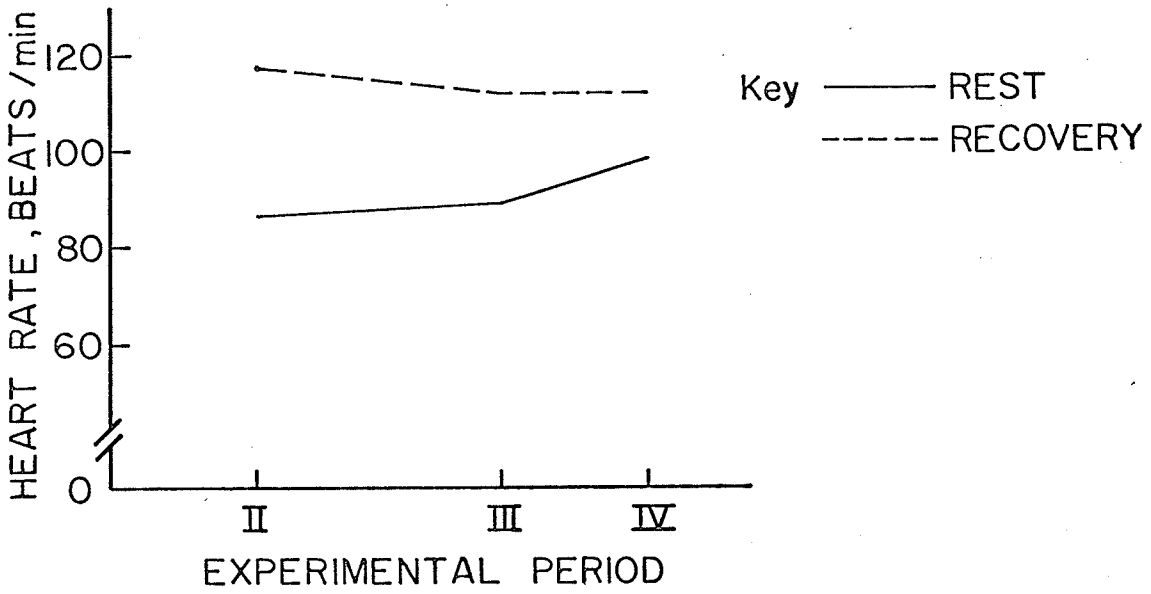

FIGURE 8

CHANGES IN MEAN HEART RATE FOR SUBJECTS
DURING REST AND RECOVERY
(UNIFORM WORK LOAD OF 70% VO_2 MAX)

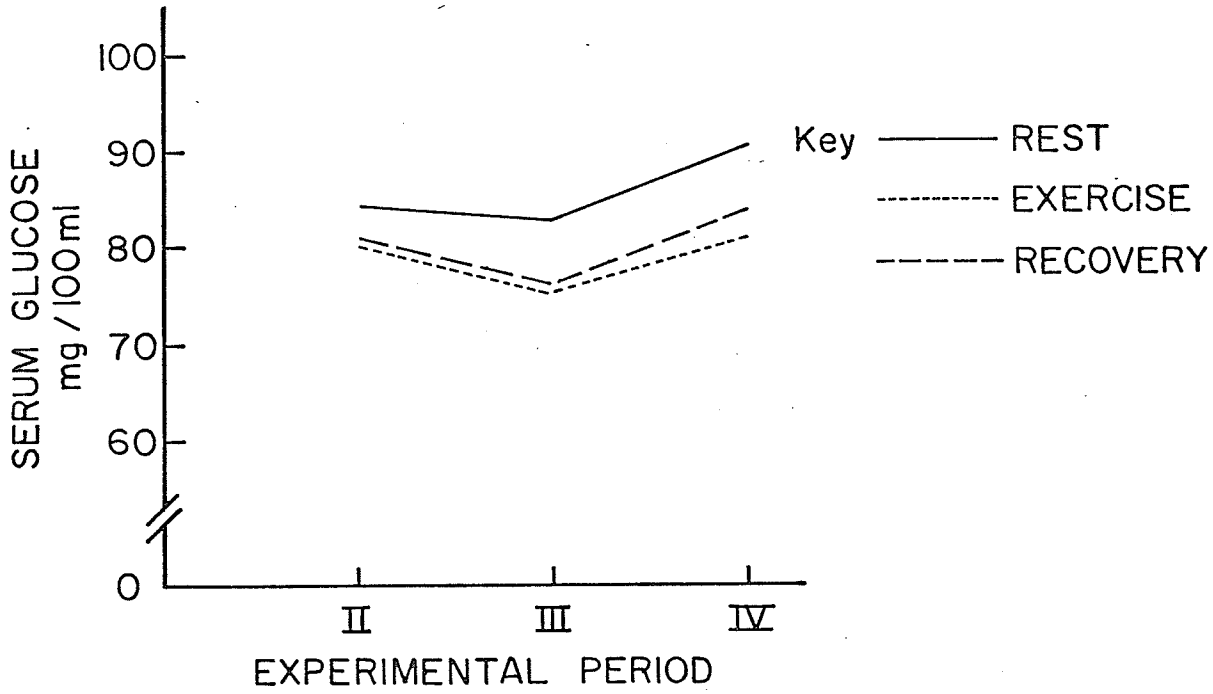

FIGURE 9

CHANGES IN MEAN SERUM GLUCOSE FOR SUBJECTS
DURING REST, EXERCISE AND RECOVERY
(UNIFORM WORK LOAD OF 70% VO_2 MAX)

experimental period II, to 76.9 mg/100 ml in experimental period III, but increased to 84.8 mg/100 ml in experimental period IV. During exercise, mean serum glucose did not differ significantly between experimental periods although a similar pattern was observed (Appendix, Table 25). During exercise, mean serum glucose levels for subjects in experimental periods II, III and IV were 81.5, 76.4 and 81.7 mg/100 ml, respectively (Figure 9).

The combined statistical analysis for serum glucose during rest, exercise and recovery however, showed a significant difference over time, i.e. between experimental periods, as well as between rest, exercise and recovery (Appendix, Table 26).

The combined statistical analysis for serum glycerol during rest, exercise and recovery showed a significant difference between rest, exercise and recovery, and time, i.e. between experimental periods (Appendix, Table 36). During rest, exercise and recovery serum glycerol levels increased over time (Figure 10). During rest, mean serum glycerol levels were 3.97, 5.06 and 6.73 mg/100 ml in experimental periods II, III and IV, respectively. A similar increase in mean serum glycerol levels was observed with each successive experimental period during both exercise and recovery.

During rest and exercise plasma pyruvate concentrations differed significantly over time, i.e. between experimental periods (Appendix, Table 28). During rest, mean

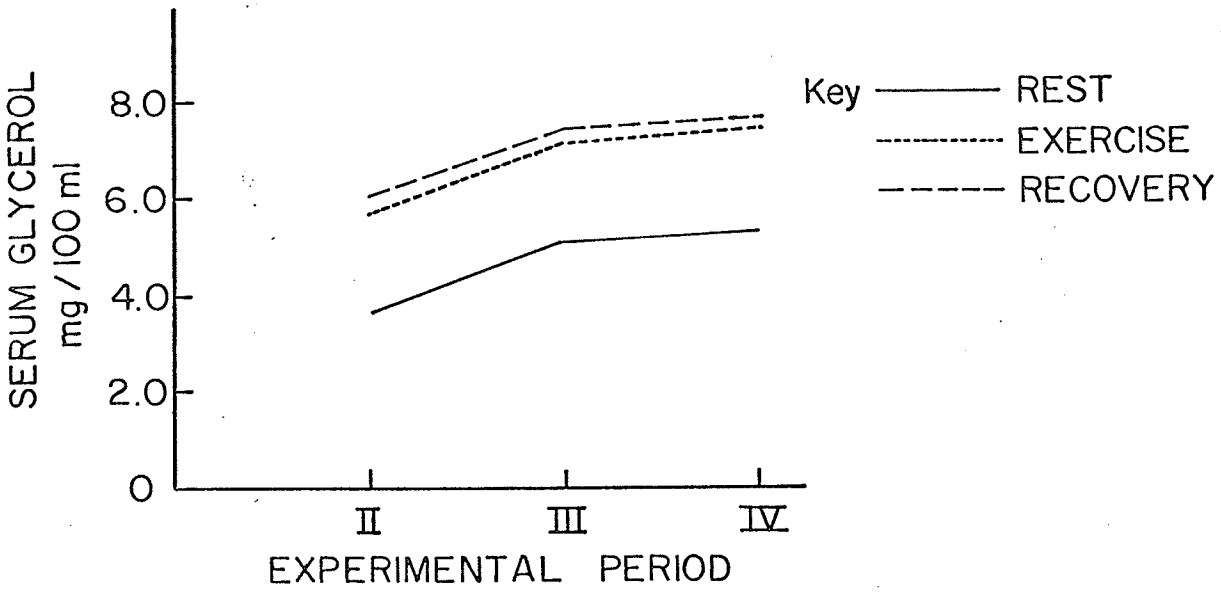

FIGURE 10

CHANGES IN MEAN SERUM GLYCEROL FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY (UNIFORM WORK LOAD OF 70% VO_2 MAX)

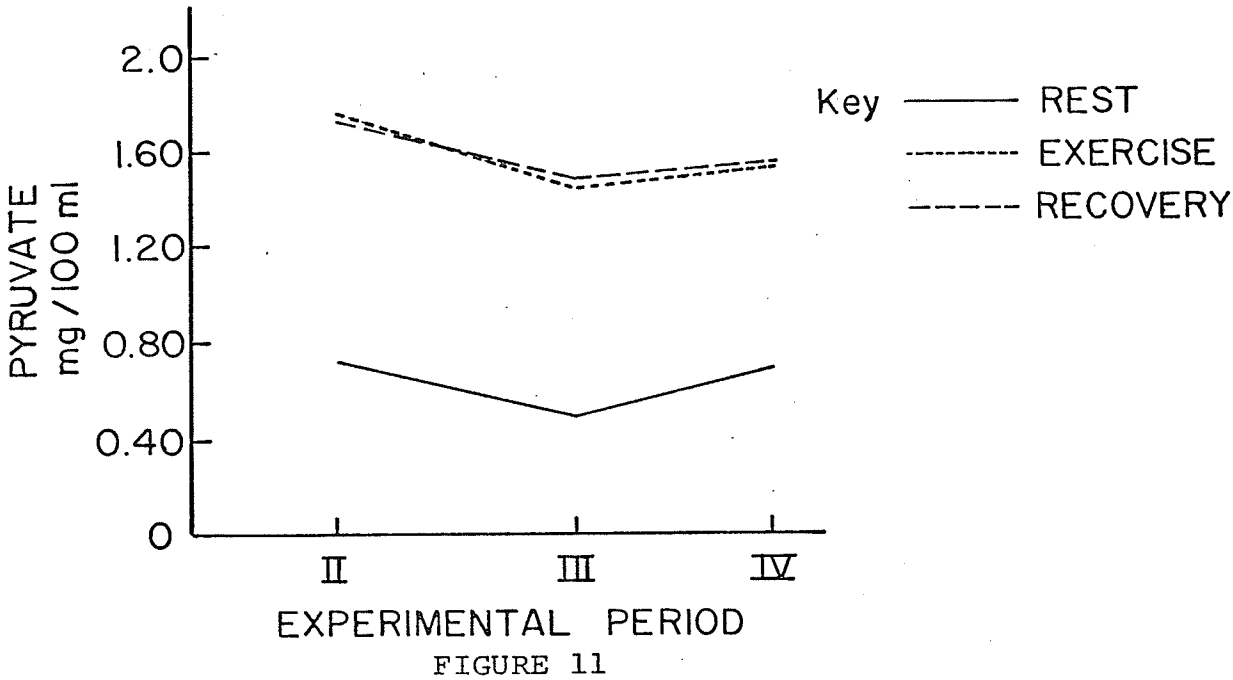

FIGURE 11

CHANGES IN MEAN PLASMA PYRUVATE FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY (UNIFORM WORK LOAD OF 70% VO_2 MAX)

plasma pyruvate concentrations decreased from 0.73 mg/100 ml in experimental period II, to 0.48 mg/100 ml in experimental period III, but increased to 0.67 mg/100 ml in experimental period IV. Similarly, during exercise, mean plasma pyruvate concentrations decreased from 1.76 mg/100 ml in experimental period II, to 1.42 mg/100 ml in experimental period III, but remained relatively constant at 1.46 mg/100 ml in experimental period IV (Figure 11). During recovery, mean pyruvate did not differ significantly between experimental periods although a similar pattern was observed (Appendix, Table 28).

During rest and exercise, the lactate/pyruvate differed significantly over time, i.e. between experimental periods (Appendix, Table 29). During rest, the mean lactate/pyruvate ratio rose from 9.83 in experimental period II, to 21.87 in experimental period III, but decreased to 12.73 in experimental period IV. Similarly, during exercise the mean lactate/pyruvate ratio rose from 22.52 in experimental period II, to 33.08 in experimental period III, but decreased to 28.61 in experimental period IV. During recovery, a similar pattern in the lactate/pyruvate ratio was observed (Figure 12). However, the mean lactate/pyruvate ratio did not differ significantly between experimental periods (Appendix, Table 29). The mean lactate/pyruvate ratio rose from 14.42 in experimental period II, to 19.41 in experimental period III, but decreased slightly to 18.82 in experimental period IV.

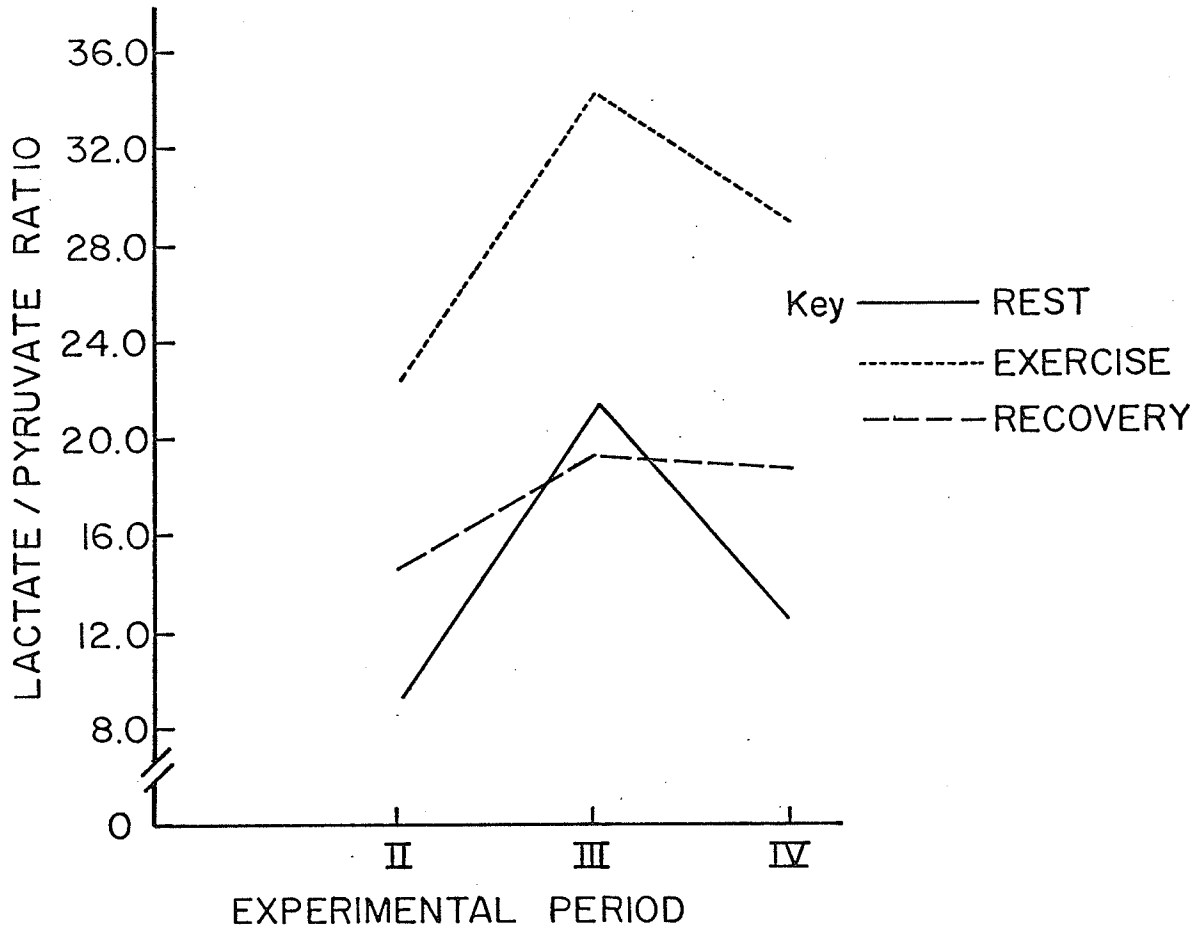

FIGURE 12

CHANGES IN THE MEAN LACTATE/PYRUVATE RATIO FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY (UNIFORM WORK LOAD OF 70% VO_2 MAX)

RESULTS AND DISCUSSION

STUDY II

During study I laboratory facilities could only handle analysis of blood samples taken during exercise at a uniform work load of 70% VO_2 max. One week following termination of study I, seven of the original eight subjects participated in a four day metabolic study during which time a mixed fat diet was fed. On the fourth day of the study, subjects exercised at the adjusted work loads assigned in study I, either 60 or 80% VO_2 max. Blood samples were taken during rest, within 30 seconds following exercise, and during recovery.

Adjusted work loads of 60 and 80% VO_2 max had no significant effect (α=0.05) during exercise and recovery on any of the blood parameters measured for all 7 subjects fed a mixed fat diet. Individual data and group means for serum glucose, plasma lactate and pyruvate concentrations, the lactate/pyruvate ratio and serum glycerol for subjects exercised at adjusted work loads of 60 and 80% VO_2 max are given in Tables 24, 25, 26, 27 and 28, respectively.

During rest, mean serum glucose differed significantly between subjects assigned to work loads of 60 and 80% VO_2 max (Appendix, Table 37a). Mean serum glucose was higher for subjects assigned to a workload of 80% VO_2 max, 94.8 mg/100 ml, than for subjects assigned to a work load of 60% VO_2 max, 81.7 mg/100 ml (Table 24). Similarly,

TABLE 24

THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON SERUM GLUCOSE FOR SUBJECTS FED A MIXED FAT DIET

Subject	Work Load % VO_2 Max		Mixed Fat (mg glucose/100)
2	60	rest	74.5
		ex	66.7
		rec	82.7
5	60	rest	78.7
		ex	61.2
		rec	72.5
7	60	rest	87.2
		ex	82.6
		rec	88.3
8	60	rest	86.4
		ex	84.1
		rec	74.0
Group Means & SD:		rest	81.7 ± 6.1
		ex	73.7 ± 11.4
		rec	79.4 ± 7.4

Subject	Work Load % VO_2 Max		Mixed Fat (mg glucose/100 ml)
1	80	rest	101.6
		ex	86.7
		rec	72.5
3	80	rest	86.3
		ex	84.7
		rec	84.7
4	80	rest	96.5
		ex	74.8
		rec	70.0
Group Means & SD:		rest	94.8 ± 7.8
		ex	82.1 ± 6.4
		rec	75.7 ± 7.9

during exercise mean serum glucose was higher for subjects exercised at a work load of 80% VO_2 max, 82.1 mg/100 ml, as compared to subjects exercised at a work load of 60% VO_2 max, 73.7 mg/100 ml. However, mean serum glucose did not differ significantly between work loads (Appendix, Table 37b). During recovery, mean serum glucose levels for subjects exercised at work loads of 60 and 80% VO_2 max were 79.4 and 75.7 mg/100 ml, respectively. Mean serum glucose did not differ significantly between work loads (Appendix, Table 37c).

Mean plasma lactate did not differ significantly for subjects fed a mixed fat diet and exercised at work loads of 60 and 80% VO_2 max (Appendix, Table 38b). During rest plasma lactate was slightly higher for subjects assigned to a work load of 80% VO_2 max, 8.20 mg/100 ml as compared to subjects assigned to a work load of 60% VO_2 max, 7.36 mg/100 ml, however mean plasma lactate did not differ significantly between work loads (Appendix, Table 38a). During exercise mean plasma lactate was higher for subjects exercised at a work load of 80% VO_2 max, 50.21 mg/100 ml as compared to subjects exercised at a work load of 60% VO_2 max, 36.16 mg/100 ml (Table 25). Mean plasma lactate concentrations decreased from exercise to recovery, but remained higher for subjects exercised at a work load of 80% VO_2 max, 30.06 mg/100 ml as compared to subjects exercised at a work load of 60% VO_2 max, 20.59 mg/100 ml. However, mean plasma lactate did not differ significantly between work loads (Appendix, Table 38c).

TABLE 25

THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON PLASMA LACTATE CONCENTRATIONS FOR SUBJECTS FED A MIXED FAT DIET

Subject	Work Load % VO_2 Max		Mixed Fat (mg lactate/100 ml whole blood)
2	60	rest	8.68
		ex	33.60
		rec	17.23
5	60	rest	5.88
		ex	32.40
		rec	16.23
7	60	rest	6.81
		ex	21.51
		rec	8.42
8	60	rest	8.08
		ex	57.11
		rec	40.48
Group Means & SD:		rest	7.36 ± 1.26
		ex	36.16 ± 14.99
		rec	20.59 ± 13.83

Subject	Work Load % VO_2 Max		Mixed Fat (mg lactate/100 ml whole blood)
1	80	rest	9.89
		ex	73.48
		rec	30.81
3	80	rest	5.01
		ex	17.37
		rec	18.64
4	80	rest	9.69
		ex	59.79
		rec	31.73
Group Means & SD:		rest	8.20 ± 2.76
		ex	50.21 ± 29.26
		rec	30.06 ± 10.68

Mean plasma pyruvate did not differ significantly for subjects fed a mixed fat diet and exercised at work loads of 60 and 80% VO_2 max (Appendix,Table 39b). Although mean plasma pyruvate was comparable during rest for subjects assigned to work loads of 60 and 80% VO_2 max, 0.79 and 0.80 mg/100 ml, respectively, mean plasma pyruvate was higher during exercise at a work load of 80% VO_2 max, 2.25 mg/100 ml, than during exercise at a work load of 60% VO_2 max, 1.75 mg/100 ml (Table 26). Mean plasma pyruvate decreased from exercise to recovery for subjects exercised at work loads of 60 and 80% VO_2 max, however mean plasma pyruvate was higher for subjects exercised at a work load of 80% VO_2 max, 2.16 mg/100 ml, than for subjects exercised at a work load of 60% VO_2 max, 1.53 mg/100 ml. However, mean plasma pyruvate for subjects during recovery did not differ significantly between work loads (Appendix, Table 39c).

The lactate/pyruvate ratio did not differ significantly for subjects fed a mixed fat diet and exercised at work loads of 60 and 80% VO_2 max (Appendix,Table 40b). The lactate/pyruvate ratio was slightly higher during rest for subjects assigned to a work load of 80% VO_2 max, 10.08, as compared to subjects assigned to a work load of 60% VO_2 max, 9.34, but this difference was not statistically significant (Appendix, Table 40a). Similarly, during exercise the lactate/pyruvate ratio was slightly higher for subjects exercised at a work load of 80% VO_2 max, 21.36 as compared to subjects exercised

TABLE 26

THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON PLASMA PYRUVATE CONCENTRATIONS FOR SUBJECTS FED A MIXED FAT DIET

Subject	Work Load % VO_2 Max		Mixed Fat (mg pyruvate/100 ml whole blood)
2	60	rest	0.89
		ex	1.85
		rec	1.42
5	60	rest	0.62
		ex	1.40
		rec	1.01
7	60	rest	0.79
		ex	1.52
		rec	0.81
8	60	rest	0.85
		ex	2.22
		rec	2.89
Group Means & SD:		rest	0.79 ± 0.12
		ex	1.75 ± 0.37
		rec	1.53 ± 0.94

Subject	Work Load % VO_2 Max		Mixed Fat (mg pyruvate/100 ml whole blood)
1	80	rest	0.92
		ex	3.39
		rec	3.22
3	80	rest	0.54
		ex	1.03
		rec	1.11
4	80	rest	0.95
		ex	2.34
		rec	2.15
Group Means & SD:		rest	0.80 ± 0.23
		ex	2.25 ± 1.18
		rec	2.16 ± 1.05

at a work load of 60% VO_2 max, 20.30 (Table 27). During recovery, the lactate/pyruvate ratio decreased for subjects exercised at work loads of 60 and 80% VO_2 max to 13.15 and 14.64, respectively. During recovery, the mean lactate/pyruvate ratio did not differ significantly between work loads (Appendix, Table 40c).

Mean serum glycerol did not differ significantly for subjects fed a mixed fat diet and exercised at work loads of 60 and 80% VO_2 max (Appendix, Table 41b). During rest, mean serum glycerol, was somewhat higher for subjects assigned to a work load of 80% VO_2 max, 5.25 mg/100 ml, as compared to subjects assigned to a work load of 60% VO_2 max, 4.65 mg/100 ml (Table 28). However, mean serum glycerol for subjects during rest did not differ significantly between work loads (Appendix, Table 41a). During exercise mean serum glycerol was considerably higher for subjects exercised at a work load of 80% VO_2 max, 10.12 mg/100 ml, than for subjects exercised at a work load of 60% VO_2 max, 4.92 mg/100 ml. However, mean serum glycerol for subjects did not differ significantly between work loads (Appendix, Table 41b). During recovery, mean serum glycerol increased slightly for subjects exercised at a work load of 60% VO_2 max to 5.71 mg/100 ml, but decreased for subjects exercised at a work load of 80% VO_2 max to 8.19 mg/100 ml. However, mean serum glycerol for subjects did not differ significantly between work loads (Appendix, Table 41c).

TABLE 27

THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON THE LACTATE/PYRUVATE RATIO FOR SUBJECTS FED A MIXED FAT DIET

Subject	Work Load % VO_2 Max		Mixed Fat
2	60	rest	9.75
		ex	18.16
		rec	12.13
5	60	rest	9.48
		ex	23.14
		rec	16.07
7	60	rest	8.62
		ex	14.15
		rec	10.40
8	60	rest	9.51
		ex	25.73
		rec	14.01
Group Means & SD:		rest	9.34 ± 0.49
		ex	20.30 ± 5.16
		rec	13.15 ± 2.44

Subject	Work Load % VO_2 Max		Mixed Fat
1	80	rest	10.75
		ex	21.68
		rec	12.36
3	80	rest	9.28
		ex	16.86
		rec	16.79
4	80	rest	10.20
		ex	25.55
		rec	14.76
Group Means & SD:		rest	10.08 ± 0.74
		ex	21.36 ± 4.35
		rec	14.64 ± 2.22

TABLE 28

THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON SERUM FREE GLYCEROL FOR SUBJECTS FED A MIXED FAT DIET

Subject	Work Load % VO_2 Max		Mixed Fat (mg/100 ml)
2	60	rest	5.89
		ex	5.20
		rec	6.71
5	60	rest	4.26
		ex	4.08
		rec	4.26
7	60	rest	5.08
		ex	6.54
		rec	5.42
8	60	rest	3.35
		ex	3.87
		rec	6.45
Group Means & SD:		rest	4.65 ± 1.09
		ex	4.92 ± 1.23
		rec	5.71 ± 1.12

Subject	Work Load % VO_2 Max		Mixed Fat (mg/100 ml)
1	80	rest	3.18
		ex	8.43
		rec	10.28
3	80	rest	8.64
		ex	16.56
		rec	10.24
4	80	rest	3.92
		ex	5.38
		rec	4.04
Group Means & SD:		rest	5.25 ± 2.96
		ex	10.12 ± 5.78
		rec	8.19 ± 3.59

FASTING BLOOD

Only fasting blood collected on day 17 of the study was included in the statistical analysis. Fasting and resting blood levels for all blood parameters were compared for subjects fed the SO and RSO diets (Tables 29, 30, 31, 32, 33 and 34). Fasting and resting blood analyzed for serum glucose, plasma lactate and pyruvate, serum free fatty acids and serum glycerol did not differ significantly ($\alpha = 0.05$) for subjects fed the SO and RSO diets. Nor was there a significant difference for the calculated lactate/pyruvate ratios for subjects fed the SO and RSO diets (Appendix, Table 42).

Since fasting and resting levels for all blood parameters did not differ significantly, it would appear that resting levels were within normal physiological limits.

TABLE 29

FASTING AND RESTING SERUM GLUCOSE LEVELS FOR SUBJECTS FED THE SO AND RSO DIETS

Subject	SO Diet		Subject	RSO Diet	
	Fasting	Rest		Fasting	Rest
	mg/100 ml			mg/100 ml	
1	93.4	90.0	2	81.6	66.5
5	90.6	92.7	3	83.6	90.8
6	84.4	85.5	4	80.1	76.7
7	75.4	92.0	8	78.9	85.0
Means & SD:	86.0±7.9	90.1±3.2		81.1±2.0	79.8±10.6

TABLE 30

FASTING AND RESTING PLASMA LACTATE CONCENTRATIONS FOR SUBJECTS FED THE SO AND RSO DIETS

Subject	SO Diet		Subject	RSO Diet	
	Fasting	Rest		Fasting	Rest
	mg lactate/100 ml whole blood			mg lactate/100 ml whole blood	
1	8.20	6.07	2	6.95	4.89
5	8.76	5.96	3	--[1]	10.05
6	8.20	7.57	4	9.59	4.69
7	12.72	6.07	8	11.54	5.36
Means & SD:	9.47±2.18	6.42±0.77		9.36±2.30	6.25±2.55

[1]Missing data.

TABLE 31

FASTING AND RESTING PLASMA PYRUVATE CONCENTRATIONS FOR SUBJECTS FED THE SO AND RSO DIETS

Subject	SO Diet		Subject	RSO Diet:	
	Fasting	Rest		Fasting	Rest
	mg pyruvate/100 ml whole blood			mg pyruvate/100 ml whole blood	
1	0.64	0.60	2	0.52	0.77
5	0.45	0.59	3	--	--
6	0.51	0.57	4	0.72	0.88
7	1.12	0.57	8	0.28	1.02
Means & SD:	0.68±0.30	0.58+0.02		0.89±0.10	

TABLE 32

FASTING AND RESTING LACTATE/PYRUVATE RATIOS FOR SUBJECTS FED THE SO AND RSO DIETS

Subject	SO Diet		Subject	RSO Diet	
	Fasting	Rest		Fasting	Rest
1	12.81	10.12	2	13.37	8.71
5	19.47	10.10	3	--	7.14
6	16.08	13.28	4	13.32	8.48
7	11.36	10.65	8	41.21	10.22
Means & SD:	14.93±3.61	11.04±1.52		22.63±16.09	8.64±1.26

TABLE 33

FASTING AND RESTING SERUM FREE FATTY ACIDS FOR SUBJECTS FED THE SO AND RSO DIETS

Subject	SO Diet		Subject	RSO Diet	
	Fasting ug/ml	Rest		Fasting ug/ml	Rest
1	79.41	57.57	2	148.00	--
5	109.47	66.84	3	148.19	178.12
6	126.91	209.58	4	119.00	112.63
7	109.88	91.82	8	78.61	46.85
Means & SD:	106.42±19.75	106.45±70.26		115.27±32.89±65.64	

TABLE 34

FASTING AND RESTING SERUM GLYCEROL LEVELS FOR SUBJECTS FED THE SO AND RSO DIETS

Subject	SO Diet		Subject	RSO Diet	
	Fasting mg/100 ml	Rest		Fasting mg/100 ml	Rest
1	4.00	1.55	2	7.92	2.54
5	5.80	3.10	3	7.48	7.43
6	8.00	8.06	4	7.96	2.28
7	10.06	3.44	8	3.48	3.40
Means & SD:	7.0± 2.63	4.04±2.81		6.71±2.16	3.91±2.39

SUMMARY AND CONCLUSIONS

The comparative effects of low erucic acid rapeseed oil (RSO) and soybean oil (SO) on energy metabolism were investigated in 8 male subjects. The 32-day metabolic study consisted of four experimental periods of 8 days each. Experimental period I served as a stabilization period during which time all subjects received a mixed fat diet. During experimental periods II and III, subjects received either a SO or RSO diet. The diets were fed in a cross-over experimental design. During experimental period II, four of the subjects received the SO diet and four subjects received the RSO diet. During experimental period III, subjects received the alternate diet.

On the 7th day of each experimental period subjects cycled on a bicycle ergometer at a uniform work load of 70% VO_2 max. On the 8th day of each experimental period subjects cycled at adjusted work loads of either 60 or 80% VO_2 max. The adjusted work loads remained the same for each subject throughout the study.

Respiratory parameters were monitored continuously (oxygen consumption, ventilation rate, heart rate and respiratory quotient) during exercise at both a uniform work load of 70% VO_2 max and at adjusted work loads of 60 and 80% VO_2 max. Blood samples were taken during exercise sessions at a uniform work load of 70% VO_2 max during rest, within 30 seconds following exercise, and at the end of the recovery

period. Samples were analyzed for serum glucose, plasma lactate and pyruvate, serum free fatty acids and serum glycerol. The lactate/pyruvate ratios were calculated.

Diet had no significant effect on respiratory or blood parameters during exercise at uniform or adjusted work loads, with the exception of heart rate. Heart rate was higher for subjects fed the RSO diet and exercised at adjusted work loads of 60 and 80% VO_2 max, as compared to subjects fed the SO diet. Since heart rate was the only parameter significantly affected by diet, it is doubtful whether this effect can be solely attributed to diet.

However, there was significant interaction between the RSO and SO diets and work loads with respect to oxygen consumption for subjects exercised at adjusted work loads of 60 and 80% VO_2 max. During exercise at an adjusted work load of 60% VO_2 max, oxygen consumption for subjects fed the RSO diet was somewhat greater, 1.79 l/min, than for subjects fed the SO diet, 1.49 l/min. However, during exercise at an adjusted work load of 80% VO_2 max, oxygen consumption was slightly lower for subjects fed the RSO diet, 2.02 l/min, as compared to 2.12 l/min for subjects fed the SO diet. Since the decrease in oxygen consumption was very small and occurred only at a work load of 80% VO_2 max, its significance may be questioned.

Significant interaction was also observed between the RSO and SO diets and rest and recovery, with respect to

heart rate for subjects exercised at adjusted work loads of 60 and 80% VO_2 max. Mean heart rates for subjects fed the SO diet were higher during rest but lower during recovery, 87 and 97 beats/min, respectively, than mean heart rates for subjects fed the RSO diet, 81 and 104 beats/min, respectively. A significant interaction was also observed between the RSO and SO diets and work loads during rest and recovery. During rest, mean heart rates for subjects fed the SO diet and assigned to adjusted work loads of 60 and 80% VO_2 max were 78 and 96 beats/min, respectively, as compared to 76 and 86 beats/min, respectively, for subjects fed the RSO diet. During recovery, mean heart rates for subjects fed the SO diet and exercised at adjusted work loads of 60 and 80% VO_2 max were 90 and 106 beats/min, respectively, while mean heart rates for subjects fed the RSO diet were 102 and 106 beats/min, respectively.

The effect of exercise on respiratory parameters was evident from the increase in oxygen consumption, ventilation rate and heart rate in response to work loads. Similarly, the effect of exercise on blood parameters was evident from increased levels of plasma lactate and pyruvate, and an increase in the lactate/pyruvate ratio, reflecting increased anaerobic metabolism. In addition, changes in serum glucose, free fatty acids and serum glycerol were observed in response to work loads.

Results in this study indicate that the ingestion of a diet containing low erucic acid RSO as the sole source

of dietary fat by eight young adult men for eight days had effects on energy metabolism which were similar to those when the diet contained SO.

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APPENDIX

APPENDIX TABLE 1

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.015	0.002	2.00
Time	2	0.007	0.004	4.00*
SO vs RSO	1	0.000	0.000	≤ 1
Error	13	0.012	0.001	
Total	23	0.034		

*$P \leq 0.05$

B. Exercise

Source of Variance	df	SS	MS	F-Value
Subjects	7	1.042	0.149	4.81*
Time	2	0.174	0.087	2.81
SO vs RSO	1	0.010	0.011	≤ 1
Error	13	0.401	0.031	
Total	23	1.627		

*$P \leq 0.05$

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.040	0.006	6.00*
Time	2	0.010	0.005	5.00*
SO vs RSO	1	0.000	0.000	< 1
Error	13	0.019	0.001	
Total	23	0.069		

$P \leq 0.05$

APPENDIX TABLE 2

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION FOR SUBJECTS DURING REST AND RECOVERY (UNIFORM WORK LOAD OF 70% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Rest vs Recovery	1	0.008	0.008	8.00*
Subjects	7	0.039	0.006	6.00*
Time	2	0.014	0.007	7.00*
Oil: SO vs RSO	1	0.000	0.000	≤ 1
Rest and Recovery x Time	2	0.002	0.001	1.00
Rest and Recovery x Oil	1	0.000	0.000	≤ 1
Error	33	0.048	0.001	
Total	47	0.111		

*$P \leq 0.05$

APPENDIX TABLE 3

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION FOR SUBJECTS AT REST (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.030	0.004	4.00*
Work Loads 60 vs 80% VO_2 Max	1	0.001	0.001	≤ 1
Subjects within work loads	6	0.029	0.005	
Times	2	0.005	0.003	3.00
Exp Period IV vs II and III	1	0.002	0.002	2.00
Exp Period II vs III	1	0.003	0.003	3.00
Work Loads x Time	2	0.003	0.002	2.00
Work Load x Exp Period IV vs II and III	1	0.000	0.000	≤ 1
Work Load x Exp Period II vs III	1	0.003	0.003	3.00
Oil: SO vs RSO	1	0.000	0.000	≤ 1
Oil x Work Load	1	0.002	0.002	2.00
Error	10	0.013	0.001	
Total	23	0.053		

*$P \leq 0.05$

APPENDIX TABLE 4

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION FOR SUBJECTS EXERCISED AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

Source of Variation		df	SS	MS	F-Value
Subjects		7	2.700	0.385	25.72*
Work Loads 60 vs 80% VO_2 Max	1		0.838	0.838	2.70
Subjects within work loads	6		1.862	0.310	
Times		2	0.170	0.085	5.68*
Exp Period IV vs II and III	1		0.019	0.019	1.27
Exp Period II vs III	1		0.151	0.151	10.10*
Work Loads x Times		2	0.030	0.015	1.05
Work Load x Exp Period IV vs II and III	1		0.030	0.030	2.05
Work Load x Exp Period II vs III	1	0.	0.000	0.000	◂1
Oil x SO vs RSO		1	0.035	0.035	2.39
Oil x Work Load		1	0.164	0.164	10.98*
Error		9	0.135	0.015	
Total		22[a]	3.235		

*P ◂0.05

[a]Degrees of freedom reduced by 1 due to missing value.

APPENDIX TABLE 5

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION FOR SUBJECTS DURING RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation		df	SS	MS	F-Value
Subjects		7	0.097	0.014	14.00*
Work Loads 60 and 80% VO_2 Max	1		0.046	0.046	5.75
Subjects within work loads	6		0.051	0.008	
Times		2	0.002	0.001	1.00
Exp Period IV vs II and III	1		0.002	0.002	2.00
Exp Period II vs III	1		0.000	0.000	≤ 1
Work Loads x Time		2	0.001	0.000	1
Work Load x Exp Period IV vs II and III	1		0.001	0.001	1.00
Work Load x Exp Period II vs III	1		0.000	0.000	≤ 1
Oil: SO vs RSO		1	0.000	0.000	≤ 1
Oil x Work Load		1	0.001	0.001	1.00
Error		8	0.011	0.001	
Total		21[a]	0.112		

*$P \leq 0.05$

[a]Degrees of freedom reduced by 2 due to missing values.

APPENDIX TABLE 6

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON OXYGEN CONSUMPTION FOR SUBJECTS DURING REST AND RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation		df	SS	MS	F-Value
Rest vs Recovery		1	0.026	0.026	26.00*
Subjects		7	0.095	0.014	14.00*
Work Loads 60 vs 80% VO_2 Max	1		0.032	0.033	3.3
Subjects within work loads	6		0.063	0.010	
Rest and Recovery vs Subjects		7	0.033	0.005	5.00*
Rest and Recovery x Work Loads	1		0.016	0.016	5.33
Error	6		0.016	0.003	
Time		2	0.006	0.003	3.00
Exp Period IV vs II and III	1		0.004	0.004	4.00
Exp Period II vs III	1		0.001	0.001	1.00
Work Loads x Time		2	0.003	0.002	2.00
Rest and Recovery x Time		2	0.001	0.000	< 1
Rest and Recovery x Work Loads x Time		2	0.002	0.001	1.00
Oil: SO vs RSO		1	0.000	0.000	< 1
Oil x Rest and Recovery		1	0.000	0.000	< 1
Oil x Work Load		1	0.003	0.003	3.00
Oil x Work Load x Rest and Recovery		1	0.000	0.000	< 1
Error		18	0.024	0.001	
Total		45[a]	0.193		

*P 0.05

[a]Degrees of freedom reduced by 2 due to missing values.

APPENDIX TABLE 7

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON VENTILATION RATE FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	44.69	6.38	4.59*
Time	2	0.44	0.22	$\ll 1$
Oil: So vs RSO	1	0.64	0.64	$\ll 1$
Error	13	18.02	1.39	
Total	23	63.79		

*$P \ll 0.05$

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	1386.17	198.02	6.87*
Time	2	79.49	39.75	1.38
Oil: SO vs RSO	1	33.93	33.93	1.18
Error	13	374.76	28.83	
Total	23	1874.35		

*$P \ll 0.05$

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	113.41	16.20	4.31*
Time	2	16.51	8.26	2.20
Oil: SO vs RSO	1	0.003	0.003	$\ll 1$
Error	13	48.85	3.76	
Total	23	178.80		

*$P \ll 0.05$

APPENDIX TABLE 8

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON VENTILATION RATE FOR SUBJECTS DURING REST AND RECOVERY (UNIFORM WORK LOAD OF 70% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Subjects	7	114.23	16.32	4.86*
Time	2	10.19	5.09	1.51
Oil: SO vs RSO	1	0.36	0.36	<1
Rest vs Recovery	1	14.30	14.30	4.26*
Rest and Recovery x Time	2	6.67	3.33	<1
Rest and Recovery x Oil	1	0.28	0.28	<1
Error	33	110.83	3.36	
Total	47	256.86		

*$P < 0.05$

APPENDIX TABLE 9

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON VENTILATION RATE FOR SUBJECTS DURING REST (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation		df	SS	MS	F-Value
Subjects		7	72.49	10.36	5.63*
Work Loads 60 vs 80% VO_2 Max	1		7.71	7.71	$\ll 1$
Subjects within work loads	6		64.78	10.79	
Time		2	2.10	1.05	< 1
Exp Period IV vs II and III	1		0.00	0.00	$\ll 1$
Exp Period II vs III	1		2.10	2.10	1.14
Work Loads x Time		2	0.94	0.47	$\ll 1$
Work Loads x Exp Period IV vs II and III	1		0.21	0.21	$\ll 1$
Work Loads x Exp Period II vs III	1		0.73	0.73	$\ll 1$
Oil: SO vs RSO		1	7.56	7.56	4.11
Oil x Work Loads		1	1.83	1.83	$\ll 1$
Error		10	18.42	1.84	
Total		23	103.34		

*$P \ll 0.05$

APPENDIX TABLE 10

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON VENTILATION RATE FOR SUBJECTS EXERCISED AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

Source of Variation	df	SS	MS	F-Value
Subjects	7	3055.30	436.41	16.06*
Work Loads 60 vs 80% VO_2 Max	1	886.95	886.95	2.45
Subjects within work loads	6	2168.35	361.39	
Time	2	52.60	26.3	≤ 1
Exp Period IV vs II and III	1	46.22	46.22	1.70
Exp Period II vs III	1	6.38	6.38	≤ 1
Work Loads x Time	2	315.90	157.95	5.81*
Work Loads x Exp Period IV vs II and III	1	1.73	1.73	< 1
Work Loads x Exp Period II vs III	1	314.17	314.17	11.56*
Oil: SO vs RSO	1	98.51	98.51	3.63
Oil x Work Loads	1	1.06	1.06	≤ 1
Error	10	271.72	27.17	
Total	23	3795.09		

*$P \leq 0.05$

APPENDIX TABLE 11

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON VENTILATION RATE FOR SUBJECTS DURING RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Subjects	7	148.30	21.19	8.58*
Work Loads 60 vs 80% VO_2 Max	1	89.71	89.71	9.18*
Subjects within work loads	6	58.59	9.77	
Time	2	1.96	0.98	$\ll 1$
Exp Period IV vs II and III	1	1.47	1.47	$\ll 1$
Exp Period II vs III	1	0.49	0.49	$\ll 1$
Work Loads x Time	2	0.01	0.01	$\ll 1$
Work Loads x Exp Period IV vs II and III	1	0.00	0.00	$\ll 1$
Work Loads x Exp Period II vs III	1	0.01	0.01	$\ll 1$
Oil: SO vs RSO	1	0.72	0.72	$\ll 1$
Oil x Work Loads	1	3.06	3.06	1.24
Error	10	24.73	2.47	
Total	23	178.78		

*$P \ll 0.05$

APPENDIX TABLE 12

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON VENTILATION RATE FOR SUBJECTS DURING REST AND RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Rest vs Recovery	1	27.60	27.60	12.78*
Subjects	7	171.76	24.53	11.36*
Work Loads 60 vs 80% VO_2 Max	1	75.00	75.00	4.65
Subjects within work loads	6	96.76	16.13	
Rest and Recovery vs Subjects	7	49.02	7.00	3.24*
Rest and Recovery x Work Loads	1	22.41	22.41	5.05
Error	6	26.61	4.44	
Time	2	2.98	1.49	<1
Exp Period IV vs II and III	1	0.67	0.67	<1
Exp Period II vs III	1	2.31	2.31	1.07
Work Loads x Time	2	0.42	0.21	<1
Rest and Recovery x Time	2	1.09	0.55	<1
Rest and Recovery x Work Loads x Time	2	0.53	0.27	<1
Oil: SO vs RSO	1	1.81	1.81	<1
Oil x Rest and Recovery	1	6.48	6.48	3.00
Oil x Work Loads	1	4.81	4.81	2.23
Oil x Work Loads x Rest and Recovery	1	0.08	0.08	<1
Error	20	43.14	2.16	
Total	47	309.72		

*$P < 0.05$

APPENDIX TABLE 13

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON HEART RATE FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 max

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	5	1775.12	355.02	7.50*
Time	2	505.45	252.73	5.34*
Oil: SO vs RSO	1	24.08	24.08	<1
Error	1	425.80	47.31	
Total	17	2730.45		

*$P < 0.05$

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	5	344.28	66.86	<1
Time	2	144.45	72.22	<1
Oil: SO vs RSO	1	16.33	16.33	<1
Error	7	1485.89	212.27	
Total	15[a]	1980.95		

[a]Degrees of freedom reduced by 2 due to missing values.

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	5	2761.61	552.32	5.61*
Time	2	200.78	100.39	1.02
Oil: SO vs RSO	1	2.08	2.08	<1
Error	7	689.81	98.54	
Total	15	3654.28		

*$P < 0.05$

APPENDIX TABLE 14

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON HEART RATE FOR SUBJECTS DURING REST AND RECOVERY (UNIFORM WORK LOAD 70% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Rest vs Recovery	1	4422.25	4422.25	105.49*
Subjects	5	4269.15	853.83	20.37*
Time	2	155.06	77.53	1.85
Oil: SO vs RSO	1	20.17	20.17	≤ 1
Rest and Recovery x Time	2	551.16	215.58	5.14*
Rest and Recovery x Oil	1	5.83	5.83	≤ 1
Error	33	1383.36	41.92	
Total	45	10806.98		

*$P \leq 0.05$

APPENDIX TABLE 15

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON HEART RATE FOR SUBJECTS DURING REST (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Subjects	5	3105.80	621.16	6.68*
Work Loads 60 vs 80% VO_2 Max	1	722.00	72.20	1.21
Subjects within work loads	4	238.38	595.95	
Time	2	18.78	9.39	$\ll 1$
Exp Period IV vs II and III	1	18.78	18.78	$\ll 1$
Exp Period II vs III	1	0.00	0.00	$\ll 1$
Work Loads x Time	2	192.33	96.16	1.03
Work Loads x Exp Period IV vs II and III	1	16.00	16.00	$\ll 1$
Work Loads x Exp Period II vs III	1	176.33	176.33	1.89
Oil: SO vs RSO	1	108.00	108.00	1.16
Oil x Work Loads	1	40.33	40.33	$\ll 1$
Error	6	557.56	92.93	
Total	17	4022.80		

*$P \ll 0.05$

APPENDIX TABLE 16

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON HEART RATE FOR SUBJECTS EXERCISED AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

Source of Variation	df	SS	MS	F-Value
Subjects	5	3089.83	617.97	19.04*
Work Loads 60 vs 80% VO_2 Max	1	734.22	734.22	1.25
Subjects within work loads	4	2355.61	588.90	
Time	2	217.00	108.5	3.34
Exp Period IV vs II and III	1	156.25	156.25	4.81
Exp Period II vs III	1	60.75	60.75	1.87
Work Loads x Time	2	352.77	176.38	5.43*
Work Loads x Exp Period IV vs II and III	1	0.69	0.69	≤ 1
Work Loads x Exp Period II vs III	1	352.08	352.08	10.85*
Oil: SO vs RSO	1	310.08	310.08	9.55*
Oil x Work Loads	1	10.09	10.09	≤ 1
Error	6	194.73	32.45	
Total	17	4174.50		

*$P \leq 0.05$

APPENDIX TABLE 17

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON HEART RATE FOR SUBJECTS DURING RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Subjects	5	3204.66	640.93	7.90*
Work Loads 60 vs 80% VO_2 Max	1	1283.55	1283.55	2.67
Subjects within work loads	4	1921.11	480.27	
Time	2	64.00	32.00	< 1
Exp Period IV vs II and III	1	64.00	64.00	< 1
Exp Period II vs III	1	0.00	0.00	< 1
Work Loads x Time	2	395.10	197.56	2.43
Work Loads x Exp Period IV vs II and III	1	186.77	186.77	2.30
Work Loads x Exp Period II vs III	1	208.33	208.33	2.57
Oil: SO vs RSO	1	176.33	176.33	2.17
Oil x Work Loads	1	161.33	161.33	1.99
Error	6	486.56	81.09	
Total	17	4487.99		

*$P < 0.05$

APPENDIX TABLE 18

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON HEART RATE FOR SUBJECTS DURING REST AND RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Rest vs Recovery	1	2533.94	2533.94	66.32*
Subjects	6	5591.56	931.93	24.39*
Work Load 60 vs 80% VO_2 Max	1	1965.44	1965.44	2.71
Subjects within work loads	5	3626.12	725.22	
Rest and Recovery x Subjects	6	589.56	98.26	2.57
Rest and Recovery x Work Loads	1	39.62	39.62	≤ 1
Error	6	549.94	109.98	
Time	2	76.06	38.03	< 1
Exp Period IV vs II and III	1	76.06	76.06	1.99
Exp Period II vs III	1	0.00	0.00	< 1
Work Loads x Time	2	47.40	23.70	≤ 1
Rest and Recovery x Time	2	6.23	3.12	≤ 1
Rest and Recovery x Work Loads x Time	2	576.00	288.00	7.54*
Oil: SO vs RSO	1	4.17	4.17	≤ 1
Oil x Rest and Recovery	1	280.16	280.16	7.33*
Oil x Work Loads	1	927.67	927.67	24.28*
Oil x Work Loads x Rest and Recovery	1	20.17	20.17	≤ 1
Error	10	382.13	38.21	
Total	35	11035.05		

*$P \leq 0.05$

APPENDIX TABLE 19

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.0043	0.0006	1.00
Time	2	0.0018	0.0009	1.50
Oil: SO vs RSO	1	0.0001	0.0001	< 1
Error	13	0.0076	0.0006	
Total	23	0.0138		

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.0045	0.0006	6.00*
Time	2	0.0002	0.0001	1.00
Oil: SO vs RSO	1	0.0002	0.0001	1.00
Error	13	0.0012	0.0001	
Total	23	0.0061		

*$P < 0.05$

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.0069	0.0009	4.50*
Time	2	0.0002	0.0001	< 1
Oil: SO vs RSO	1	0.0003	0.0003	1.50
Error	13	0.0029	0.0002	
Total	23	0.0103		

*$P < 0.05$

[1]Statistical analysis based on logs of the respiratory quotients.

APPENDIX TABLE 20

EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS FOR SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
1	70	rest	0.2765	0.2765	0.3201
		ex	0.3324	0.3096	0.3424
		rec	0.2833	0.2695	0.2900
2	70	rest	0.2989	0.2967	0.2672
		ex	0.3096	0.3010	0.2989
		rec	0.3032	0.2577	0.2833
3	70	rest	0.3874	0.2989	0.2900
		ex	0.3096	0.2900	0.3075
		rec	0.2833	0.2833	0.3096
4	70	rest	0.3243	0.3139	0.2765
		ex	0.3201	0.2967	0.3118
		rec	0.2455	0.2810	0.2878
5	70	rest	0.3032	0.3010	0.3160
		ex	0.3075	0.3243	0.3243
		rec	0.2695	0.2529	0.2553
6	70	rest	0.2945	0.3096	0.3054
		ex	0.2833	0.2856	0.2856
		rec	0.2900	0.2945	0.2945
7	70	rest	0.2810	0.2900	0.2718
		ex	0.2967	0.2923	0.2788
		rec	0.2553	0.2380	0.2227
8	70	rest	0.2989	0.2810	0.2833
		ex	0.3222	0.3118	0.3160
		rec	0.2672	0.2625	0.2672

[1]Respiratory quotients converted to common logs.

APPENDIX TABLE 21

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS FOR SUBJECTS DURING REST (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.217	0.031	2.82
Work Loads 60 vs 80% VO_2 Max	1	0.053	0.053	1.96
Subjects within work loads	6	0.164	0.027	
Time	2	0.038	0.019	1.72
Exp Period IV vs II and III	1	0.002	0.002	$\blacktriangleleft$1
Exp Period II vs III	1	0.036	0.036	3.27
Work Loads x Time	2	0.001	0.001	$\blacktriangleleft$1
Work Loads x Exp Period IV vs II and III	1	0.000	0.000	$\blacktriangleleft$1
Work Loads x Exp Period II vs III	1	0.001	0.001	$\blacktriangleleft$1
Oil: SO vs RSO	1	0.017	0.017	1.54
Oil x Work Loads	1	0.016	0.016	1.45
Error	10	0.110	0.011	
Total	23	0.399		

APPENDIX TABLE 22

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS FOR SUBJECTS EXERCISED AT ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.090	0.012	6.00*
Work Loads 60 vs 80% VO_2 Max	1	0.004	0.004	$\ll 1$
Subjects within work loads	6	0.086	0.014	
Time	2	0.029	0.015	7.50*
Exp Period IV vs II and III	1	0.009	0.009	4.50
Exp Period II vs III	1	0.020	0.020	10.00*
Work Loads x Time	2	0.005	0.003	1.50
Work Loads x Exp Period IV vs II and III	1	0.000	0.000	$\ll 1$
Work Loads x Exp Period II vs III	1	0.005	0.005	2.50
Oil: SO vs RSO	1	0.000	0.000	$\ll 1$
Oil x Work Loads	1	0.006	0.006	3.00
Error	10	0.018	0.002	
Total	23	0.148		

*$P \ll 0.05$

APPENDIX TABLE 23

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS FOR SUBJECTS DURING RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.131	0.019	3.80*
Work Loads 60 vs 80% VO_2 Max	1	0.035	0.035	2.19
Subjects within work loads	6	0.096	0.016	
Time	2	0.000	0.000	≤ 1
Exp Period IV vs II and III	1	0.000	0.000	≤ 1
Exp Period II vs III	1	0.000	0.000	≤ 1
Work Loads x Time	2	0.000	0.000	≤ 1
Work Loads x Exp Period IV vs II and III	1	0.000	0.000	≤ 1
Work Loads x Exp Period II vs II	1	0.000	0.000	≤ 1
Oil: SO vs RSO	1	0.000	0.000	≤ 1
Oil x Work Loads	1	0.000	0.000	≤ 1
Error	10	0.052	0.005	
Total	23	0.183		

*$P \leq 0.05$

APPENDIX TABLE 24

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON RESPIRATORY QUOTIENTS FOR SUBJECTS DURING REST AND RECOVERY (ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX)

Source of Variation	df	SS	MS	F-Value
Rest vs Recovery	1	0.109	0.109	13.63*
Subjects	7	0.233	0.033	4.13*
Work Loads 60 vs 80% VO_2 Max	1	0.088	0.088	3.67
Subjects within work loads	6	0.145	0.024	
Rest and Recovery vs Subjects	7	0.116	0.017	2.13
Rest and Recovery x Work Loads	1	0.001	0.001	<1
Error	6	0.115	0.019	
Time	2	0.023	0.012	1.50
Exp Period IV vs II and III	1	0.002	0.002	<1
Exp Period II vs III	1	0.021	0.021	2.63
Work Loads x Time	2	0.002	0.001	<1
Rest and Recovery x Time	2	0.016	0.008	1.00
Rest and Recovery x Work Loads x Time	2	0.000	0.000	<1
Oil: SO vs RSO	1	0.009	0.009	1.12
Oil x Rest and Recovery	1	0.008	0.008	1.00
Oil x Work Loads	1	0.009	0.009	1.12
Oil x Work Loads x Rest and Recovery	1	0.006	0.006	<1
Error	20	0.162	0.008	
Total	47	0.892		

*$P < 0.05$

APPENDIX TABLE 25

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON SERUM GLUCOSE FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	853.99	121.99	4.35*
Time	2	233.58	116.79	4.17*
Oil: SO vs RSO	1	20.70	20.70	$\ll 1$
Error	13	364.46	28.04	
Total	23	1472.73		

*$P \ll 0.05$

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	702.97	100.42	3.03*
Time	2	145.36	72.68	2.19
Oil: SO vs RSO	1	17.43	17.43	$\ll 1$
Error	13	430.93	33.15	
Total	23	1296.69		

*$P \ll 0.05$

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	596.55	85.22	4.62*
Time	2	257.61	128.81	6.98*
Oil: SO vs RSO	1	70.14	70.14	3.81
Error	13	239.54	18.43	
Total	23	1163.84		

*$P \ll 0.05$

APPENDIX TABLE 26

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON SERUM GLUCOSE FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Source of Variation	df	SS	MS	F-Value
Rest x Exercise x Recovery	2	589.66	294.83	8.37*
Subjects	7	1322.48	188.93	5.37*
Time	2	558.55	279.28	7.93*
Oil: SO vs RSO	1	97.47	97.47	2.77
Rest x Exercise x Recovery x Time	4	77.99	19.50	≤ 1
Rest x Exercise x Recovery x Oil	2	10.81	5.41	≤ 1
Error	53	1865.96	35.21	
Total	71	4522.92		

*$P \leq 0.05$

APPENDIX TABLE 27

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON PLASMA LACTATE CONCENTRATIONS FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.0954	0.0136	1.15
Time	2	0.0332	0.0166	1.41
Oil: SO vs RSO	1	0.0006	0.0006	≤ 1
Error	12	0.1421	0.0118	
Total	22[a]	0.2713		

[a]Degrees of freedom reduced by 1 due to missing value.

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.5746	0.0821	4.59*
Time	2	0.0225	0.0113	≤ 1
Oil: SO vs RSO	1	0.0016	0.0016	≤ 1
Error	13	0.2326	0.0179	
Total	23	0.8313		

*$P \leq 0.05$

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	1.0081	0.1440	4.53*
Time	2	0.0093	0.0047	≤ 1
Oil: SO vs RSO	1	0.0000	0.0000	≤ 1
Error	13	0.4135	0.0318	
Total	23	1.4309		

*$P \leq 0.05$

[1]Statistical analysis based on logs of plasma lactate concentrations.

APPENDIX TABLE 28

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON PLASMA PYRUVATE CONCENTRATIONS FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.0279	0.0040	3.33*
Time	2	0.0195	0.0098	8.17*
Oil: SO vs RSO	1	0.0015	0.0015	1.25
Error	13	0.0160	0.0012	
Total	23	0.0649		

*$P < 0.05$

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.0492	0.0070	4.67*
Time	2	0.0153	0.0077	5.13*
Oil: SO vs RSO	1	0.0004	0.0004	< 1
Error	13	0.0195	0.0015	
Total	23	0.0844		

*$P < 0.05$

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.2304	0.0329	10.28*
Time	2	0.0111	0.0056	1.75
Oil: SO vs RSO	1	0.0019	0.0019	< 1
Error	13	0.0419	0.0032	
Total	23	0.2853		

*$P < 0.05$

[1]Statistical analysis based on logs of plasma pyruvate concentrations.

APPENDIX TABLE 29

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON THE LACTATE/PYRUVATE RATIOS FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

A. Rest

Source of Variation	df	SS	Ms	F-Value
Subjects	7	0.0387	0.0055	1.10
Time	2	0.1068	0.0534	10.68*
Oil: SO vs RSO	1	0.0019	0.0019	≤ 1
Error	12	0.0598	0.0050	
Total	22[a]	0.2072		

*$P \leq 0.05$

[a]Degrees of freedom reduced by 1 due to missing value.

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.2267	0.0324	4.50*
Time	2	0.1101	0.0551	7.65*
Oil: SO vs RSO	1	0.0001	0.0001	≤ 1
Error	13	0.0932	0.0072	
Total	23	0.4301		

*$P \leq 0.05$

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	0.1363	0.0194	1.44
Time	2	0.0662	0.0331	2.45
Oil: SO vs RSO	1	0.0067	0.0067	≤ 1
Error	13	0.1749	0.0135	
Total	23	0.3841		

[1]Statistical analysis based on logs of the lactate/pyruvate ratios.

APPENDIX TABLE 30

EFFECT OF DIETARY FAT ON THE PLASMA LACTATE CONCENTRATIONS OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
1	70	rest	0.8871	0.7832	0.8762
		ex	1.8910	1.8937	1.9083
		rec	1.7243	1.5885	1.7188
2	70	rest	1.1770	0.8965	0.8267
		ex	1.3581	1.7170	1.3086
		rec	1.0924	1.4099	1.0663
3	70	rest	0.8722	0.7459[2]	0.7832
		ex	1.5600	1.3998	1.4904
		rec	1.4492	0.8772	1.3438
4	70	rest	0.8182	0.9703	0.8727
		ex	1.7388	1.4814	1.5879
		rec	1.5655	1.3491	1.3406
5	70	rest	0.8096	0.7752	0.8722
		ex	1.4856	1.7394	1.8762
		rec	1.2940	1.6198	1.6564
6	70	rest	0.7818	0.8791	0.7267
		ex	1.5253	1.5843	1.5752
		rec	1.2792	1.3288	1.2817
7	70	rest	0.8722	0.7832	0.7024
		ex	1.3718	1.3833	1.4521
		rec	1.1239	1.1173	1.0781
8	70	rest	1.0241	0.7497	1.0179
		ex	1.8361	1.7729	1.6131
		rec	1.7751	1.7177	1.5145

[1]Original date (mg/100 ml whole blood) converted to common logs.

[2]Based on calculated value.

APPENDIX TABLE 31

EFFECT OF DIETARY FAT ON THE PLASMA PYRUVATE CONCENTRATIONS OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
1	70	rest	0.2041	0.2041	0.1732
		ex	0.4969	0.5465	0.4314
		rec	0.5276	0.5378	0.5038
2	70	rest	0.3284	0.1987	0.2480
		ex	0.3139	0.4099	0.3711
		rec	0.2788	0.3541	0.2742
3	70	rest	0.1875	0.1487[2]	0.2672
		ex	0.4330	0.3385	0.4425
		rec	0.4014	0.3201	0.3874
4	70	rest	0.1903	0.2304	0.2742
		ex	0.4082	0.3747	0.4594
		rec	0.4771	0.3181	0.4082
5	70	rest	0.2405	0.2014	0.1703
		ex	0.3284	0.4378	0.4133
		rec	0.3010	0.5289	0.4249
6	70	rest	0.1584	0.1959	0.1239
		ex	0.3560	0.3909	0.3222
		rec	0.2900	0.3560	0.2810
7	70	rest	0.1673	0.1959	0.1399
		ex	0.3054	0.3945	0.3444
		rec	0.2625	0.3345	0.2577
8	70	rest	0.2810	0.1703	0.3054
		ex	0.4772	0.4265	0.4594
		rec	0.5717	0.5527	0.5899

[1]Original data (mg/100 ml whole blood) converted to common logs.

[2]Based on calculated value.

APPENDIX TABLE 32

EFFECT OF DIETARY FAT ON THE LACTATE/PYRUVATE RATIO OF SUBJECTS EXERCISED AT A UNIFORM WORK LOAD OF 70% VO_2 MAX[1]

Subject	Work Load % VO_2 Max		Mixed Fat	Soybean Oil	Rapeseed Oil
1	70	rest	1.1089	1.0052	1.1861
		ex	1.5606	1.4923	1.6778
		rec	1.3495	1.1992	1.3784
2	70	rest	1.1239	1.1332	0.9400
		ex	1.3328	1.5211	1.1781
		rec	1.1380	1.3096	1.1219
3	70	rest	1.1399	1.1255[2]	0.8537
		ex	1.3269	1.3280	1.2423
		rec	1.2674	0.8344	1.1855
4	70	rest	1.0777	1.1252	0.9284
		ex	1.5457	1.3458	1.3139
		rec	1.2646	1.3158	1.1474
5	70	rest	0.9405	1.0043	1.1909
		ex	1.4325	1.4989	1.6748
		rec	1.2940	1.2433	1.4363
6	70	rest	1.1383	1.1232	1.2082
		ex	1.4214	1.4200	1.5338
		rec	1.3015	1.2251	1.3226
7	70	rest	1.2000	1.0273	1.1225
		ex	1.3632	1.2130	1.3692
		rec	1.2047	1.0527	1.1697
8	70	rest	1.0652	1.0700	1.0095
		ex	1.5808	1.5502	1.3389
		rec	1.3389	1.3077	1.0535

[1]Original data converted to common logs.

[2]Based on calculated value.

APPENDIX TABLE 33

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON SERUM FREE FATTY ACID CONCENTRATIONS FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	58,224.942	8,317.848	2.09
Time	2	729.921	364.961	$\ll 1$
Oil: SO vs RSO	1	2,908.973	2,908.973	$\ll 1$
Error	12	47,560.888	3,963.407	
Total	22[a]	109,424.724		

[a]Degrees of freedom reduced by 1 due to missing value.

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	64,703.750	9,243.393	1.68
Time	2	10,441.570	5,220.785	$\ll 1$
Oil: SO vs RSO	1	500.976	500.976	$\ll 1$
Error	12	65,880.454	5,490.038	
Total	22[a]	141,526.750		

[a]Degrees of freedom reduced by 1 due to missing value.

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	85,514.946	12,216.420	3.94*
Time	2	202.931	101.466	$\ll 1$
Oil: SO vs RSO	1	2,353.876	2,253.876	$\ll 1$
Error	13	40,311.163	3,100.859	
Total	23	128,282.916		

*$P \ll 0.05$

APPENDIX TABLE 34

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON SERUM FREE FATTY ACID CONCENTRATIONS FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Source of Variation	df	SS	MS	F-Value
Rest x Exercise x Recovery	2	6,785.63	3,392.82	1.01
Subjects	7	191,951.80	27,421.69	8.18*
Time	2	5,333.17	2,666.58	<1
Oil; SO vs RSO	1	5,107.98	5,107.98	1.52
Rest x Exercise x Recovery x Time	4	6,040.88	1,510.22	<1
Rest x Exercise x Recovery x Oil	2	555.85	277.93	<1
Error	51	170,974.39	3,352.44	
Total	69[a]	386,749.70		

*$P < 0.05$

[a]Degrees of freedom reduced by 2 due to missing values.

APPENDIX TABLE 35

ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON SERUM FREE GLYCEROL FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

A. Rest

Source of Variation	df	SS	MS	F-Value
Subjects	7	78.913	11.273	2.39
Time	2	12.538	6.269	1.33
Oil: SO vs RSO	1	0.490	0.490	< 1
Error	13	61.219	4.709	
Total	23	153.159		

B. Exercise

Source of Variation	df	SS	MS	F-Value
Subjects	7	149.624	21.375	2.59
Time	2	14.451	7.226	< 1
Oil: SO vs RSO	1	5.700	5.700	< 1
Error	13	107.125	8.24	
Total	23	276.899		

C. Recovery

Source of Variation	df	SS	MS	F-Value
Subjects	7	150.263	21.466	3.53*
Time	2	13.183	6.592	1.09
Oil: SO vs RSO	1	4.209	4.209	< 1
Error	12	72.882	6.074	
Total	22[a]	240.537		

*$P < 0.05$

[a]Degrees of freedom reduced by 1 due to missing value.

APPENDIX TABLE 36

COMBINED ANALYSIS OF VARIANCE FOR THE EFFECT OF DIETARY FAT ON SERUM FREE GLYCEROL FOR SUBJECTS DURING REST, EXERCISE AND RECOVERY AT A UNIFORM WORK LOAD OF 70% VO_2 MAX

Source of Variation	df	SS	MS	F-Value
Rest x Exercise x Recovery	2	66.577	33.289	5.73*
Subjects	7	317.993	45.428	7.82*
Time	2	39.975	19.988	3.44*
Oil: SO vs RSO	1	8.774	8.774	1.51
Rest x Exercise x Recovery x Time	4	0.195	0.049	<1
Rest x Exercise x Recovery x Oil	2	1.585	0.792	<1
Error	52	302.033	5.808	
Total	70[a]	737.132		

*$P < 0.05$

[a]Degrees of freedom reduced by 1 due to missing value.

APPENDIX TABLE 37

ANALYSIS OF VARIANCE FOR THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON SERUM GLUCOSE DURING REST, EXERCISE AND RECOVERY FOR SUBJECTS FED A MIXED FAT DIET

A. Rest

Source of Variation	df	SS	MS	F-Value
Work Load	1	294.19	294.19	6.27*
Error	5	234.56	46.91	
Total	6	528.75		

*$P < 0.05$

B. Exercise

Source of Variation	df	SS	MS	F-Value
Work Load	1	121.44	121.44	1.28
Error	5	473.82	94.76	
Total	6	595.26		

C. Recovery

Source of Variation	df	SS	MS	F-Value
Work Load	1	22.73	22.73	<1
Error	5	290.59	58.12	
Total	6	313.32		

APPENDIX TABLE 38

ANALYSIS OF VARIANCE FOR THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON PLASMA LACTATE CONCENTRATIONS DURING REST, EXERCISE AND RECOVERY FOR SUBJECTS FED A MIXED FAT DIET

A. Rest

Source of Variation	df	SS	MS	F-Value
Work Load	1	0.506	0.506	<1
Error	5	19.702	3.940	
Total	6	20.208		

B. Exercise

Source of Variation	df	SS	MS	F-Value
Work Load	1	338.800	338.800	<1
Error	5	2385.957	477.191	
Total	6	2724.757		

C. Recovery

Source of Variation	df	SS	MS	F-Value
Work Load	1	153.740	153.740	<1
Error	5	802.290	160.458	
Total	6	956.030		

APPENDIX TABLE 39

ANALYSIS OF VARIANCE FOR THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON PLASMA PYRUVATE CONCENTRATIONS DURING REST, EXERCISE AND RECOVERY FOR SUBJECTS FED A MIXED FAT DIET

A. Rest

Source of Variation	df	SS	MS	F-Value
Work Load	1	0.000	0.000	<1
Error	5	0.147	0.147	
Total	6	0.147		

B. Exercise

Source of Variation	df	SS	MS	F-Value
Work Load	1	0.438	0.438	<1
Error	5	3.203	0.641	
Total	6	3.641		

C. Recovery

Source of Variation	df	SS	MS	F-Value
Work Load	1	0.664	0.664	<1
Error	5	4.888	0.978	
Total	6	5.552		

APPENDIX TABLE 40

ANALYSIS OF VARIANCE FOR THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON THE LACTATE/PYRUVATE RATIO DURING REST, EXERCISE AND RECOVERY FOR SUBJECTS FED A MIXED FAT DIET

A. Rest

Source of Variation	df	SS	MS	F-Value
Work Load	1	0.930	0.930	2.53
Error	5	1.839	0.368	
Total	6	2.769		

B. Exercise

Source of Variation	df	SS	MS	F-Value
Work Load	1	1.956	1.956	<1
Error	5	117.861	23.572	
Total	6	119.817		

C. Recovery

Source of Variation	df	SS	MS	F-Value
Work Load	1	3.776	3.776	<1
Error	5	27.704	5.541	
Total	6	31.480		

APPENDIX TABLE 41

ANALYSIS OF VARIANCE FOR THE EFFECT OF ADJUSTED WORK LOADS OF 60 AND 80% VO_2 MAX ON SERUM FREE GLYCEROL DURING REST, EXERCISE AND RECOVERY FOR SUBJECTS FED A MIXED FAT DIET

A. Rest

Source of Variation	df	SS	MS	F-Value
Work Load	1	0.621	0.621	<1
Error	5	21.110	4.222	
Total	6	21.731		

B. Exercise

Source of Variation	df	SS	MS	F-Value
Work Load	1	46.370	46.370	3.25
Error	5	71.308	14.262	
Total	6	117.678		

C. Recovery

Source of Variation	df	SS	MS	F-Value
Work Load	1	10.521	10.521	1.78
Error	5	29.519	5.904	
Total	6	40.040		

APPENDIX TABLE 42

MEAN DIFFERENCES BETWEEN FASTING AND RESTING BLOOD LEVELS FOR SUBJECTS FED THE SO AND RSO DIETS

Blood Parameter	SO	RSO
Serum Glucose	-4.1 ± 8.8	1.3 ± 10.4
Plasma Lactate	3.05 ± 2.6	4.4 ± 2.8
Plasma Pyruvate	0.10 ± 0.003	-0.38 ± 0.32
Lactate/Pyruvate Ratio	3.89 ± 3.77	13.49 ± 14.09
Serum Free Fatty Acids	-0.03 ± 56.14	2.74 ± 25.35
Serum Glycerol	2.96 ± 2.76	2.80 ± 3.16