NUTRIENT INTAKE AND EATING HABITS OF PROFESSIONAL WOMEN TENNIS PLAYERS

by

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Thesis submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

MASTERS OF SCIENCE

in

Human Nutrition and Foods

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March 25, 1994

Blacksburg, Virginia

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(ABSTRACT)

The dietary status of 40 professional women tennis players was evaluated. The nutrition section of the Health Habits and History Questionnaire was used to collect the data. The analysis of the questionnaires found a mean daily caloric intake of 2020 kcal or 33 kcal/kg. The mean percentage of kcal from carbohydrates of 50% was lower than the recommended range of 60% to 70% for athletes; the percentage of kcal from fat was 31%; and the mean intake of protein was in the recommended range of 1.0 to 1.5 g/kg. The mean intake of vitamins and minerals was over 100% of the RDA; however, some of the individual intakes were below 67% of the RDA for vitamin E, riboflavin, calcium, folacin, and iron. The use of supplements resulted in 200% or higher of the RDA in the daily intakes of vitamin C, vitamin A, vitamin E, thiamin, iron, and calcium.

The analysis of the subjects weekly food intake revealed a mean intake of 4.6 servings of chicken and fish compared to 1.0 to 0.3 for beef and pork. The mean intake for fruit was

16.8 servings and vegetables was 23.3 servings. The mean intake for pasta was 5.9 servings and dairy products was 2.6 servings.

The nutrient intake of the professional women tennis players was comparable to that of other women athletes of various sports found in the literature.

ACKNOWLEDGEMENTS

I would like to thank my committee members, Dr. Mary Korslund, Dr. Forrest Thye and Dr. Janet Rankin for their professional guidance in completing my thesis. I would also like to thank the Womens Tennis Association, their Health Services Director, Kathleen Stroia, and the players for giving me the opportunity to conduct my thesis project with professional women athletes. Lastly, I would like to thank my Mother, Brother, Anna, Spanky, Dillon, and Baby Cat for their help, patience and understanding during long hours in front of the computer.

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INTRODUCTION

The majority of women athletes are intensely concerned with optimal performance in their events. Good nutrition plays an important role in supporting the effects of regular training for strength and endurance. For athletes, the effect of the diet may make the difference between winning and losing, between world-class and ordinary status. Their energy and nutrient needs differ depending on the type, intensity, frequency and duration of the sport as well as physical conditioning and the environmental conditions present during participation in the sport. A four-year study of university athletes' dietary intake by Short and Short (1) found, when caloric and nutrient intake are reported, athletes cannot be lumped together. The specific sport must be mentioned, as intakes of the various athletes in this study were very different.

Carbohydrates should be the major source of kcal in the athlete's diet, with 6 to 10 g/kg of carbohydrates or approximately 60 to 70% of total caloric intake (2). Female athletes consuming low (1.2 g/kg) and moderate (4.3 g/kg) carbohydrate diets have been reported to have reduced performance in comparison with athletes who had a higher (6.4 g/kg) carbohydrate diet (3). The major source of energy for

muscles and anaerobic type activity is muscle glycogen, and a determinant for endurance in aerobic activity is the amount of muscle glycogen. The primary source of muscle glycogen comes through the dietary emphasis of carbohydrates (4).

Protein is not a major source of energy for the athlete but is primarily required for healing injuries, growth and development and building muscles. The protein requirement for women athletes depends on the type of sport and the intensity and duration of the exercise. Lemon (5) recommends an intake of 1 to 1.5 g/kg or approximately 15% of total caloric intake. In the results of studies with women athletes (6) protein intake ranged from a high of 2.1 g/kg for gymnasts to a low of 0.9 g/kg for basketball players.

Fat is a necessary source of energy for women athletes, but they must be cautious of the amount they consume since fat supplies more than twice the kcal per gram than protein and carbohydrate food. The Dietary Guidelines for Healthy Americans, developed by the American Heart Association, suggest daily fat intake should be reduced to 20 to 30% of total kcal, with less than one-third of these kcal coming from saturated fat. Cholesterol intakes should be maintained at 300 mg per day or less (7).

The optimal diet for women athletes must provide

sufficient quantities of vitamins and minerals to meet the Recommended Dietary Allowances (RDA); the major source of these should be nutrient dense foods. Certain athletes, in an effort to achieve maximum athletic performance, use nutrient supplements (8,9). Studies focusing on the supplementation behaviors of specific groups have targeted elite athletes as having a considerably greater prevalence of supplementation then that cited for the general public (10,11,12).

For the competing athlete, water is the single most important nutrient in sports nutrition. Even mild dehydration impairs thermal regulatory ability, leading to decreased endurance and decreased performance (12).

Many studies have analyzed the dietary intake of elite women athletes, but very little research has been conducted on the eating patterns of professional women tennis players. The objective of this study was to investigate the dietary practices of professional women tennis players to determine the quality and quantity of their general diets and to compare their dietary intake with other women athletes as reported in the literature.

REVIEW OF LITERATURE

Nutrition Assessment

Proper nutrition plays an important role in maximizing athletes' ability to maintain higher levels of physical activity, regardless of age and type of activity. The need for accurate and appropriate information to help athletes improve their nutritional status can only be reliably accomplished by a nutrition assessment. (13)

A comprehensive nutrition assessment consists of weight analysis, eating and lifestyle patterns, fitness and laboratory tests, and psychosocial influences. These elements would be considered in assessing the athletes' nutritional needs (a) during training and (b) immediately preceding, during and following competition. The factors involved in assessing weight control needs are determining optimal body weight, calculating kcal expenditure, and identifying weight history. The characteristics that influence an athlete's eating habits can be learned by assessing their eating and lifestyle patterns in analyzing nutrient intake, evaluating eating habits, identifying use and abuse of dietary supplements and evaluating lifestyle routines. Useful information can be obtained from fitness and laboratory tests that relates to nutrition status which can be obtained by

fitness assessment, blood tests and medical assessment. The psychosocial influences on an athlete's dietary habits involve the consideration of social influences, self-concept, competitive goals and commitment, and attitudes and philosophy toward life. The assessment of the athletes' dietary habits can reveal inadequacies that hamper top performance during training and competition and provide them with knowledge to develop a nutrition plan that will help them understand their special needs.

Energy Expenditure and Caloric Requirement

Physical activity is the major variable that affects energy expenditure and, therefore, kcal requirements. An athlete's caloric intake must be increased according to the energy expended during periods of physical conditioning, training and competition (14). The goal is to achieve and maintain optimal body weight and composition for the particular type of competition. Factors influencing the energy expenditure associated with physical exercise include age, sex, body weight and size, body composition and configuration, plus the type, intensity, frequency and duration of the activity (14). Energy needs for the athlete range from 2000 to 6000 kcal/day, or more, depending upon the sport and training program (15,16).

Maximum Oxygen Uptake (VO2 max)

During extended physical activity either of intense intermittent or a constant rate, cumulative energy consumption will depend on oxygen supply. The point where there is no further increase in oxygen comsumption is maximum oxygen consumption (VO2 max), which varies with body size, sex, age, and state of physical training (14). Male athletes usually have a VO2 max from 4.5 L/min to 6.0 L/min and female athletes are 30% lower. This gives the potential to consume 25 kcal/min and 17.5 kcal/min for males and females, respectively (14). In a study by Vodak et al, (17) with recreational tennis players, the reported mean VO2 max for women was 2.45 L/min and for men 3.87 L/min. The results from a similar study with prepubescent competitive tennis players found the mean VO2 max for girls was 52.6 ml/kg and for boys 56.3 ml/kg (18). In other studies where the VO2 max was measured, varing results were obtained depending on the given sport involved (14).

Types of Energy Subtrates Used During Exercise

The fundamental basis of all sports performance is the energy production needed to sustain high power outputs either in repeated burst of intense activity or during prolonged continuous exercise. The fuels that supply energy to working muscles for power is obtained from the diet in the form of carbohydrates (glucose and glycogen), fat (triglycerides and

free fatty acids), and proteins (amino acids) (19).

The muscle cell functions to transform chemical into mechanical energy and heat through the use of the high energy phosphate bond of adenosine triphosphate (ATP) (20). Muscle contraction depends on the availability of ATP, which can be regenerated from phosphoryl creatine (PC) (20). Although PC is a rapidly available source of high energy phosphates, only a small amount is stored intracellularly, and it is rapidly depleted with the onset of exercise. Continued activity requires utilization of other energy substrates for production of ATP (20).

Carbohydrate is present in the blood and is stored in the liver and muscle. Liver glycogen is primarily utilized to maintain blood glucose, and muscle glycogen is available only to the muscle in which it is contained. Fats are both stored in the cell as triglycerides and obtained from the circulation as free fatty acids from metabolism of peripheral adipose tissue (21). Under usual conditions, protein is not a fuel for the muscle cell. In recent years, however, studies have shown amino acids may contribute to energy metabolism depending upon the type and intensity of the sport (5).

Aerobic vs Anaerobic

Energy can be produced by both aerobic and anaerobic means. Glucose, glycogen, triglycerides, and free fatty acids

can be aerobically utilized in the muscle cell by a series of reactions to produce energy (22). For aerobic metabolism to occur adequate oxygen must be available to the cell's mitochondria for terminal oxidation. In the absence of sufficient oxygen, anaerobic metabolism occurs without the final stages of oxidation. Anaerobic metabolism is limited to the use of muscle glycogen with the formation of lactic acid. This form of fuel utilization is less productive in generating high-energy phosphate bonds yielding less ATP per glucose molecule (15).

Determination of Energy Substrate During Exercise

The energy substrates utilized during exercise depends on their availability; the type, intensity and duration of exercise; the adequacy of tissue oxygenation; and the effects of prior conditioning. During exercise of low intensity at less than 30% of VO2 max (such as golf and walking), blood-borne free fatty acids and intramuscular triglycerides contribute about 75% of the energy consumed. During mixed anaerobic and aerobic moderate exercise intensity at 40 to 100% VO2 max (such as soccer, basketball, and tennis), fat and carbohydrate contribute equal amounts of energy. For the high intensity and anaerobic exercise at 75% VO2 max or more (such as sprinting), the predominate fuel is glucose derived primarily from the breakdown of muscle glycogen (14).

In a study of fat and carbohydrate metabolism during low intensity exercise by Maughan et al (23), four male adult subjects were studied to determine how dietary manipulation affects the availability of muscle glycogen. On the basis of the respiratory exchange ratio values and the oxygen uptake for each subject, the relative contribution of fat and carbohydrate to the total oxidative energy metabolism was calculated. On the normal diet, the mean percentage contribution of carbohydrate metabolism was 62.1%. On the low carbohydrate diet it was 35.7%, and on the high carbohydrate diet 70.9%.

The study revealed that possibly there is a direct relationship between the amount of glycogen stored in the working muscles and the proportion of the total oxidative energy which is derived from carbohydrates. It also revealed that there was an inverse relationship between the muscle glycogen content and the plasma fatty acid concentration. Following the high carbohydrate diet, plasma fatty acid concentrations were lower than normal. Following low carbohydrate diet when the availability of muscle glycogen was limited, the use of the fatty acid for energy was increased due to higher plasma fatty acid concentrations.

An important criteria for the use of fat or glycogen is the duration of the exercise. Exercise of long duration will

result in the use of more fat for fuel. Fat can supply as much as 70% of the energy needed for moderate intensity exercise lasting four to six hours (24). As the duration of the exercise increases, the intensity must decrease. When muscle glycogen stores are low, fat breakdown supplies most of the energy needed for exercise. However, fat can only be used as fuel up to 60% of aerobic capacity (24).

Another determinant as to the fuel used by the athlete is the individual aerobic capacity during exercise (25). Endurance training increases the aerobic capacity and enhances stamina in two ways. The VO2 max is increased and the muscular metabolic adaptations are induced that favor the use of fat as fuel, and thereby, sparing glycogen. The training increases the level of oxidative enzymes, especially those concerned with fat metabolism, in the trained muscle cells. This glycogen-sparing effect of fat utilization is advantageous during prolonged exercise such as marathon running, triathlete competition, and cross-country skiing, because muscle glycogen depletion limits performance (25).

The effect of training on muscle triglyceride utilization during exercise was studied by Hurley et al (26) with nine adult male subjects who had not done endurance exercise training for at least six months. They performed a prolonged bout of exercise of the same absolute intensity before and

after adapting to a strenuous 12 week program of endurance exercise. The results showed the proportion of the caloric expenditure derived from fat, calculated from the respiratory exchange ratio during the exercise test increased from 35% before training to 57% after training. The exercise resulted in 41% less muscle glycogen utilization in the trained than in the untrained state. The mean concentration of glycogen remaining in quadriceps muscle after the prolonged exercise was more than twofold higher after training (209 mmol/kg dry wt vs 82 mmol/kg dry wt) before training. The authors concluded that evidence collected in this study reveals that the greater utilization of fat during exercise of the same intensity in the trained state compared with the untrained state is fueled by increased lypolysis of muscle triglycerides.

Another means of increasing the utilization of fatty acids during exercise has been to feed high-fat diets. Studies have found no difference in endurance time between high-fat and moderate-carbohydrate (57%) diet after 1 month adaptation (27,28,29). Initial glycogen stores were lower on the high-fat diet; however, the final glycogen level reached after exhaustive exercise was not dependent on diet. The high-fat diet did not hamper performance, but neither did in provide any advantage. Thus, even though one can adapt to

utilization of fat rather than glucose as the primary energy source during exercise, high-fat diets are not recommended for athletes. High-fat diets can increase the risk of cardiovascular disease, cancer and obesity (30). The recommendation is fat should not make up more than 30% of total daily kcal and saturated fat 10% of total kcal (30).

While some sports demand continuous effort and endurance, others are characterized by intermittent activity. Endurance is as important for sports that demand repeated effort as those that require continuous exercise. Glycogen utilization follows a similar course during intermittent exercise as in continuous exercise of comparable average power production (14). Regulatory factors retard the rate of glycolysis and muscle oxygen stores in the myoglobin allow aerobic fat metabolism to proceed. The difference between intermittent and continuous exercise are seen in the recruitment pattern of the muscle fibers types. During continuous exercise, type I (slow, oxidative) fibers show the most glycogen depletion while both type I and type II (fast, glycolytic) fibers are depleted with intermittent exercise (24).

Carbohydrate Requirements for athletes

The daily recommended intake for carbohydrate is dependent upon the intensity and duration of exercise. In general, approximately 60% of total kcal is recommended for

athletes participating in intermediate sports (31). If the athlete is training at ≥70% V02 max to exhaustion for several days or competing in endurance sports such as marathons or triathlons, a diet of 65% to 70% of kcal from carbohydates may be necessary to prevent fatigue and provide adequate muscle glycogen stores to optimize training and performance (32). The percentages convert to a recommendation of 6-10 g/kg. (33).

O'keeffe et al (3) varied the carbohydrate content in the diets of seven trained female cyclists. The athletes rode a cycle ergometer at 80% Vo2 max to fatigue following a week-long consumption of diets containing low carbohydrate (LCHO), moderate carbohydate (MCHO), and high carbohydrate (HCHO) content (13%, 54%, and 72% of total kcal). Diets were administered in random order and each subject received all diet treatments. Results indicated that mean exercise time to fatigue increased with increasing dietary carbohydrate content (LCHO: 60min; MCHO: 98min; HCHO: 113min).

Pascoe et al (34) fed subjects a diet containing 45% of the daily energy consumption as carbohydrate. Subjects exercised on a inclined treadmill for 60 minutes at 75% VO2 max. Pre-exercise muscle glycogen declined from approximately 120 mmol/kg dry wt^{-1} on the first day to approximately 105 mmol/kg dry wt^{-1} on the third day.

Influence of Carbohydrate intake on Increased Training

Several studies have attempted to determine whether dietary carbohydrate intake influences the athlete's ability to train when the daily training volume is suddenly increased.

Costill et al (35) studied the effects of 10 days of increased training on muscle glycogen and swimming performance. The eight swimmers regularly trained one and one-half hours per day, five days per week, averaging 4266 meters per day at 94% VO2 max. Training time and distance were doubled during the 10 day study. Four of the subjects consumed a diet containing an estimated 8.2 g/kg carbohydrate per day. Results showed muscle glycogen declined to 110 mmol/kg dry wt^{-1} on day 10 from 130 mmol/kg dry wt^{-1} before the study. The swimmers reported local muscle fatigue and had difficulty completing the training sessions. The remaining four subjects consumed only 5.3 g/kg of carbohydrate per day and their muscle glycogen decreased from 100 mmol/kg dry wt^{-1} to 80 mmol/kg dry wt^{-1}. These subjects were unable to tolerate the heavier demands and were forced to swim at significantly slower speeds.

In a similar study Kirwan et al (36) had 10 runners increase their daily training load one and one-half times for five days while consuming a diet of 3.9 g/kg or 8.0 g/kg carbohydrate per day. Overall, muscle glycogen averaged 82

mmol/kg dry wt^{-1} (low carbohydrate diet) compared to 121 mmol/kg dry wt^{-1} for the high carbohydrate diet. The low carbohydrate diet resulted in significantly higher ratings of perceived exertion and higher oxygen consumption at a fixed running speed compared to the high carbohydrate diet.

Carbohydrate Intake Before Exercise

Athletes rely primarily on the preexisting glycogen and fat stores during exercise (14). The pre-exercise meal does not provide immediate energy, but it can provide energy when the athlete exercises longer than one hour. The carbohydrate in the meal can elevate blood glucose, and as a result, provide energy for the exercising muscle. Carbohydrate feeding before exercise can also help restore suboptimal liver glycogen stores, which will help performance during prolonged exercise (14). High-carbohydrate meals immediately before exercise should be avoided because carbohydrate may elevate blood insulin at the start of exercise, resulting in subsequent hypoglycemia and fatigue during exercise (24).

Costill et al (37) studied the effects of ingesting 75 g of glucose 45 minutes prior to a 30 minute run on a treadmill. Plasma insulin levels were significantly elevated coupled with enhanced insulin sensitivity induced by exercise caused a rapid fall in blood glucose levels. This rapid fall to a hypoglycemic state persisted until the end of exercise and

reduced endurance.

In a later study by Hargreaves et al (38) the results showed subjects consuming 75 g of glucose 45 minutes before cycling to exhaustion did not experience hypglycemia, contradicting earlier findings. These findings suggest that individuals differ in susceptibility to lowering of blood glucose during exercise (4). The physiologic and biochemical basis for this difference has not been determined.

In an attempt to provide additional carbohydrate shortly before the start of exercise without producing an earlier onset of fatigue, fructose has been used instead of glucose. The results found fructose solution maintains more stable blood glucose and insulin concentrations during exercise than does the glucose solution, but it does not enhance endurance performance (22).

The recommendation for pre-exercise carbohydrate consumption is one to four g/kg of carbohydrate one to four hours before exercise (33). To avoid potential gastro-intestinal distress, the carbohydrate content of the meal should be reduced as the time to exercise decreases.

Liquid supplements have been recommend as good pre-exercise meal and several types are available. There are several advantages of liquid meals: they are high in carbohydrates and palatable, and contribute to calories and

hydration; they can be consumed closer to competition than regular meals because of their shorter gastric emptying time and they produce a low stool residue, keeping immediate weight gain to a minimum; and they can provide a convenient alternative to solid meals for athletes competing in day-long competitions, tournaments, and multiple events (22).

A study researched the effects of liquid and solid meals and time of feeding on VO2 max (22). Ten males and seven females participated in the first part of the study. Subjects were fed a liquid or solid meal exactly two hours before a maximal exercise test on a bicycle ergometer at increased resistance. On line measures of VO2 max, heart rate and expired gas values were conducted. The liquid meal was a commercial product consisting of 1065 kcal and a nutrient content of 53.3% carbohydrate, 32.0% fat and 14.7% protein. The solid meal averaged 1015 kcal and a nutrient content of 51% carbohydrate, 34% fat and 15% protein. During the second part of the study, eight male and two females were fed the liquid meal 30 min and one, two, and three hours before the same exercise test as in part one. For the third experiment six male and four females subjects were fed liquid and solid meals (similar to part one) 30, 90, and 180 minutes before exercise. The exercise consisted of running to maximum on a treadmill while speed and grade was increased. The results

showed the only significant difference was in VO2 max when expressed in terms of body weight. However, this difference was due to a decrease in weight after consuming the liquid meals for 24 hours. Liquid supplements are digested and absorbed faster then solid food. The authors concluded that there was no difference in metabolic and circulatory responses during maximal exercise after eating a meal two hours before exercise; there was no difference in performance after ingesting a liquid meal at intervals ranging from 30 minutes to three hours before exercise; and eating either a liquid or solid meal as early as 30 minutes before maximal run on a treadmill caused no detrimental effects on either metabolic or circulatory parameters, when compared to a non-feeding control. The authors suggested that liquid or solid food can be eaten before high-intensity short-term exercise, as long as gastrointestinal function is not impaired. They also suggest that during competition other physiological or psychological actors could change the out-come of these results.

Athletes may compete several times a day during scheduled athletic events (track and field, volleyball tournaments swimming, and single and double tennis matches) and may not have sufficient time to eat at normal meal periods. In a study to compare the physiological responses to multiple daily exercise, ten men and nine female subjects consumed liquid

meals versus those consuming solid meals (22). The exercise consisted of three 45-minute bouts performed on the same day spaced four hours apart. They consisted of walking at 6.4 km/hr, 8% grade (male subjects) and 4.8 km/hr, 8% grade (female subjects). The experimental diets consisted of a liquid supplement supplying 355 kcal and contained 53.3% of the kcal as carbohydrates, 31.9% fat, and 14.6% protein. The solid meal provided on the average 2200 kcal for the men and 1300 kcal for the women and 44% of the total kcal as carbohydrate, 38% fat, and 17% protein. During each of the 45 minute exercise bouts VO2 max, heart rate, perceived exertion, and blood glucose were measured. The results showed no significant difference for VO2 max, heart rate, and blood glucose between solid and liquid meals. The perceived exertion ratings showed no significant difference between meals. However, the ratings were statistically significantly lower for the liquid meal in the last 45-minute bout for the women. The authors concluded that in this study liquid diet can be substituted for solid diet without decreasing multiple daily exercise performance.

Carbohydrate intake During Exercise

Ingesting carbohydrates during endurance exercise lasting longer than 90 minutes may enhance endurance by providing glucose for the muscles to use when their glycogen stores have

dropped to low levels. As the muscles are depleted of glycogen they will began to take up more blood glucose, which is being supplied by liver glycogen. The longer the exercise session, the greater utilization of blood glucose by the muscles for energy (39). Although supplies of blood glucose can be drawn from the liver glycogen, this is not the case for muscle glycogen which stays in the muscle and cannot provide glucose for the blood. When liver glycogen is depleted, the blood glucose drops and muscle fatigue occurs resulting in reduced exercise intensity. The improvement in performance as a result of consuming carbohydrate during exercise is probably due to the maintenance of blood glucose (39).

In a study to enhance performance with carbohydrate supplements during endurance performance (22), 10 male subjects under went test sessions of two days of controlled exercise, diet and a 12-hour overnight fast. The exercise session consisted of a psychomotor test (eye-hand coordination, reaction time, coincidence anticipation timing, and balance) followed by walking on a treadmill at 45% VO2 max at differing speeds and grades until exhaustion. They repeated the psychomotor test, followed by 10-minute rest and then a run to exhaustion on the treadmill at 80% VO2 max. Each subject performed the exercise protocol under three different treatments: termed practice (P), control (C), and

glucose polymers (GP). The results indicated that carbohydrate taken during the second hour of exercise significantly (11%) increased endurance performance. Exercise time to exhaustion at 80% VO2 max did increase 20% after GP ingestion. There was no significant difference in psychomotor performance between treatments. The authors concluded that glucose polymers can delay the point of exhaustion by sparing muscle glycogen stores.

The ingestion of glucose polymers during exercise has also been found to be effective in increasing running speeds over a two hour period (40). The polymer consisted of 32.5 g maltodextrin, 24.1 g sucrose, and 5.7 g fructose and was consumed in 125 mL aliquots at 20 min intervals. The recommendation for glucose polymer ingestion, based on evidence, suggests 25 to 30 g of carbohydrate every 1/2 hour (41,42). Commercial carbohydrate supplement drinks have a carbohydrate content range of 2.5% to 7.2% and can contain sucrose, fructose, glucose and maltodextrin. The concentration of carbohydrate should be at least 6% when the intent is to improve endurance, but not more than 10% because of gastric emptying (22).

Carbohydrate Intake After Exercise

During exercise the majority of glucose-6-phosphate flux through glycolysis is derived from muscle glycogen (43). For

athletes who participate in intermittent exercise and/or strenuous exercise over successive days, the rapid replenishment of muscle glycogen stores can delay fatigue and enhance exercise performance. During the initial hours of recovery from exercise, muscle glycogen synthesis occurs at rates approximately 1-2 mmol/kg wet wt^{-1}/hr if no carbohydrate is consumed (43). When carbohydrate is consumed during recovery, the maximal rate of glycogen synthesis approximates 7-10 mmol/kg wet wt^{-1}/hr. The rate of muscle glycogen synthesis after exercise is dependent on the type, amount and frequency of carbohydrate feeding and the type and intensity of exercise.

Costill et al (35) studied the effect of dietary carbohydrate in muscle glycogen resynthesis after strenuous running. Ten trained male runners performed a 16.1 km run at 80% VO2 max and a 300 meter sprint performance to decrease muscle glycogen. A complex or simple carbohydrate diet (648 g) resulted in similar muscle glycogen levels 24 hours after exercise. Forty-eight hours after exercise the complex carbohydrate diet resulted in significantly higher glycogen levels. The mean change in muscle glycogen was 22.1 mmol/kg wet wt for the complex carbohydrate diet and 7.8 mmol/kg wet wt for the simple carbohydrate diet. Consuming increasing amounts of carbohydrate, between 188 to 648 g of carbohydrate

a day, resulted in increasingly larger amounts of muscle glycogen resynthesis 24 hours after exercise.

Ivy et al (44) also found similar results when studying the effect of time of carbohydrate ingestion on muscle glycogen synthesis after exercise. Twelve male cyclist exercised continuously for 70 minutes on a cycle ergometer at 68% VO2 max, interrupted by six two-minute intervals at 88% VO2 max, on two separate occasions. A 25% carbohydrate solution (2g/kg) was ingested immediately post-exercise (P-EX) or 2 hours post-exercise (2P-EX).

The results showed muscle glycogen immediately post-exercise was not significantly different for the P-EX and 2P-EX treatments. During the first two hours of recovery, the muscle glycogen storage rate was threefold faster during the P-EX than during the 2P-EX treatment. During the second two hours of recovery, the rate of glycogen storage slowed 44% during treatment P-EX but increased 67% during treatment 2P-EX. This rate, however was still 45% slower than that for the P-EX treatment during the first 2 hours of recovery. The authors concluded that muscle glycogen storage after exercise was increased above the basal rate when a carbohydrate supplement was provided. However, the time of its administration was significant. A two-hour delay in administering the supplement resulted in a slower rate of

glycogen storage than if the supplement were provided immediately post-exercise. The suggested intake for carbohydrate after exercise is 100 g (400 Kcal) within 15 to 30 minutes and additional 100 g feedings every two to four hours thereafter (43).

Protein Metabolism During Exercise

During exercise, the muscle is the site of increased protein (amino acid) oxidation. The skeletal muscle has the ability to oxidize several amino acids, and during exercise the oxidation of some amino acids increases in proportion to metabolic rate (5). Liver and muscle protein provide amino acids for exercise fuel and/or for repair of exercise related muscle injury (5). Several factors have been identified that play a role in determining how much protein is utilized during exercise. These include type, amount, intensity, and duration of exercise, and whether one is trained.

Tarnopolsky et al (45) studied the influence of protein intake and training status on nitrogen balance and lean body mass. The study was performed with six sedentary men (S), six elite endurance athletes (EA) who has been training for at least five years as runners or nordic skiers, and six bodybuilders (BB) who had trained for at least three years. The experiment included a 10-day adaptation period in which the EA group's caloric intake was 4590 kcal/day and protein

intake was 1.70 g/kg. BB group's caloric intake was 4802 kcal/day and protein intake was 2.77 g/kg. S group's caloric intake was 3220 kcal/day and protein intake was 1.05 g/kg. The adaptation period was followed by a ten-day period of altered protein intake in which the EA group's protein intake was increased to 2.56 g/kg; S group's protein intake was increased to 1.90 g/kg; BB group's protein was decreased to 1.05 g/kg. The nitrogen balance data revealed that BB group required 1.12 times and the EA required 1.67 times more daily protein than the S group. Lean body mass was maintained in the BB group consuming 1.05 g/kg per day.

Protein Requirements for Athletes

Protein needs can be calculated both as a percentage of total kcal and on a per g/kg. For athletes with high energy intakes, providing 12% to 15% of total kcal from protein may be excessive. If energy intake is insufficient as a result of the increased energy expenditure of training, or if food intake is restricted to maintain body weight (wrestling, gymnastics), protein needs calculated as a percentage of energy may be inadequate (46).

Several requirements for protein intake have been suggested because of the various procedures used to assess protein utilization and different interpretation of data available on this topic (5). Lemon (5) concluded that the

protein needs of the endurance athlete are 50% more than the RDA. To avoid deficiencies, he suggests the daily protein intake represent 12% to 15% of total kcal. This calculates to 2.16 g/kg based on a 70 kg individual. Another recommendation concludes that male endurance athletes require 1.0 to 1.2 g/kg (47). Suggested protein intake for a woman athlete on a 1500-1700 kcal diet has been 1.5 g/kg (48). Recommendations for strength athletes have also varied from 1.12 g/kg to 2.0 g/kg (45). Lemon (49) suggested that protein intake above the RDA may be necessary to generate optimal gains in muscle strength and size. He suggested 1.2 to 1.5 g/kg for those individuals attempting to increase muscle strength and size by weight training. In a recent study by Butterfield et al (50) with recreational weight lifters, the results of nitrogen balance studies revealed the quantity of dietary protein needed to achieve maximal protein deposition was 1.5 g/kg, and that the limiting factor for muscle protein deposition is energy intake, not protein.

Vitamin Supplementation and Athletic Performance

Vitamin and mineral supplements are frequently used by competitive and recreational athletes (51). In competitive events where the difference between winning and losing is measured in seconds, poor nutrition could have a negative effect. Vitamins are a group of unrelated organic compounds,

needed in micro-amounts by the body for normal cellular metabolism, growth and maintenance of health (51). Thirteen nutrients have been recognized as vitamins: vitamins A, D, E and K are fat soluble and stored by the body with fat; and the remaining are B complex and vitamin C which are water soluble and distributed in the fluid compartments of the body and excreted on a daily basis. The water soluble vitamins, B complex and C, act as coenzyymes or cofactors in metabolic reactions involved in the oxidation of carbohydrates, fats and proteins and the production of energy (51).

Thiamin (B1), as thiamin pyrophosphate, is an important coenzyme in the oxidative decarboxylation of pyruvate to acetyl CoA, for entrance in the Krebs cycle and subsequent oxidation to ATP (52). Thiamin deficiency could impair carbohydrate metabolism, the major energy process in aerobic exercise (52). It could also result in inadequate amounts of succinate, a co-ingredient of hemoglobin, also influencing aerobic exercise (52).

A study was conducted by Wood et al (53) with 18 young men to examine the effects of thiamin restriction on their athletic performance. The subjects followed a low thiamin diet with or without a 5 mg supplement or placebo for five weeks. The control and supplemented groups showed marked variation in thiamin status as measured by urinary and blood

levels. Although there was a clear separation in thiamin status between the two group, there was no difference between groups in minutes to exhaustion or watts generated during a progressive cycle ergometer test. The need for thiamin depends on energy expenditure and is influenced by high carbohydrate intake.

Riboflavin (B2) is involved in energy release as a constituent of two coenzymes involved in electron transport: flavin mononucleotide and flavin adenine dinucleotide. Riboflavin plays an additional role in the oxidative reactions in the mitochondria (52).

In a series of experiments conducted at Cornell University, the relationship between exercise and riboflavin requirements was studied in young women (54). During these studies, women were fed controlled amounts of riboflavin during periods of non-exercise and periods of supervised exercise. Two methods were used to assess riboflavin status: urinary excretion and blood enzymatic tests. Two different amounts of riboflavin were fed: 0.96 mg per 1000 kcal and 1.16 mg per 1000 kcal. As expected, excretion was greater in the high riboflavin intake group. Riboflavin requirement appeared to increase with exercise in women who had presented low riboflavin status initially. Supplemental riboflavin did not improve the ability to exercise.

Niacin functions as a coenzyme in nicotinamide adenine dinucleotide to produce ATP from glycolysis and coenzyme nicotinamide adenine dinucleotide phosphate in fat synthesis. A study was conducted to determine the effect of 75 mg of niacin upon the endurance capacity of 86 subjects as measured by performance on either a bicycle ergometer or a forearm ergometer (52). Niacin may increase aerobic and anaerobic capacity by inhibiting fatty acid mobilization, thus facilitating glycogen utilization. However, the investigators found niacin did not increase the ability to perform near-maximal or prolonged submaximal exercise (52). In another study niacin supplementation caused a detrimental effect by causing increased muscle fatigue during exercise which could impair performance (52).

Pyridoxine (B6) Pyridoxal 5-phosphate, the active form of vitamin B6, is essential to glycogenolysis because it is an intregral part of the glycogen phosphorylase enzyme. This exzyme cleaves glucose-1-phosphate from glycogen, thus providing glucose for energy production. It is also essential to gluconeogenesis as a co-factor for aminotransferase enzymes which participate in the glucose-alanine cycle. Vitamin B6 is also involved in the formation of hemoglobin, myoglobin, and the cytochrome (55).

A study by Dreon et al (56) was conducted to monitor

vitamin B6 metabolism in a group of healthy, trained male runners and to compare their utilization of the vitamin to that of a group of sedentary controls. The trained group (T,n=4) ran 10 miles a day for the first 29 days and five miles a day for the second 29 days to investigate the differences in vitamin B6 metabolism with difference in activity level. The sedentary group (S,n=6) did not engage in strenuous physical activity on a routine basis. Both groups were fed a diet of 33% fat, 17% protein and 50% carbohydrates in the amounts equivalent to the proportion of his total energy need and were provided 4.2 mg of vitamin B6 each day.

After three weeks, vitamin B6 utilization was determined in each man by monitoring 1) 4-pyrioxide acid (4-PA), a vitamin B6 metabolite, in 24-hour urine samples collected during the last four days of each study period, and 2) 24-hour urinary 4-PA excretion in response to a 60 mg/kg N-acetyl-L-methionine load which requires B6 for metabolism and has been useful as a vitamin B6 challenge.

The results found physical activity was associated with lower 4-PA excretion, reflecting less conversion of the vitamin to 4-PA, thus an actual increase in the need for more vitamin B6. However, the results of the methionine challenge given found the demand for vitamin B6 did not increase when methionine increased and the portion excreted as 4-PA

increased in the T group. The authors suggested that athletes may have a labile pool of pyridoxine because of physical activity. When the need for the vitamin is increased, as with the methionine load, this pool is mobilized for use, the coenzime released, and the excess vitamin converted to 4-PA. The authors concluded that basal 4-PA excretion provides no conclusive evidence of increased need for vitamin B6 during exercise.

The effect of carbohydrate and vitamin B6 on fuel substrates during exercise with women was explored by Manore et al (57). Fifteen healthy females were included for one of three groups: young/trained, young/untrained, and post-menopausal/untrained. Four high or moderate carbohydrate diets were fed during a seven week period and the diets were supplemented with 8.0 mg of vitamin B6 the last two weeks. Subjects were exercised at the end of each dietary period at 80% VO2 max for 20 minutes on a cycle ergometer.

The results of analysis indicated the effects of a high carbohydrate diet and/or supplemental vitamin B6 on fuel substrate during short-term exercise depend on age and level of training. Regardless of the diet, the post-menopausal/ untrained women had significantly lower glucose response to exercise then the young women. The trend was for a high carbohydrate diet and/or supplemental vitamin B6 to produce

lower plasma free fatty acids concentrations during exercise in untrained subjects. Training had a more stabilizing effect on plasma FFA concentrations during exercise regardless of the diet. The authors did not recommend athletes take vitamin B6 supplements based on this research. They did emphasize since the exercise period was only 20 minutes, that further research on the effect of vitamin B6 supplementation on fuel substrate during endurance exercise still needs examined.

Cyanocobalamin (B12) is involved in carbohydrate and fat 0metabolism. It functions as a coenzyme involved in the transfer of single-carbon units in nucleic acid metabolism and in the production of red blood cells (52). A study investigated vitamin B12 supplementation and physical performance with 36 male students upon physical performance variables. The experimental group received 1 mg of vitamin B12 three times a week for six weeks. Post test results showed no beneficial effects on VO2 max or other standard tests of strength, power, and muscular endurance.

Pantothenic acid is a part of coenzyme A (CoA) which is involved in the oxidation of fatty acids and pyruvate as well as the synthesis of fatty acids. Earlier research suggested deficiency in pantothenic acid could possibly decrease the availability of substrate for the citric acid cycle and shift energy production to anerobic which is less efficient (52).

Human studies are few and more data is needed.

Biotin is a coenzyme for a varity of enzymes known as carboxylases, including carboxylase, which is involved in gluconeogenesis and in maintaining a proper level of citric acid cycle intermediates. Little information is available about the effects of supplementation in relation to exercise in humans (55).

Folacin is involved in DNA synthesis and red blood cell formation (55). Theoretically, a deficiency could cause anemia and thus handicap endurance. Matter et al (58) studied the effects of iron and folate therapy on maximal exercise performance in 27 female marathon runners with iron and folate deficiency. The women were placed in four groups: normal, low serum ferritin, low serum folate, and control (high serum ferritin). The subjects were exercised on a treadmill at a initial speed of 6 km/h with incremental increases of 0.5 km/h until exhaustion. Blood samples were taken to assess iron and folate levels. One week after treatment with oral folate (5 mg/day) or iron (50 mg/day), serum ferritin and folate levels were normal but VO2 max, treadmill running time, and lactate levels were not changed from values measured during an identical test performed one week earlier. These parameters were also unchanged in the third exercise test performed after a further ten weeks of treatment. Serum folate or serum

ferritin levels in a control (placebo treated group), with initially high serum ferritin or folate, fell with placebo treatment, but VO2 max, treadmill running time, lactate level and running speed were unchanged.

The authors concluded that the correction of low serum ferritin levels in subjects who are not anaemic is not associated with any measurable change in maximal treadmill performance or any physiological and biochemical parameters during exercise to exhaustion. Similarly, the correction of low serum folate levels, in the absence of anaemia, is not associated with enhanced performance.

Vitamin C participates in many enzymatic reactions by acting as an electron transmitter. It is involved in hydroxylation reactions in the synthesis of collagen, which is important for connective tissue stability and wound healing, and of carnitine, which plays a role in energy transport. Vitamin C is further required for the biosynthesis or functions of several hormones, such as norepinephrine and corticoid hormones, which are involved in stress. Another important function of vitamin C is its ability to enhance iron absorption from non-meat sources and so help to prevent iron deficiency anemia. It is also a antioxidant, scavenging free radicals such as the hydroxyl radical and singlet oxygen which cause tissue damage. It is assumed that physical exertion

induces the production of free radicals in muscle. The practical significance of these different reactions in physical performance and the amount of vitamin C required to support them are not yet known (59).

Studies of the effect of vitamin C supplementation on human performance have been contradictory (59). This is in part due to failure to control the dietary intake of vitamin C, lack of comparable tests and control groups, and standardized test conditions. The effect of vitamin supplemention on endurance was studied with 16 female athletes. The exercise protocol included a Harvard step test and a 9-minute walk and run to measure VO2 max efficiency. They were given 500 mg per day of vitamin C for four weeks. The finding indicated increased VO2 max and improved performance in nine-minute walk and run. This study did not include a placebo control group (59).

In a study using a placebo control group Keren et al (60) used a double blind study to investigate the interaction of physical training and vitamin C supplementation upon aerobic and anaerobic performance. Thirty-three subjects were given 1 gm vitamin C per day or a placebo and undertook a training program for 21 days. The training program consisted of either 30 minute intervals on a bicycle ergometer at approximately 50% VO2 max or 30 second intervals at maximal performance.

Although the training program increased aerobic capacity, the authors concluded that vitamin C supplementation exerted no beneficial effect on oxygen uptake.

Vitamin C supplements have been found to have no effect on grip strength when 15 male subjects were given either 600 mg of vitamin C or a placebo (59). Because of the role vitamin C plays in collagen synthesis, the effect of supplements on athletic injuries was studied with 286 Air Force officers (59). The officers were given 1 g of vitamin C or a placebo for 12 weeks. Distance covered and injury were measured after daily 12 minute walk-run tests. No difference was found in performance time or the frequency and duration of injuries between the supplemented and placebo groups. Studies have found significant increases in blood vitamin C levels in ultra endurance athletes after physical exertion. The findings suggested that increased vitamin C concentration in plasma and leukocytes after exertion were positively correlated with increased plasma cortisol concentrations released from the adrenal glands in response to stress (59).

Studies with vitamin C supplementation with subjects having marginal vitamin C status have resulted in improved aerobic capacity when 70 mg of vitamin C was given for three months (59). A low vitamin C status may also affect heat tolerance. Subjects receiving 250 and 500 mg of vitamin C for

10 days had lower rectal temperature and improved heat acclimatization than those recieving a placebo (51).

Fat-soluble vitamins, A, D, E and K, are stored by the body in lipids, and excess intake can lead to toxicity (51). Although the main function of vitamin A is to help maintain the visual system, it may be involved in glycogen biosynthesis and muscle protein synthesis (52).

In a study, five subjects were placed on a vitamin A deficient diet for six months and then placed on a vitamin supplement program for six weeks. Physical performance was tested on a treadmill, with a 15 minute warmup followed by a run to exhaustion. No effect of supplementation or a deficiency on physiologic functions during sub maximal or maximal exercise was found (51).

Vitamin E may act as an antioxidant of polyunsaturated fatty acids and may help keep red blood cells intact during exercise by preventing oxidation of the phospholipids in the cell membrane (55). In an early study with two groups of swimmers, one received 400 mg of vitamin E daily while the controlled group received a placebo. The subjects undertook a six-week training period which included swimming and other fitness activities. Although some beneficial effect on performance was due to training, there was no significant effect of vitamin E on any of the tests (52).

Mineral Supplementation and Athletic Performance

Minerals are essential to the human body in numerous metabolic processes. Previous research has focused on the needs of the exercising individual for five minerals: Calcium, magnesium, zinc, iron, and potassium.

Calcium is the mineral found in the largest quantity in the body, and bone is the major reservoir for calcium and stores 99% of the total (61). Calcium is required for the formation of bone during growth, with the greatest need occurring during the adolescent growth spurt (61). Once growth has stopped, bone remodeling will continue. Maximal bone content, and therefore calcium storage, is achieved at age 30 and women will have 15% lower bone mineral density and 30% lower bone mass than men. Bone loss in women is characterized by increased bone resorption whereas in men it can be attributed to decrease bone formation. Moreover, women tend to lose more of the structural (trabecular) support network of bone and at a greater rate than men (61). The primary concern for achieving as high a peak bone mass as possible during early childhood is the possibility that it could delay or even prevent nontraumatic fractures associated with osteoporosis from occuring later in life (61).

The remaining 1% of the calcium is distributed among a number of tissues and is involved in several important

functions. Calcium ions (Ca^{2+}) stored in the sarcoplasmic reticulum of muscle fiber are involved in the linkage of actin and myosin in the contractile process. The release of neurotransmitters at the synapse is stimulated by the influx of Ca^{2+} in to axtom. Ca^{2+} found in the plasma is one of catalysts needed for blood clotting (51).

Research indicates that lifetime fracture risk linked to osteoporosis can be minimized by meeting the daily recommended dietary allowance for calcium, calcium supplements, or physical activity. Bone mineral density, lifetime milk and supplemental calcium intake, and lifetime physical activity were studied by Ulrich et al (62) with 25 elderly women (mean age 72 years) and their premenopausal daughters (mean age 41 years). Bone mineral density of the total, entire axial, and entire peripheral skeleton was measured. Calcium intake and activity level were estimated by questionaire and interview. Neither lifetime or current milk consumption nor lifetime physical activity was correlated with bone density among the mothers. Their calcium intake from supplements after age 60, however, was positively associated with total and peripheral bone density. Among daughters, lifetime weight-bearing exercise was positively associated with total and peripheral bone density but milk consumption and calcium supplementation were not.

In a another study investigating physical activity and bone mineral content in 83 women ages 30 to 85 years, results showed a significant difference in bone mineral content between the most active group of women and the two less active groups, even with age and menstrual status as co-variates. No difference was found between the moderate and low activity group. The data from this study indicated that high levels of exercise could be a factor in reducing age-related bone loss (63).

Women athletes engaging in endurance sports often have a high incidence of amenorrhea, a condition associated with low bone mineral density (64). The vertebral bone mineral density of amenorrheic women athletes is 20 to 30% lower than age-matched controls (61). Researches have found amenorrheic women have low body fat, low estrogen levels, and low dietary intakes of iron, copper, and zinc (61).

O'Donnell et al (65) assessed the bone status of Division 1A female athletes participating in basketball, volleyball, softball (power athletes), cross-country, track (endurance athletes), gymnastics, and swimming. Bone status, body composition, nutrient intake, menstrual status, and eating disorder tendencies were examined. Bone scans of the lumbar spine, femoral neck, trochanter, and Ward's triangle were completed. Height, weight, skinfolds, menstrual function,

contraceptive use, four-day food records, and athletic histories were taken. The results found the power sports appeared signicantly to promote bone development more than swimming in all scanned areas. Power athletes had significantly greater bone mineral density and bone mineral content in the spine, femoral neck, and Ward's triangle than the cross-country runners. Gymnasts had greater measurements than swimmers and runners in bone mineral density of the spine and Ward's triangle and in bone mineral content of Ward's triangle. Swimmers were lower than gymnasts in bone mineral density of the femoral neck and bone mineral content of the trochanter. Athletes with increased lean body weight had greater bone measurements in comparison to other athletes. All athletes had dietary deficiencies but no specific nutrient was correlated with bone density. The authors concluded that power sports may be more effective in stimulating bone accretion than swimming because of the weightless nature of swimming.

Calcium balance and bone metabolism in the body can be influenced by increased intakes of vitamin A, C, and D and the minerals phospherous, zinc, and boron (61,66). In addition, high protein intakes with low intakes of calcium can increase urinary calcium excretion (67).

Magnesium is essential for many metabolic reactions

including glycolysis, citric acid cycle, fatty acid oxidation, and amino acid metabolism (68). Muscle contains about 25% of the total magnesium and more than 50% is found in bone (51). The effect of exercise on magnesium metabolism has been studied in recent years with varied results. During prolong exercise, serium magnesium concentrations decreases (51) or with endurance athletes, no significant increase was found (51). A study found an increased magnesium content in exercising muscles during prolong work which was paralleled by a decline in plasma magnesium. The author suggested that the reduction in serum magnesium may be a function of both sweat loss and redistribution into the working muscle.

The effect of magnesium deficiency and exercise performance has also varied in resent studies. In one study with 44 male university athletes, maximal oxygen consumption measured during a treadmill exercise test was significantly correlated with plasma magnesium concentrations (68). In contrast to this study made with trained athletes, no correlation was observed in untrained men (68).

Zinc is a essential part of key enzymes involved in nutrient metabolism and energy production in the muscle cell (51). Studies have revealed athletes may be at risk for poor iron status because of altered zinc metabolism (68). Athletes who emphasize high-carbohydrate diets and restrict

intake of fresh food may have low dietary zinc intakes (68). Exercise can increase zinc losses through sweat and urine (68). Researchers have reported mixed results on the effect of exercise training or strenuous daily exercise on plasma and serium levels in athletes (68). Limited data are available on whether training induces chronic changes in plasma and urine zinc levels in untrained individuals.

Manore et al (69) studied the effects of two different 12 week exercise training programs and zinc supplementation on zinc status in untrained men. The first group participated in a 12 week aerobic training program on cycle ergometers 35 to 40 minutes three times per week. The second group had the same protocol as the aerobic group except that they alternated between days of continuous (aerobic) and interval (anaerobic) training. Subjects within each group were randomly assigned a zinc supplement (20 mg) or a placebo daily.

Results found no significant changes in nutrient intake over time and mean dietary zinc intake was 13.1 mg/day. No differences in plasma zinc levels were found between supplemented and placebo subgroups regardless of training protocol. There was a significant difference in plasma zinc levels when group-by-time was analyzed. In the aerobic group, training significantly decreased plasma zinc levels from baseline to midpoint and significantly increased zinc levels

from midpoint to end. The opposite response was observed in the aerobic/anaerobic group. The authors suggested the transient decrease in plasma zinc in the aerobic group may be attributed to total body zinc redistribution. The intense exercise protocol of the aerobic/anaerobic group may have contributed to muscle tissue damage, causing the elevated plasma zinc levels. No significant changes in urinary zinc excretion occurred for either training mode or supplementation. Urine zinc levels were within normal ranges. The authors also reported that mean plasma zinc levels returned to baseline for both training groups by week twelve and the difference in serum zinc levels observed during training may represent only transient changes in blood levels.

Iron is a constituent of hemoglobin, myoglobin, and several respiratory enzymes and thus plays a vital role in energy production. Hemoglobin carries oxygen to the body tissues for utilization during aerobic metabolism. Maintenance of normal levels of hemoglobin is essential because aerobic metabolism plays a important role in endurance-type exercise. Myoglobin helps transport oxygen to the site of ATP for energy production (70).

The relationship between iron status and athletic performance becomes very important in the presence of iron deficiency anemia. Decreased performance in iron deficient

anemic athletes can occur despite their level of fitness (71). The determining factor affecting iron status in athletes is the adequancy of iron stores. Iron stores are influenced by long-term dietary adequacy, growth needs, and reproductive and menstrual history. There is also the possibility that athletes lose more than the normal amount of iron through feces, urine, and sweat (70). Athletes who are at an increased risk for developing anemia include female athletes, teenage athletes, endurance athletes, low-body weight athletes, and those who do not consume meat (71).

Blum et al (72) studied the effects of fitness-type exercise on iron status with 35 adult female volunteers. Twenty-four women were placed in an anerobic exercise class for 13 weeks. The remaining 11 female volunteers did not exercise and served as a sedentary control group. At six week intervals whole blood samples were taken for determination of hemoglobin and hematocrit. Plasma was recovered and stored to determine plasma iron, total iron binding capacity, and ferritin. Results in the exercise group showed hemoglobin levels were higher at week six, but returned to initial values by week 13. Hematocrit decreased from week six to week 13, but did not differ from the week one value. Plasma ferritin levels decreased from week one to week six and remained at that level. In the sedentary group, there were no changes in

hemoglobin, hematocrit, and plasma ferritin levels for the 13-week period. Plasma iron, total iron-binding capacity, and transferrin saturation were unchanged in the exercise group. The sedentary group had lower plasma iron at week six but returned to week one level by week 13. Dietary analysis showed there were no significant differences for the intake of total iron and total iron absorbed between the exercise group and sedentary group.

The authors proposed the underlying cause of an exercise induced iron cost may be related to an increased demand for and/or turnover of iron containing compounds. The results of this study indicated that 13 weeks of moderate fitness-type exercise decreased iron stores in previously untrained women, but had no effect on hematological status.

In properly diagnosed cases of iron deficiency anemia, theraputic doses of iron will be required to improve iron status and physical work performance (71). Risser et al (73) studied iron deficiency and its prevalance and impact on performance with female varsity athletes in various sports. The effect of iron supplementation on the treatment of iron deficiency was also analyzed. The subjects were 100 female varsity athletes participating in track, swimming, volleyball, tennis, basketball, field events, and diving. Sixty six nonathletic women were also included in the study as controls.

Initially 31% of the athletes had iron deficiency compared to 45.5% of the controls. Compared to normal athletes, iron-deficient athletes did not have more symptoms of iron deficiency or differences in mood state, but they considered their performance to be worse. Their total iron intakes were similar, as were menstrual blood losses. At re-evaluation 15.6% initially normal athletes were iron-deficient and 63.6% initially iron-deficient athletes were normal. Athletes recieving a 325 mg iron supplement did not report a greater improvement in performance or mood than athletes recieving a placebo.

Potassium is a electrolyte found predominantly intracellularly (51). Its concentration in the intracellular water helps to maintain fluid balance. Potassium is also involved in the conduction of nerve impulses and skeletal muscle contractions. It has been observed that acclimatization to the heat has little effect on the amount of potassium lost in the urine or sweat (51). Individuals who are exercising or working in the heat and losing large amounts of sweat could be in negative potassium balance if the dietary intake were low. A study found that a potassium intake of 3000 mg/day maintained a slightly positive potassium balance in subjects losing 3L of sweat per day. Reducing potassium intake to less than 2000 mg/day significantly reduces the

amount of potassium lost in the urine but has little effect on sweat and fecal potassium loss (51).

In a study by Lane et al (74), the effect of physical activity of human potassium metabolism in a hot and humid environment was examined. The study evaluated the potassium balances resulting from potassium supplementation in athletes and whole body potassium before and after exercise. Seven long-distance runners who ran twice daily in hot and humid weather were recruited. The subjects receiving supplements had higher urinary sodium and potassium losses, but 98 mEq/liter of potassium supplement resulted in positive potassium balance.

Multivitamin and Mineral Supplementation and Athletic Performance

There are three primary reasons why supplementing the diet with specific vitamins and/or minerals might be beneficial: a) the athlete's diet is deficient in one or more of the vitamins and minerals; b) athletes have a greater need for a specific vitamin or mineral than the general population because they use or lose more of that nutrient; c) the addition of certain vitamins and mineral improves performance (51).

Weight et al (75) examined the vitamin and mineral status of trained athletes including the effects of supplemention.

Subjects were 30 male long distance runners who ran competitively for at least three years and trained more than 70 km/wk. The subjects were assigned to two groups so that 15 received a multivitamin and mineral supplement, which ranged from 14.5% to 4300% of the RDA, and 15 received a placebo for three months. This was followed by three months during which both groups received no supplement. For the next three months the two groups were crossed over so that the group who had initially received supplements received the placebo. During the study each subject completed a 5-day dietary record. Blood samples were drawn for vitamin and hematological analysis. The findings revealed that the blood vitamin and mineral concentrations and hematological variables were within the normal ranges except for pyridoxine and riboflavin. Analysis of the 5-day dietary record showed that the mean daily intake of all the vitamins and minerals was above the RDA for adult males. There was no clinical evidence of serious vitamin toxicity; in particular, the fat soluble vitamins remained normal even after three months of high dose supplementation.

Guillan et al (76) also studied the vitamin status of athletes including the effect of supplementation. Subjects consisted of 55 well trained male athletes and a control group of 20 male sedentary students. Subjects recorded their food

intake for seven days and received a daily multivitamin supplement for 30 days. The mean dietary intake of riboflavin, vitamin A and vitamin C was well above the RDA. A substantial percentage of the athletes and control subjects was consuming less than the requirement for vitamin B6, vitamin E and vitamin C. The blood analysis revealed deficiencies in vitamins thiamin, riboflavin, vitamin B6 and vitamin E were found more frequently in the athletes than in the control group despite a higher mean vitamin intake.

After supplementation, significant improvement was affected in mean serum vitamin C, plasma vitamin B6, and thiamin concentrations. The percentage of subjects with deficiencies for riboflavin, vitamin B6, and vitamin E remained higher in the athletes than in the control group. Vitamin supplementation failed to normalize the status of these vitamins in a small percentage of the athletes.

Barnett et al (77) performed a study on the effects of a commercial dietary supplement on human performance. Twenty trained male subjects were given a vitamin/mineral supplement or a placebo for four weeks. A 60 minute submaximal treadmill run (60 to 75 VO2 max) was completed before and after supplementation. The results found no significant difference for muscle glycogen, blood glucose, blood free fatty acids, and lactate levels between the placebo and supplement groups.

Similarly, supplements had no beneficial effect on VO2 max.

Singh et al (78) also studied the effect of physical performance of male athletes after a multivitamin-mineral supplementation and found similar results . The purpose was to determine the effects of supplementation with a high potency multivitamin-mineral on maximum aerobic capacity, endurance running, and muscle endurance and strength.

The results showed no significant differences between the supplemented group and the placebo group for VO2 max, total time spent on the treadmill, maximal heart rate and muscle strength.

Hydration and Fluid Replacement

Increased muscular activity leads to an increase in heat production in the body; this is dissipated, in part, through the production of sweat (46). To prevent dehydration, water must be replaced at a faster rate. Dehydration has an adverse effect on muscle strength, endurance, and coordination and increased risk of cramps, heat exhaustion, and life threatening heat stroke (46). Athletes can lose up to six pounds of sweat per hour during strenous activity (46). To ensure that lost fluid is replaced, body weight should be measured before and after training sessions; each pound lost should be replaced with 16 ounces of fluid (22). If weight is not within one to two pounds of the previous day's exercise

weight, additional fluid should be consumed before exercising (46). Guidelines for fluid consumption include consuming at least 16 to 20 ounces of fluid before exertion, followed by another 16 to 20 ounces fluid 15 to 20 minutes before endurance exercise (46). During exercise, especially in hot and humid environments, frequent small servings four to six ounces every 15 minutes of plain water or rehydration beverage should be taken (46).

Athletes should become accustomed to consuming fluid at regular intervals (with or without thirst) during training sessions so that they do not experience discomfort during competition. Water is the appropriate fluid replacement for athletes exercising for one hour or less (46). Longer exercise and/or extreme environmental conditions, such as high temperature/humidity index, may warrent consumption of sports beverages as part of the hydration-replacement process. Commercial sports beverages are available that contain electrolytes to enhance absorption and supply energy through various carbohydrate sources.

Dietary Intake of Male and Female Athletes

In recent years, the dietary intake of male and female athletes has been studied with varying results. Short and Short (1), conducted a four-year study with college athletes at Syracuse University to collect baseline data on the dietary

intake of trained athletes in order to advise individual athletes about nutrition, suggest training table menus, and provide nutrition education. The sample population was athletes who trained on a regular basis at least two hours a day to strengthen muscular and cardiovascular systems. The men's teams participating in the study were football, wrestling, basketball, crew, track, lacrosse, gymnastics, soccer, mountain climbers, and body builders and the women's teams were basketball, crew, dancers, lacrosse, swim, and volleyball. The athletes kept a three-day food record when they were in vigorous training. Vitamin and mineral supplements were recorded but were not part of the diet analysis.

The diets were analyzed using a computer program written in APL Plus, using the United States Department of Agriculture Handbook No. 456, updated with the first five sections of revised Agriculture Handbook No. 8 Tapes as a data base (79).

The study found variable nutrient intakes in members of the various men's and woman's teams. The mean caloric intake for the football players was 5270 kcal. The mean percentage of kcal from carbohydrate was 44%, fat 39%, and protein 16%. The mean intakes for vitamin and minerals met the RDA with the exception of vitamin A. Half of the players only met 66% of the RDA for vitamin A. The wrestlers had varied meam caloric

intakes from a low of 1531 kcal to a high of 6709 kcal. The team member with the lowest caloric intake ate very limited amounts so he could stay in his weight class. The percentage of wrestlers not meeting the RDA for vitamins and minerals ranged from a low of 10% for calcium to a high of 39% for vitamin A. On a daily bases 13% took a multiple vitamin and mineral supplement and all members were given 250 mg. of vitamin C. The mean caloric intakes for the other men's teams ranged from 2000 kcal for the gymnasts to 4700 kcal for the basketball players. The mean percentage of kcal from carbohydrate ranged from 36% for the body builders to 55% for members of the track team. The mean percentage of kcal from fat ranged from 32% to 42%, with gymnasts having the lowest intake. The mean percentage of kcal from protein ranged from 14 to 26% with crew members having the highest intake. The majority of the various team members met the RDAs for vitamins and minerals except 8% to 33% had low intakes of vitamin A. The study reported only the basketball players taking vitamin and mineral supplements.

The mean caloric intake for the women's teams ranged from 1,812 kcal for the volleyball players to 3240 kcal for the basketball players. The mean percentage of kcal from carbohydrate ranged from 44% for the swimmers to 53% for the volleyball players. The mean percentage of kcal from fat

ranged from 31% to 40% with basketball players having the highest intake. The mean percentage of kcal from protein ranged from 13% to 17% with volleyball players having the lowest intake. The mean calcium intake ranged from 798 mg for lacrosse players to 1,418 mg for basketball players. The majority of the various teams met the RDA for vitamins and minerals except for vitamin A, calcium and iron.

In a study by Chen et al (80), at the Institute of Sports Medicine in Beijing China, a dietary investigation was conducted with 37 elite athletes from four teams and 17 amateur athletes from three teams. Dietary analysis was conducted by a food weighing method and nutrient intakes were then calculated from a food composition table with a computer. In the elite athletes the mean caloric intake for the men ranged from 3310 kcal (56 kcal/kg) for the gymnasts to 5938 kcal (80 kcal/kg) for the swimmers. The highest mean percentage of kcal from carbohydrate came from the gymnasts at 43%. The mean percentage of kcal from fat was high for all elite men's teams ranging from 38% to 48%. The mean percentage of kcal from protein ranged from 20% for the gymnasts and weightlifters to 22% for the throwing team. The swimmers had the highest intake of protein at 4.3 g/kg. The elite men's teams met or exceded the RDA for all vitamin and minerals analyzed.

The mean caloric intake for the elite women ranged from 2298 kcal (51 kcal/kg) for the gymnasts to 4595 kcal (71 kcal/kg) for the swimmers. The percentage of kcal from carbohydrate ranged from 35% to 42% with gymnasts having the highest intake. The mean percentage of kcal from fat was higher than the elite men ranging from 42% to 49%. The mean percentage of kcal from protein ranged from 16% (2.1 g/kg) for the gymnasts to 26% (3.5 g/kg) for the swimmers. The elite women met the RDA for all vitamin and minerals analyzed except for mean intakes of calcium, vitamin A and vitamin C for the gymnasts.

For the amateur athletes the mean caloric intake for the men ranged from 2654 kcal (78 kcal/kg) for table tennis players to 4113 kcal (58 kcal/kg) for the weight lifters. The mean percentage of kcal from carbohydrate and fat was similar to the elite men. The mean percentage of kcal from protein was lower than the elite men, ranging from 12% to 14%. The amateur mens teams met the RDA for vitamins and minerals analyzed except for the gynmasts.

The mean caloric intake for the only amateur women's team, gymnasts, was 1,637 kcal (74 kcal/kg). The percentage of kcal from carbohydrate was 44%, fat 45% and protein 11%. The women gymnasts did not meet the RDA for vitamin A, vitamin C, niacin, and calcium.

Grandjean (81) conducted a study to compare the macronutrient intake of US athletes with the general population. Subjects included 275 professional, collegiate and olympic athletes. Each subject completed a three-day food intake record during training and in the competitive season. The diet records were evaluated by Dietary Intake Analysis (Computrition Inc.). The mean caloric intake for female athletes was 2141 kcal compared to a USDA Continuing Survey of Food Intakes by Individuals (CSFII 1985) of 1707 for females 19 to 34 years of age. Male athletes mean caloric intake was 3118 kcal compared to CSFII of 2667 kcal. Female cyclists had a mean caloric intake of 3029 kcal, gymnasts of 1935 kcal, and figure skaters of 1809 kcal. The percentage of kcal from carbohydrate ranged from 49% to 52%, protein 13% to 15%, fat 33% to 36%. Male athletes mean caloric intake ranged from a high of 4654 kcal for baseball players to a low of 2154 kcal for wrestlers. Swimmers had a mean caloric intake of 4018 kcal, basketball players - 4,076 kcal, cyclists - 4144 kcal, football players - 3961 kcal, weight lifters - 3643 kcal, judo players -3357 kcal, distance runners - 3034 kcal, and figure skaters - 2660 kcal. The percentage of kcal from carbohydrate ranged from 43% to 54%, protein from 12% to 18%, and fat 33% to 41%.

In a study by Nutter (82) the dietary intakes of 24

female athletes in various sports were compared during the competitive season and post season to those reported by 24 non-athletes during the same time period. Subjects recorded their food intake using a seven-day dietary record. The athletes recorded their food intake approximately midway through their competitive season and two weeks after their season ended. The non-athletes recorded food intake during the same time period. The food intake data was analyzed using the Nutritionist II software package (N-Squared Computing, Salem, Oregon).

Mean caloric intakes for the female field hockey players (n=9) for the competitive season was 1513 kcal (23.9 kcal/kg) and postseason 1426 kcal (22.7 kcal/kg). No significant changes were observed in the percentage of kcal as carbohydrate (54%), fat (27%), or protein (15%) from competitive season to postseason. Protein intake was 0.95 g/kg competitive season and 0.90 g/kg postseason. Intakes of vitamin A, vitamin C, thiamin, riboflavin, niacin, and folacin were adequate, but their intake of calcium and iron was less than 70% of the RDA both competitive season and postseason (82).

Mean caloric intakes for the golfers (n=5) were 2021 kcal (35.1 kcal/1kg) competitive season and 1678 kcal (27.1 kcal/kg) post season. The percentage of kcal as carbohydrate

fat, and protein did not change significantly during the study. The fat consumption was 34% of kcal during the competitive season and 38% of kcal postseason. Protein intake was 17% (1.60 g/kg) of kcal during the competitive season and 17%(1.21 g/kg) of kcal postseason. In season, subject's consumption of the selected vitamins exceeded the RDA except calcium and iron. Folacin, vitamin C, calcium and iron were below recommended amounts postseason (82).

Mean caloric intake for the cross-country runners (n=6) were 1664 kcal (32.2 kcal/kg) competitive season and 1463 (27.8 kcal/kg) post season. No significant changes occurred in the percentage of kcal derived from carbohydrate, fat and proteins. The mean percentage of kcal for carbohydrate was 57% competitive and 62% postseason and protein was 16% (1.34g/kg) competitive and 14% (1.03 g/kg) postseason. Mean calcium and iron intakes were less than 80% of the RDA for both seasons (82).

The mean caloric intakes for the tennis players (n=4) were 1664 kcal (31.0 kcal/kg) competitive season and 1495 kcal (26.9 kcal/kg) postseason. No significant change occurred in percentage of kcal from carbohydrate, fat, and protein across seasons. The tennis players did, however, consume higher carbohydrate postseason (55%) then competitive (49%) and lower fat postseason. Protein intake was 17% of kcal (1.21g/kg)

during the competitive season and 17% of kcal (1.18g/kg) postseason. Vitamin consumption was adequate during the season. However, calcium was less than 70% of the RDA both seasons and iron was less than 70% postseason (82).

The mean caloric intakes were reduced significantly ($p<0.05$) between seasons for the non-athletes because of dieting. The intakes were 1579 kcal (25.4 kcal/kg) competitive and 1363 kcal (22.0 kcal/kg) postseason. The percentage of kcal from carbohydrates was 49% during the competitive season and 53% postseason. The percentage of kcal from fat was 34% during the competitive season and 31% postseason. Protein consumption was 17% of kcal (1.0 g/kg) during the competitive season and 16% of kcal (.87 g/kg) postseason. Mean intakes of riboflavin, niacin and vitamin C exceeded the RDA during the competition season. While only vitamin C exceeded the RDA postseason, intakes of both calcium and iron were only less than 70% of the RDA for both seasons.

Mean caloric intakes competitive season and postseason of the athletes did not differ significantly from the non-athletes during the study. However, when comparing caloric intake by kcal/kg, the non-athletes were consuming fewer kcal than the tennis players, cross-country runners, and golfers. Postseason, there were no significant differences between any of the groups for kcal. Field hockey players and cross-

country runners were consuming a lower percentage of fat than the non-athletes during competitive season. At the postseason period, non-athletes consumed more carbohydrates than the golfers but less than the crosscountry runners. Non-athletes had significantly higher intakes of fat than cross-country runners but lower intakes compared to the golfers. The non-athletes consumed less protein (g/kg) than the cross-country runners and golfers during competitive season. There was no significant differences for vitamin and mineral intakes between the non-athletes and athletic groups during the study, although the amounts were greater for the athletes (82).

The purpose of a study conducted by Nowak et al (8) at the University of Wisconsin in Milwaukee with 26 male and female collegiate basketball players was to collect data on their dietary intake in order to advise athletes about nutrition practices that might maximize performance. Dietary records and supplement use were recorded for three weekdays by the subjects. The completed records were analyzed for nutrient composition by the Nutritionist III software program (N-Squared Computing, Silverton, OR).

The study revealed that the mean caloric intake for women was 1730 kcal and mean caloric distributions were found to be 52% from carbohydrate, 16% from protein and 32% from fat. Only two of the women's diets met the RDA for all nutrients

assessed. However, nutrient supplements consumed by five of the 10 women made a significant contribution to the mean intake for vitamin A, vitamin C, vitamim B6, vitamin B12 and niacin. None of the diets of the subjects using supplements was adequate in itself (providing at least two-thirds of the RDA for all nutrients). The mean caloric intake for men was 3,558 kcal and mean caloric distribution was 48% from carbohydrate, 16% from protein, and 32% from fat. Ten of the 16 men received at least two-thirds of the RDA for all nutrients assessed. The diet of the only male supplement taker was adequate, thus, supplementation was of little benefit.

Khoo, et al (83) used three-day food records to investigate the dietary intakes and use of supplements of 29 triathletes participating in the Ironman Triathlon World Championship. Information concerning the dietary adequacies of these competitive athletes was sought for the purpose of dietary planning and counseling. Trained personnel coded the diet records using the Michigan State University Nutrient Database.

The mean caloric intake for the women was found to be 2,464 kcal and the primary source of kcal came from carbohydrate and fat, at about 56% and 30%, respectively. The mean intake for protein was 1.45 g/kg. All of the vitamin

intakes analyzed exceeded 100% of the RDA and the mineral intakes were above 66% of the RDA except for iron, zinc, and copper. At least 80% of the women used vitamin and mineral supplements and this increased the intakes to 50% and above the recommendation. The iron supplement intake averaged 700% above the RDA. The mean caloric intake for the men was 3623 kcal and percentage of kcal from carbohydrate (56%) and fat (30%) was similar to the woman. The mean protein intake was 1.65 g/kg. All of the vitamin and mineral intakes analyzed exceeded 100% of the RDA and the mineral intakes were above 66% of the RDA. At least 60% of the men used vitamin and mineral supplements and this increased their intakes to over 100% of the RDA for all vitamins and minerals. The vitamin C supplement intake averaged 2250% above the RDA. Thirty five of the men and 28 of the women consumed commercial carbohydrate liquid meals.

The purpose of a study of the nutrient intake of 347 marathon runners by Nieman et al (84) was to analyze the dietary practices of a large group as previous studies were done with a relative small number of subjects. A three-day food and supplementation record was completed by the participants, using Sunday, Monday and Tuesday. The results were analyzed using the Nutritionist III Software Program (N-Squared Computing, Silverton, OR).

The study revealed a mean caloric intake for the women of 1,868 kcal per day: 52.7% of kcal were in the form of carbohydrate, 15.8% protein (1.3 g/kg) and 32% fat. The intake of vitamins and minerals was above two-thirds the RDA except for Vitamin D and zinc. The mean caloric intake for the men was 2526 kcal per day: 51.8% of the kcal were in the form of carbohydrate, 16.6% protein (1.4 g/kg) and 30.9% fat. The vitamin and mineral intakes for men were above two-thirds the RDA for all male runners.

Duester et al (85) at the Uniformed Services University, conducted a nutritional survey with 51 women runners who had qualified for the Women's Olympic Marathon trials. The purpose of the study was to examine macronutrient intakes and dietary and supplement intake of calcium, magnesium, iron, zinc, and copper. The women completed a three-day diet record including supplements at least two weeks prior to the Marathon Trials. The results were analyzed using the University of Maryland nutrient data base. Results showed a mean caloric intake of 2397 kcal (46.3 kcal/kg). The percentage of kcal from carbohydrate was 55%, fat 32% and protein 13%. The results of the mineral intakes were food and supplements combined. Mean intake for calcium was 1227 mg and magnesium 409.8 mg. The percentage of women consuming calcium and magnesium less than the RDA was approximately 23%. Mean

intakes of iron, zinc, copper were 41.9 mg, 14.2 mg, and 2.2 mg respectively. The percentage of women consuming less than 100% of the RDA for iron was 43%, zinc 76.5% and copper 60%. Nutritional supplement was taken by 27 of the 51 women. For the 24 women taking iron supplements, intake from food was less than 60% of the RDA and after supplement the intake increased to over 300%. Supplementation also increased the intakes of zinc from 80% of the RDA to 200% and copper from 70% to 180%.

Keith et al (86) conducted a study of eight highly trained female cyclists to determine the dietary intake and compare the data to the RDA and dietary guidelines for athletes. A three-day food intake and nutrient supplementation was recorded by the athletes; however, the supplementation data was not included in the analysis. Food intake data was analyzed for nutrient composition using the Nutritionist II software package (N-Squared Computing, Silverton, OR). It revealed a mean caloric intake of 1,730 kcal per day with the mean percent of kcal from carbohydrate of 60%, from protein 14%, and from fat 26% The daily dietary intake was below the RDA for folacin (76%), magnesium (81%), iron (59%) and zinc (67%). Without the inclusion of the dietary supplement data, subjects mean intake was above the RDA in vitamin A (248%), thiamin (155%) and vitamin C (133%).

Fourteen members of a women's collegiate swim team were subjects in a study by Barr (87) to address their attitudes toward eating and dietary intake. Subjects completed a three-day record of food intake but nutrient supplements were not included. The data was analyzed using Nutri-Calc program (CAMDE Corporation, Tempe, AZ). Their mean caloric intake was 2,296 kcal per day. The mean percent of kcal from carbohydrate was 56%, from protein 12%, and from fat 32% The mean vitamin and mineral intake was above the RDA except for calcium which was 67% of the RDA.

In summery, the male athletes in the previous studies had a wide range of kcal intakes. The athletes who purposely keep their body weight lower for competition (wrestlers, gymnasts, figure skaters) had the lowest caloric intake. The majority of the male athletes did not meet the recommendation of 60% to 70 of total kcal from carbohydrate (31,32). Mean fat intakes by sport met or exceeded the recommendation of 30% of total kcal from fat (30). The mean protein intakes by sport met or exceeded the recommendation of 12% to 15% of total kcal (5). The protein intakes also met or exceeded the recommendations for g/kg (5). The majority of male athletes met or exceeded the RDA for all vitamin and minerals except for vitamin A and calcium.

The kcal intakes for the women athletes did not vary as

extensively as the men. The women athletes with the highest caloric intakes were cyclists and members of a throwing team. The women did slightly better in meeting the recommendation for carbohydrate (31-32). Fat intakes consistantly met or were slightly lower or higher than the recommendations (30). The exception was female athletes in the Chen et al (80) study. Protein intakes met or were slightly higher than the recommendations (5). The vitamin and minerals intakes that were consistantly lower than the RDA were vitamin A, vitamin C, calcium, and iron.

Dietary Assessment Methods

The relationship between dietary intake and its effects on health is central to the study of nutrition. Several methods have been developed to measure specific food consumption during a given period of time, while others quantify usual or habitual dietary intake (88). These dietary assessment methods include dietary histories, 24-hour recall, multiday food records, and food frequency questionnaires (FFQ). Numerous studies in recent years have tried to establish the reliability or validity of these various dietary assessment methods (89). Validation, the demonstration that a method measures what it is intended to measure, requires the truth be known, and for dietary intake that is the difficulty. The ability to gather valid dietary information over a certain

period of time must be coupled with a demonstration that it accurately reflects intake over an extended period of time. Investigators can validate their methods against more accepted methods or by producing similar results on two different occasions. In evaluating these methods and validations, it is important to bear in mind two dimensions which affect both dietary research and investigations of its methodology: 1) The dichotomy of group vs individual. Assessment methods that have been faulted for failing to achieve accuracy at a individual level may produce valid and useful research for the group level; and 2) Quantitative precision vs classification or ranking of individuals. Research to assess intake in precise quantities is not essential for useful epidemiologic research. Less precise methods which locate individuals on the distribution in broad categories of low, medium, and high intake would still permit the examination of nutritional hypothesis and the assessment of dose-response relationships (88).

The dietary history method includes any method which consists of an extensive interview designed to elicit the usual or customary diet. This method is time-consuming and relies heavily upon the skills of a professional interviewer. Attempts to validate this method have found higher or similar dietary intake values when compared with diet record method

and reliability, based on repeated administrations, have concluded that the method is reflecting the usual diet and changes in it (88). Mahalko et al (90) compared dietary histories and seven-day food records in a nutritional assessment of older adults. The results showed the means from the two methods were often quite similar, and varied less than 20% for every nutrient. The authors concluded that because the difference in dietary intake between the methods is relatively small, both methods are useful in measuring long-term dietary status of groups. The method of choice would depend upon the qualifications of the interviewer and the abilities and cooperation of the subjects.

A second method is the 24-hour recall and is used substantially because it is easy to administer. It is generally agreed that for large groups of subjects, 24-hour recalls provide estimates of group average intakes that are comparable to those obtained from other methods (88). However, the use of 24-hour recall has been criticized because it does not provide a reliable estimate of the usual intake of an individual over a extended period of time and it is not a reliable description of the distribution of usual intakes of a population. Increasing the number of 24-hour recalls over a extended period of time would be necessary to represent adequately the average or usual intake of a individual (88).

Treiber et al (91) studied the reliability of parental responses to the 24-hour recall and tested the validity with a three-month FFQ in assessing dietary intake of preschool children. Test-retest reliability estimates for the 24-hour recall indicated significant variability in energy intake, but similar intakes in the other nutrients analyzed. The FFQ showed significant positive test-retest reliability estimates for all nutrients. Comparison of the recall and FFQ showed similar percentage of intakes of energy, fat, carbohydrate, and protein and significant correlations for reported intakes of cholesterol, protein, calcium, and potassium.

The third method involves keeping detailed records of all food consumed and measurements of portion sizes for a specific amount of days. This may be time consuming and require considerable training. There have been significant associations between the mean values obtained and the actual weighing of intakes (88). However, the validity of this method may be limited to group mean values, since individuals' records may become unreliable after the first few days (88). Stuff et al (92) measured the dietary intake of 40 lactating women with a 7-day record (7DR) and compared the results using a 1-day record (1DR), 3-day record (3DR) and a food frequency form (FFF).

The results showed mean energy intakes of 2206 kcal

(FFF), 2057 kcal (1DR), 2059 kcal (3DR), and 2028 kcal (7DR). Significant differences were found between estimates by FFF and 7DR for protein, calcium, iron, and phosphorus. No differences were detected between 1DR or 3DR with the 7DR. Intraclass correlations for measuring agreement between methods for estimated intakes showed the 3DR had good to strong agreement with the 7DR. In contrast, the FFF showed poor agreement with the 7DR. The level of agreement between the 1DR and 7DR was intermediate. The authors concluded the 3DR can be used to obtain qualitative nutrient intake data. Although it may provide estimates for population groups, precision in predicting true estimates of intake for individuals, as measured by the 7DR, is inadequate. The 3DR is adequate to assess the general quality of the diet. The 1DR and the FFF did not appear in this study to be good qualitative approaches in assessing the diet. The author provided possible explanations that the 1DR is not a true indicator of intake and the FFF covered recent intake and is dependent upon subject recall.

Kim et al (93) studied the reliability of diet records by studying the effects of making duplicate food collections on nutrient intakes calculated from diet records. The study covered a one-year period in which dietary records were obtained daily. Twenty-nine adult subjects were asked to make

duplicate food collections during four 1-week periods. Mean calculated caloric intakes were 12.9% less during the food collection periods than the mean for the entire year. The yearly mean was 2188 kcal and the mean for the four collection periods was 1905 kcal. There were also significant reductions in reported intakes of all nutrients during the collection period. Protein, vitamin A, saturated fat, and cholesterol intakes were decreased to the greatest extent. There was no significant differences in percentage decline in energy and nutrient intakes between the sexes. Actual decrease in energy intake was greater for the males than for the females, but the percentage was the same (12.9%). The mean caloric intake for men was 2692 kcal (yearly) and 2344 kcal (4 1-wk periods) and the women was 1820 kcal (yearly) and 1585 kcal (4 1-wk periods). The greatest reduction in nutrient intakes during the collection period in males was protein, saturated fat, and cholesterol, and in females, protein, vitamin A, and cholesterol.

Comparison of intakes for the weeks preceding and following the collection periods with those during the collection period showed that 28 of the 29 subjects decreased their energy intake from 1.1 to 32.3%. The authors concluded that the declines in energy and nutrients during the four 1-week collection times may be due to the increase of tasks to

be performed when food collections were made. When comparing the year with the collection period, the mean percentage of kcal from carbohydrates was 46% and 48%, protein 16% and 15% and fat 38% and 37%, respectively. The data suggested that food collections reflect the qualitative aspects of food intake records correctly, even though they are less reliable quantitatively as a measure of habitual intake.

The fourth method, the food frequency questionnaire (FFQ), consists of a list of food items for which average frequency of consumption is determined in reference to a specified period in the past, e.g., a usual week, and one or more months. Information on serving size as well as frequency of consumption allows for estimates of nutrient intake (nutrient estimate= food frequency x serving size x nutrient standard). Data on serving size may be obtained from the respondent or imputed by the researcher. The food list may consist of foods that contribute to a majority of nutrients in the diet or foods that contribute to specific nutrients (94). The FFQ can be used to determine habitual intake, and therefore, is especially applicable to studies relating diet to long-term health effects, notably chronic diseases (88). The advantages: it requires neither specialized training for respondents nor a lengthy interview, which may increase participation; requires less specialized interviewer training

and can be conducted by personal interview, telephone, and by mail. These advantages translate into lower cost which can be especially important for large-scale studies (94). The FFQ may be useful for classifying individuals by rank, identifying groups of extremes of intake, and monitoring trends in dietary patterns over time. The disadvantages: may not be appropriate for all subgroups and information is limited by the food list and the completeness with which it represents the nutrient or nutrients of interest (94). Dietary intake estimates have been better for foods comprising main meals, rarely eaten foods, and calcium and vitamin C than for fruits and vitamin A (94).

Studies have found the reliability of the FFQ did not vary significantly for mean intakes of all nutrients assessed when administered twice or compared to other methods (91,95).

Studies researching the validity of FFQ in measuring usual diets have found high correlations or poor correlations between dietary assessment methods. In a study by Mullen et al (96) with 31 college students, a food frequency questionnaire was validated with diet records. The authors found that the frequency technique was highly successful in estimating usual intakes with groups and compared favorable to actual intake. They did not recommend the technique to estimate precise estimates for individual intake. In

addition, the frequency technique does not possess the same level of accuracy for all food categories. Food categories that are major components of a meal were estimated with great accuracy while foods used in small quantities were reported with lower validity. Block et al (97) also validated a self-administered diet history questionnaire with diet records. The results showed the questionnaire estimated nutrient intakes within 20% of estimates produced by the mean of the food records.

The purpose of a study by Larkin, et al (98) was to design a quantitive FFQ that would describe and evaluate an individual's usual diet over a 12 month period compared with that of a 16 day diet recall and records covering all four seasons of the same 12 month period. The results involving the 121 female subjects revealed a 35% difference in mean kcal intake per day; a difference of 138% in vitamin A; a difference of 75% in vitamin C; a difference of 42% in calcium; and a difference of 51% in iron. The FFQ assessments were higher in all the energy and nutrient intakes. It was assumed that the mean values from the food records, which depend upon recent memory, were more reliable and valid than those from the FFQ which depend upon long term memory; however, the FFQ values have greater validity as they purport to represent behavior over a longer period. The researchers

concluded that the differences between the FFQ and the food record estimates are more ascribable to under reporting on the recall/record than to over reporting on the FFQ.

Block, et al (99) compared two dietary questionnaires covering a one-year period against multiple dietary records collected at four intervals over a one-year period. The study was conducted with 85 participants at the University of Michigan. The University of Michigan (UM) food frequency questionnaire was developed to estimate the usual diet of individuals over a one-year period and included 187 food items. Energy and nutrient values were assigned to each food frequency item from the Michigan State nutrient composition data base. A daily average was computed by summing across all food items the product of frequency, amount typically consumed, and energy and nutrient composition.

The second food frequency questionnaire, the Health Habits and History Questionnaire (HHHQ), was developed by the National Cancer Institute, National Institutes of Health. HHHQ asked for frequency (times per day, week, month, or year) of consumption of 98 food items during the past year. The nutrient data base used in the analysis was developed from the second National Health and Nutrition Examination Survey (NHANES II). The program multiplies the report of frequency times the reported portion size times the nutrient content and

sums over all foods.

The UM questionnaire revealed the highest level of energy intakes. The mean caloric intake for men was 2652 kcal for the food records, 3476 kcal for the UM and 2632 kcal for the HHHQ. The mean caloric intake for the women was 1818 kcal for the food records, 2370 kcal for the UM, and 1755 kcal for the HHHQ. The UM reflected accurately the ranking of the four age-sex groups; however, it considerably overestimated energy intake. The HHHQ also accurately ranked these groups and accurately estimated energy intakes in each age-sex group; in no case was the HHHQ estimate significantly different from the food record estimate. The HHHQ questionnaire produced significantly higher estimates for linoleic acid, vitamin C, calcium, sodium, and potassium and a lower estimate in cholesterol when compared to the food records. The UM was higher for all nutrients when compared to the food records and HHHQ except for linoleic acid with HHHQ. The authors concluded that the HHHQ has a reasonably good ability to place individuals along the distribution of energy and nutrient intake. The HHHQ estimates of the actual level of the group's mean intake for energy and many nutrients correlated higher with the food records than the UM questionnaire.

MATERIALS AND METHODS

The researcher contacted the Womens Tennis Association, with headquarters at St. Petersburg, Florida, in February 1990 and again in April 1991, concerning the possibility of conducting this thesis project with their organization. Because of the vigorous worldwide traveling schedule of their health services director and the players, it was not possible to get a positive commitment until August 1992. The study was then conducted by the researcher with over 100 professional tennis players who were recruited in New York City at the Association's annual meeting and in the training room at the 1992 U.S. Open Tennis Tournament at Flushing Meadows, New York.

The researcher was introduced at the annual meeting as a graduate student of Virginia Tech and was given the opportunity to address the members regarding their participation in her thesis research. One hundred questionnaires were distributed at the meeting and 40 of them were completed and returned at that time or in the training room the following day.

The study was designed to gather data for an analysis of the dietary intake of:

- Kcal

- Carbohydrate, fat, protein
- Vitamin and minerals
- Water
- Supplements

The questionnaire, Health Habits and History Questionnaire, was prepared by Dr. Gladys Block et al (100) at National Cancer Institute, National Institutes of Health, Bethesda, Maryland. This questionnaire can be found in Appendix A. This is a self-administered, frequency (times per day, week, month or year) diet history questionnaire developed for epidemiologic and clinical use. Both the food list and the nutrient values to be associated with it were developed using dietary data from 11,868 adult respondents to the Second National Health and Nutrition Examination Survey (NHANES II) (101).

The questionnaire was used because of the development of a food list which would be adequate for the assessment of a wide range of nutrients consumed. This was achieved in two ways:

- By ensuring that the food list included foods representing at least 90% of the total U.S. consumption of each of 18 major nutrients.
- By including, in the list, foods representing approximately 93% of the total U.S. caloric

consumption.

Nutrient estimates for the questionnaire dietary assessment are based on the NHANES II nutrient content database. This database is based on USDA food composition data tapes, as well as industry and other sources. The foods database includes portion sizes, in grams, for 98 food items on the questionnaire as well as for any additional foods not included on the food list. It analyzes the nutrients per 100 grams. For each food, the program calculates nutrient intake using the following formula: gram portion size times the nutrient content per 100 grams, times the respondent's reported frequency of that food/100. Nutrients are summed over all foods and expressed as average intake per type of food. For some foods the frequency is adjusted to accommodate the fact that they are eaten only in season. Milk on cereal is added automatically by the program, or asked as a separate line item. Fats are adjusted in response to the answers on trimming meat, cooking fat, etc. The program also provides for the analysis of weekly consumption of certain foods and restaurant type food such as fried chicken, burgers, pizza, and ethnic foods. The medium serving size listed on the questionnaire is the standard. A small serving is .5 and a large serving is 1.5 of the standard.

The questionnaire provided a section to record

information concerning vitamin and mineral supplementation. The program kept this information separate from vitamin and minerals derived from food. The nutrient analysis database contained only three types of multivitamins: one-a-day, stress tabs and therapeutic. Subjects provided the brand names of many multivitamins which were not in the database and whose contents were not available. Therefore, the analysis for the one-a-day type was used as a standard for all subjects. In addition to the multivitamins, the questionnaire asked for separate intakes of vitamin A, C, E iron and calcium supplements. If subjects consumed any of these in addition to the multivitamin, they were combined in the database analysis. The only vitamin and mineral analysis the database provided was for vitamins A, C, D, E, thiamin, and iron and calcium.

The questionnaire did not provide for the dietary analysis from food or supplements for vitamin D, vitamin B6, vitamin B12, magnesium, zinc, and iodine.

The complete questionnaire covers demographic data, dietary intake, health habits, health history, family history, occupational data, psychological and social factors. However, only the dietary section found in Appendix A was used due to its pertinence to this study and due to the confidentiality of participants. The replies to the questionnaires were coded, reviewed for accuracy and analyzed four times by the

researcher using DIETQ, DIETUTIL, DIETEDIT, and DIETANAL, which were included in the software program provided with the Health Habits and History Questionnaire package. DIETQ is a computer assisted program consisting of the questionnaire into which the replies are coded. DIETUTIL provides the option to rearrange, delete or add questions or input additional food items, review a completed or aborted questionnaire, or delete an unnecessary questionnaire. It also provides for altering the food/nutrient data base by adding foods which are not currently on the data base or by modifying the names, portion sizes or nutrient contents. DIETEDIT identifies input errors in responses to the diet section as well as unreasonable replies in the questionnaire, i.e., high food frequency responses, number of foods skipped, excessive food portions coded one size, number of frequency for which once-per-day was used and number of total servings of food per day. DIETANAL performs the dietary analysis of the responses to the questionnaire. The researcher performed the statistical analysis by using the Number Cruncher Statistical System (102) to calculate the mean and standard deviation.

RESULTS

The 40 subjects were from a diversified cultural background spanning several countries, but specific information was not available for use in this study due to their desire for anonymity. The age, height and weight of subjects is presented in Table 1. The age range was from 20 to 35 years with the mean age being 25. Six were over 30 years of age. The weight ranged from 46.4 kg (102 pounds) to 69.8 kg (154 pounds) with a mean of 60.9 kg (134 pounds).

A comparison of the daily caloric intake of subjects ranged from 1035 kcal to a high of 3211 kcal, shown in Figure 1, and a daily caloric intake per kcal/kg from 16.2 to 55 kcal/kg in Figure 2. The daily dietary intake data for kcal and the various nutrients can be found in Table 2. The mean caloric intake was 2026 kcal. The mean intake for carbohydrates was 254 gm. The mean percentage of kcal from carbohydrate was 50%. Four subjects' carbohydrate intake was 60% of kcal or above; for 16 it was 50-60%; for 18 it was 30-40%; and for 2 it was 30% of kcal or below. The percentage of kcal from protein ranged from 15% to 20%, with 2 subjects having intakes above 20%. The mean percentage of kcal from fat was 31.3%. Two subjects fat intakes below 20%; for 18 it was 20-30%; for 19 it was 30-40% and for 1 it was above 40% of

TABLE 1. AGE, HEIGHT AND WEIGHT OF SUBJECTS

variable	mean	minimum	maximum
age (years)	25.13±4.0[a]	20	35
height (cm)	167.5±5.7	157	180
weight (kg)	60.9±4.9	46.4	69.8

[a] mean±standard deviation

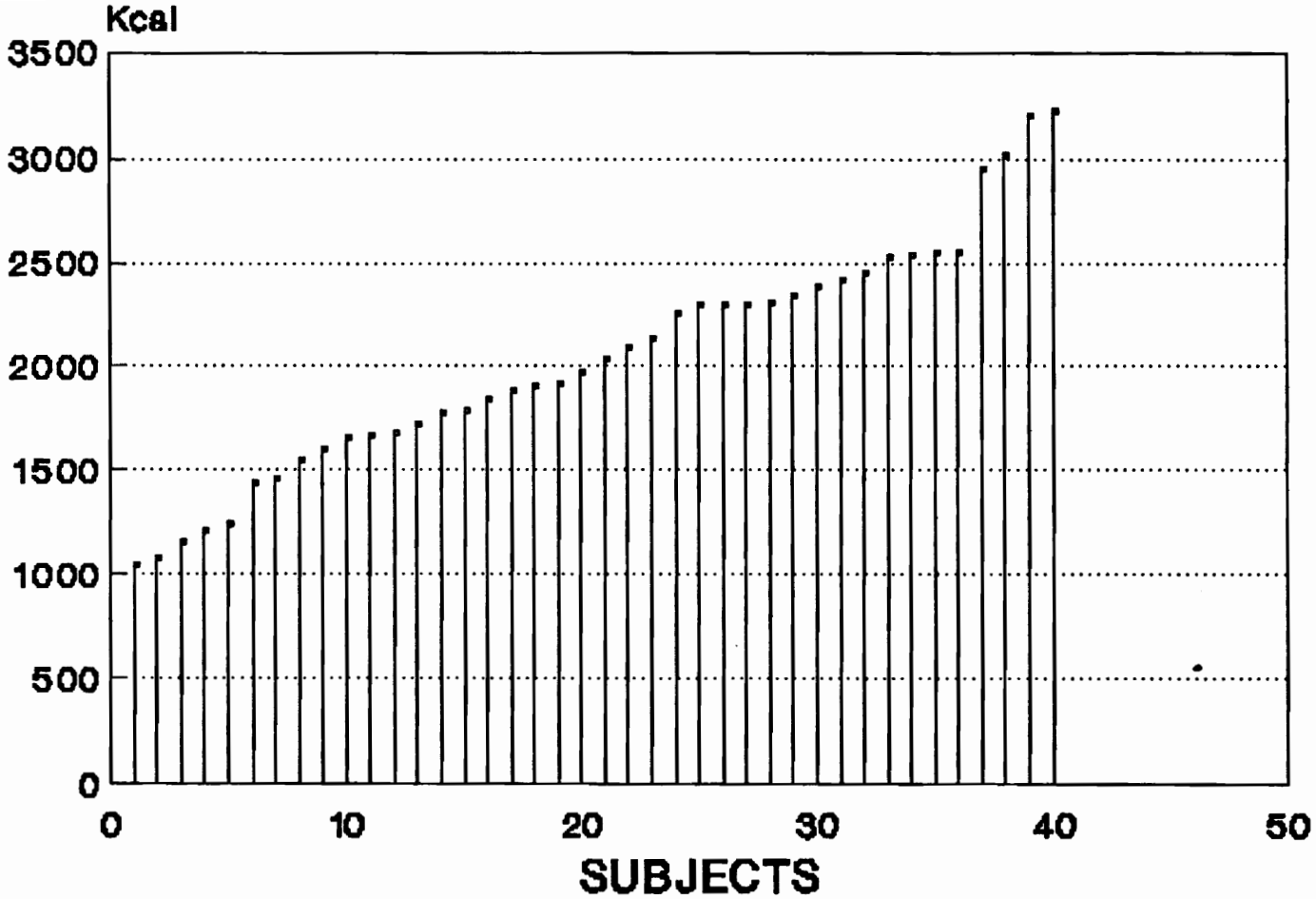

FIG. 1. Comparison of daily kcal intake

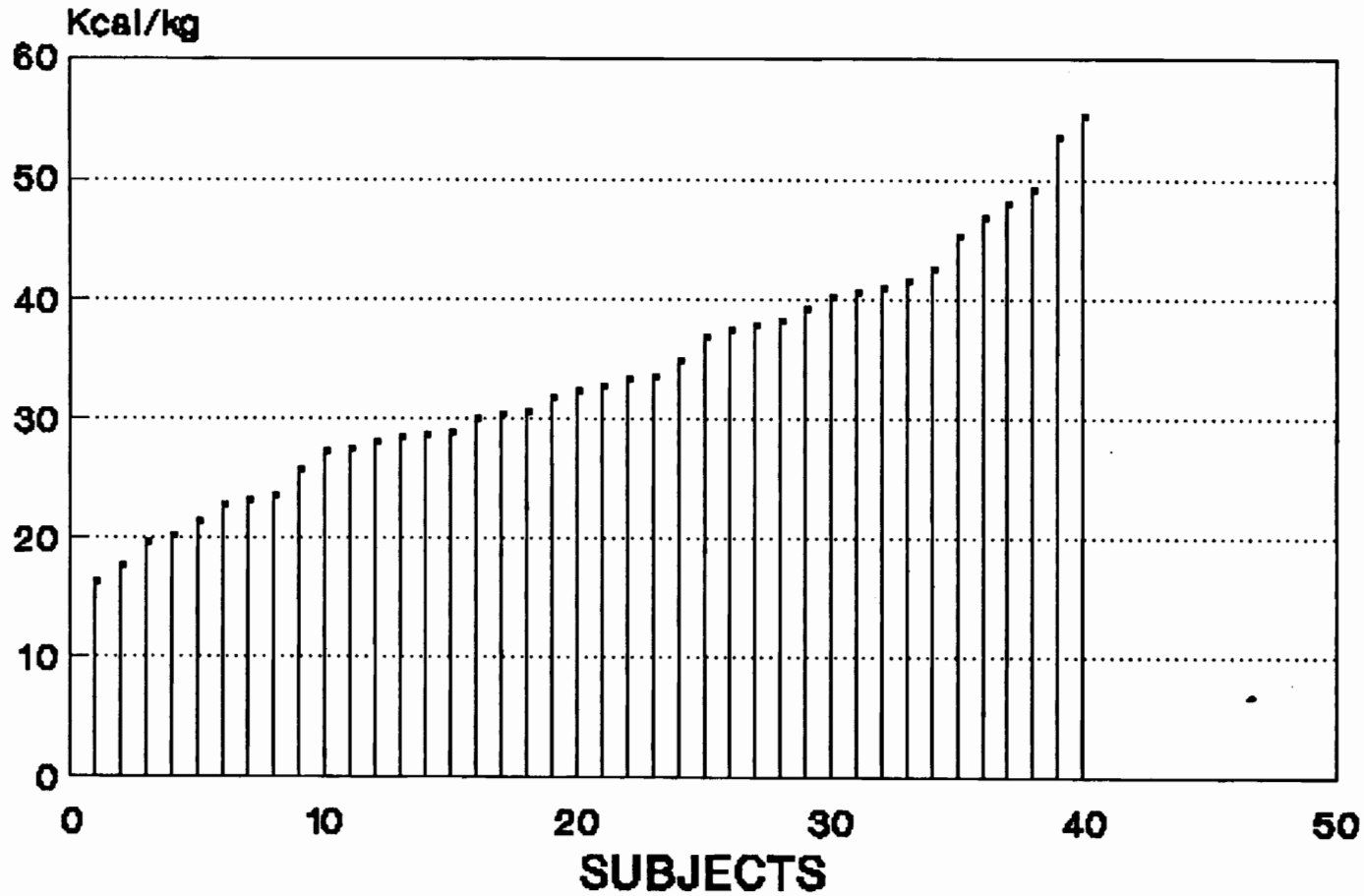

FIG. 2. Comparison of daily kcal intake per kg body weight

TABLE 2. MEAN ENERGY AND NUTRIENT INTAKE FROM FOOD

variable	mean	minimum	maximum
Energy (kcal)	2026±561[a]	1035	3211
Protein (gm)	86±26	39	148
(%kcal)	17±2	13	23
Fat (gm)	72±29	25	142
(%kcal)	31±6	18	43
Carbohydrate (gm)	254±69	112	396
(%kcal)	50±6	39	63
Alcohol (%kcal)	2±3	0	10
Saturated Fat (gm)	24±10	7	51
Oleic Acid (gm)	27±11	7	56
Linoleic Acid (gm)	11±5	3	27
P:S Fat Ratio	0.5±0.2	0.2	0.8
Cholesterol (mg)	279±98	101	596
Dietary Fiber (gm)	16±4	9	26

[a] Mean±standard deviation.

kcal. The mean intake for cholesterol was 279 mg; and 17 subjects' had intakes above 300 mg.

Data concerning the vitamin and mineral intake from food are found in Table 3. The mean intake of the group was over 100% of the RDA with the highest mean intake of 356% for vitamin C, 184% for vitamin A and riboflavin and 180% for phosphorous. However, some of the subjects' individual intakes were below 67% of the RDA for the following nutrients: three for vitamin E, one for riboflavin, seven for calcium, 11 for folacin, and four for iron. The mean intake for water was 37 fluid ounces with a minimum of 8 to a maximum of 120 fl oz.

The mean vitamin and mineral intake of subjects from food was over 100% of the RDA as shown in Table 3. However, as shown in Figure 3, with supplementation, the mean percentage of the RDA for vitamin A was 337%, vitamin C - 1047%, vitamin E - 267%, thiamin - 454%, iron - 231%, and calcium - 226%. The percentage of vitamins and minerals increased relative to the RDA with the addition of supplements. Types of supplements used were one-a-day multivitamins and multivitamins for athletes as well as vitamin C, calcium and iron supplements. Ten subjects did not take any supplements.

Analysis of certain foods consumed weekly by subjects is shown in Table 4. It was revealed that there was a mean

TABLE 3. MEAN VITAMIN AND MINERAL INTAKE FROM FOOD

variable	mean	minimum	maximum	%RDA
Vitamin A (IU)	9,233±3384[a]	3,758	19,258	184
Vitamin E (mg)	10±4	3	23	170
Vitamin C (mg)	207±92	59	548	346
Thiamin (mg)	1±.6	0.7	3	170
Riboflavin (mg)	2±.9	0.7	5	184
Niacin (mg)	22±7	9	45	173
Folacin (ug)	420±204	76	1,074	105
Calcium (mg)	948±471	118	1,982	118
Phosphorous (mg)	1,445±491	605	2,631	180
Iron (mg)	16±5	8	34	111
Sodium (mg)	3,573±1,128	1,014	6,403	--
Potassium (mg)	3,502±1,015	1,200	5,628	--
Sodium/potassium	1±.2	0.9	1	--
Carotene Estim	2,455±1,438	427	5,680	--
Retinol Estim	928±646	114	3,805	--
Water (fl oz)	37±29	8	120	--

[a] Mean±standard deviation

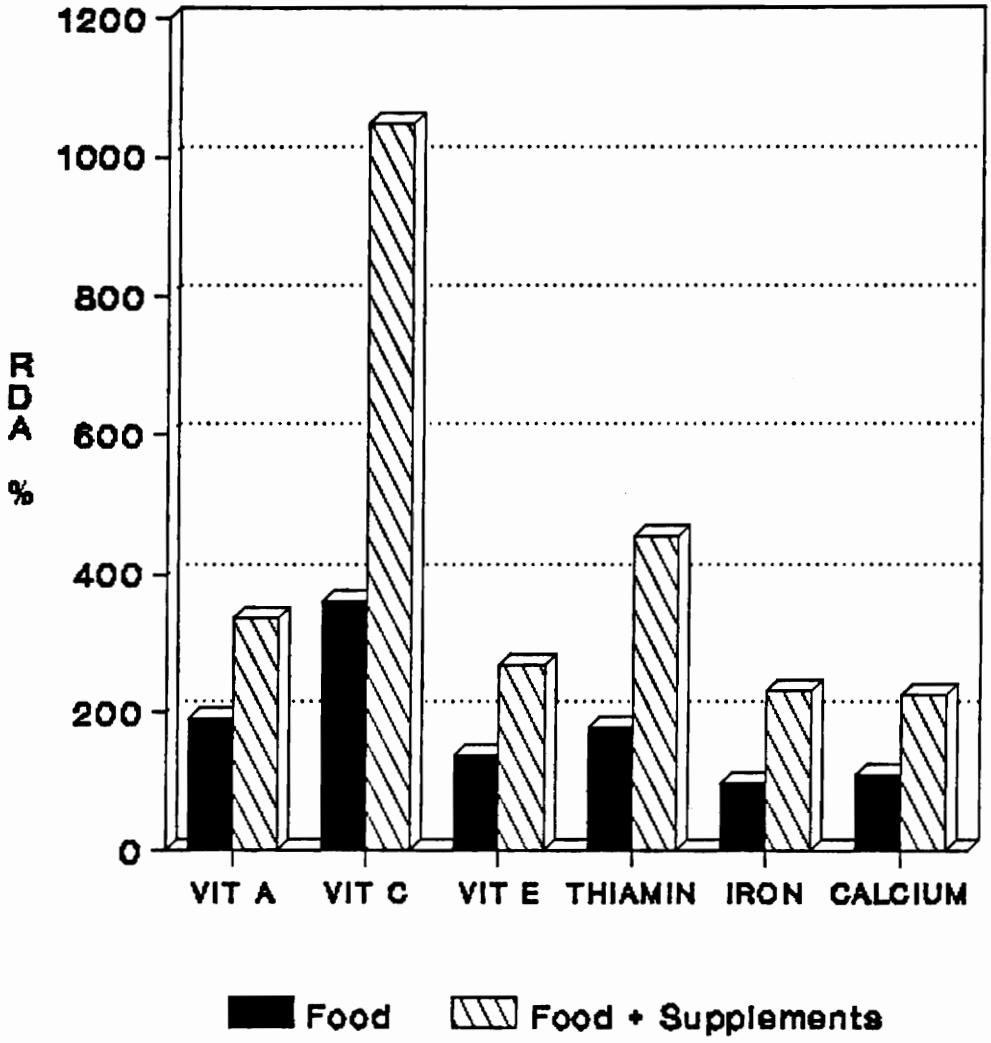

FIG. 3. Comparison of % RDA from food vs. food plus supplements.

TABLE 4. Weekly Frequency of Consuming Certain Foods

variable	mean servings
Any fruit or juice	16.8
Citrus fruit for juices	7.6
Any vegetable	23.3
Vegetables excluding potatoes, rice	17.1
Salad	4.7
Carrots	1.2
Tomatoes	3.1
Deep yellow or dark green vegetables	3.1
Whole grains or bran cereal	6.8
Pasta	5.9
Fish or chicken	4.6
Beef	1.0
Pork	0.3
Eggs	1.1
Butter or margarine	5.3
Cheeses	2.9
Whole milk	.6
Ice cream	1.5
Pastries, sweets, sodas, sugar	10.8

intake of 4.6 servings of chicken or fish and lower intakes of 1.0 servings of beef and 0.3 of pork. Fruit intake was 16.8 servings per week with almost one-half consisting of citrus fruit. Over 23 servings of vegetables were consumed by subjects, with only three coming from the deep yellow and dark green variety. Approximately seven servings of whole grains or bran cereal were consumed. Subjects consumed approximately five servings of butter or margarine, 11 servings of pastries, sodas, sweets, sugar, and six servings of pasta per week.

The frequency of eating food from restaurants or fast food places is shown in Table 5. Pizza, Chinese and Mexican foods were the most frequently consumed.

TABLE 5. Restaurant Food Intake

restaurant food	daily	1-4x week	1-3x month	1-10x year	never
Fried Chicken	0	2	3	13	22
Burgers	0	2	5	17	16
Pizza	0	13	11	11	05
Chinese Food	0	11	13	11	05
Mexican Food	0	5	7	9	19
Fried fish	0	1	2	11	26
Other	5	8	3	4	20

DISCUSSION

The results of the dietary intake evaluations in this study, as compared with results of several recent studies, can be seen in Table 6. This study used a questionnaire to collect yearly data of food intake and supplements to make a dietary assessment of professional women tennis players. The other studies used diet recalls or food records.

The mean caloric intake of subjects in this study was higher than that in all the other female studies looking at dietary intake except for female collegiate swimmers in the by Barr (87). The mean caloric intake of the professional women tennis players in this study was higher than female collegiate tennis players (n=4) in a study by Nutter (82). Their mean caloric intake is also in the range of 1600 to 2400 kcal/day recommended for normal healthy non-athletic women (103), but this may be inadequate when you consider the energy expended for exercise.

If one assumes an approximate caloric expenditure for competitive tennis of 8.7 kcal/min (104) for a 61 kg person (mean kg for the professional women tennis players was 60.9) the cost of playing tennis estimated at 240 minutes (4 hours) per day would add 2088 kcal or 34.2kcal/kg to daily energy requirements. This also does not take into account other

TABLE 6. **Mean Kcal and Nutrient Intakes (Without Supplements) in Female Athletes: A Comparison of Studies**

sport	N	kcal	carbo-hydrate (%)	fat (%)	protein (%)	Vitamin C (mg)	CA (mg)	FE (mg)
Tennis[a]	40	2026	51	31	17	208	948	17
Volleyball[b]	7	1812	53	34	13	156	711	12
Basketball[c]	10	1730	52	32	16	55	903	10
Gymnastics[d]	5	2298	42	42	16	37	506	27
Tennis[e]	4	1664	49	33	17	144	544	11
Running[f]	56	1868	53	32	16	115	797	14
Cycling[g]	8	1781	60	26	14	80	719	11
Swimming[h]	14	2296	56	32	12	138	808	15

[a] This study
[b] Short et al (1)
[c] Nowak et al (8)
[d] Chen et al (80)
[e] Nutter et al (82)
[f] Nieman et al (84)
[g] Keith et al (86)
[h] Barr et al (87)

cross-training exercise such as drills, running, biking, weight-lifing or other sports in which they may participate. Because the subjects are professional tennis players they lead a hectic lifestyle which requires additional caloric demands. Caloric requirement for the professional women tennis players will depend on: (1) determining the optimal body weight by a) anthropometric measures (height, weight, bone and body diameters, girth or circumferences and skinfold thicknessess), b) personal weight goal, c) desirable weight prediction (height based, % body fat), and d) identification of optimal targets for age and specific competitive goals (weight, % body fat); (2) kcal expenditure by estimating a) basal metabolism, b) average daily activity kcals, and c) differences in training and competition; and (3) weight history by analyzing a) weight fluctuations, b) cause of weight fluctuations, and c) pathogenic weight behaviors.

The low caloric intakes for some of the professional women tennis players may be the result of under reporting of dietary intake. The questionnaire used in this study, had small, medium or large portions with medium serving size as the standard, and a large serving of 1.5 of the standard to estimate daily caloric intake (100). It is possible that they consumed even larger daily servings than 1.5 which could not be recorded. The questionnaire compared favorably to multiple

food records when analyzing diets of the average population (99). When analyzing the diets of athletes, food records may be more applicable because of increased intakes of certain foods such as carbohydrate and protein. Because of time restraints with subjects in this study, a questionaire was the most practical dietary analysis instrument to use. The women were also from diverse cultural backgrounds which could result in food choices that were not on the questionnaire.

Tennis is a anaerobic and aerobic intermittent sport, and depending upon the intensity and duration of the matches, both muscle glycogen and fatty acids can be used for energy. The mean percentage of kcal from carbohydrate for professional women tennis players was lower than the recommendation of approximately 60% total caloric intake for athletes (31). The studies for female volleyball players, basketball players, marathon runners, and swimmers showed higher mean percentages of kcal from carbohydrates than this study at 50% of kcal (1, 8, 84, 87). However, the intakes ranging from 51 to 56% were lower than the general recommendation (31,32). In the study by Keith et al (86) the women cyclists had a mean of 60% of kcal from carbohydrate, which met the recommendation for endurance athletes of 60 to 70% (32). Female athletes consuming low and moderate carbohydrate diets have been reported to have reduced performance in comparison with

athletes who had a higher carbohydrate diet (3).

Professional tennis tournaments can be very demanding when singles and doubles matches have to be played on the same day. There may be limited time between matches to eat meals and athletes should eat two to three hours before exercise (33). Depending upon the intensity and duration of the tennis matches, small, more frequent meals may be warranted. To cover carbohydrate requirements, 1 g/kg can be consumed one hour before competition (33) and if precompetition nausea or delayed gastric emptying is a problem, liquid meals of glucose polymers can be selected.

Forty-five percent of kcal from carbohydrate should be complex carbohydrates and the remainder from simple carbohydrates (24). Food sources for complex carbohydrates are fruits and vegetables (apples, corn, potatoes, peas, dried beans), whole grain breads cereals, pasta, rice, and pancakes.

The mean percentage of kcal from protein for both the professionals in this study and the collegiate women tennis players was 17%, as shown in Table 6, which was slightly above the recommendation of 12 to 15% (5). The mean range for the other female athletes was from 12% for swimmers in the research by Barr (87) to 16% for runners in the study of Nieman et al (84) and basketball players investigated by Nowak et al (8). Food sources for protein are meat, poultry, fish,

dairy products, and cereal, rice, legumes, and seeds combined with or without dairy products (48).

According to the Dietary Guidelines for Healthy Americans, developed by the American Heart Association (7), kcal from fat should comprise 20 to 30% of total kcal. Table 6 reveals that the professional women tennis players' mean percentage of kcal from fat was 31%, or slightly above the recommendation. Women cyclists in the study by Keith et al (86) had the lowest mean percentage of 26%, and the remaining women athletes had fat intakes ranging from 32 to 34% of kcal. Food sources for a low fat diet are fish, chicken without the skin, shellfish, lean cuts of redmeat, lowfat dairy products, egg whites, unsaturated vegetable oils (corn, olive, canola), low fat baked goods.

As seen in Table 6, women basketball players in the Nowak et al study (8) had the lowest mean intake of vitamin C at 55 mg/day. The RDA for vitamin C is 60 mg. The professional women tennis players in this study had the highest mean intake of 208 mg. The low intake of the women basketball players was due to limited consumption of fruits and vegetables whereas the professional women tennis players had a high consumption of these food groups. The remaining women athletes had a mean intake in the range of 80 to 156 mg. Food sources for vitamin C are dark leafy green vegetables, broccoli, citrus fruit

(oranges, grapefruit), strawberries, melons.

The RDA for calcium is 800 mg, but only three of the six groups met this recommendation as shown in Table 6. The professional women tennis players in this study had the highest mean intake of 948 mg due to the large intake of dairy products consisting of low fat milk and yogurt. Three groups were below the recommendation which may be due to their lower caloric intake. Food sources for calcium are lowfat dairy products, broccoli, dark leafy vegetables, salmon.

The professional women tennis players and swimmers in the research by Barr (87) met the RDA for iron which is 15 mg. The women cyclists in the study of Keith et al (86) had a low mean intake of 11 mg which could be due to a low intake of meat and legumes. The lowest mean intake was 10 mg by women basketball players investigated by Nowak et al (8) due to their low caloric intake as well as their pattern of food choices. Food sources for iron are lean meats, legumes, whole grains, enriched cereal, nuts.

Kcal, protein and carbohydrate by g/kg were also compared between studies in Table 7. The caloric intake for the women basketball players in the study by Nowak et al (8) was the lowest at 24.1 kcal/kg and the gymnasts investigated by Chen et al (80) had the highest caloric intake at 52.0

TABLE 7. Mean Kcal, Protein and Carbohydrate Intakes by g/kg: A Comparison of Studies

sport	N	Energy kcal/kg	Protein g/kg	Carbohydrate g/kg
Tennis [a]	40	33.4	1.2	4.2
Basketball [b]	10	24.1	.9	3.2
Gymnastics [c]	5	51.0	2.1	5.4
Tennis [d]	4	31.0	1.2	3.8
Running [e]	56	33.6	1.3	4.4
Cycling [f]	8	29.9	1.1	4.4
Swimming [g]	14	36.4	1.2	5.1

[a] This study
[b] Short et al (1)
[c] Nowak et al (8)
[d] Chen et al (80)
[e] Nutter et al (82)
[f] Nieman et al (84)
[g] Keith et al (86)

kcal/kg. Protein intakes were at or above the recommendation of 1.0 to 2.0 g/kg depending upon the sport (5). The carbohydrate intakes were lower than the recommendation of 6.0 to 10 g/kg for all of the groups.

To improve performance and to compensate for less than optimal diets, many athletes, as shown in Table 8, use supplementation in their daily diets. Supplements were used by over 50% of the athletes in the studies cited. The basketball players in the study of Nowak et al (8) had the lowest percentage of users at 50% and the triathletes in the research by Khoo et al (83) had the highest at 80%. Seventy-five percent of the professional women tennis players in this study use supplements. Mean daily intakes of vitamins and minerals exceeded the RDA, but the recommendation for supplements should be done on a individual basis. Because professional women tennis players travel extensively all over the world, a multivitamin may be warranted because of widely varying vitamin and minerals dietary intakes day to day or week to week.

TABLE 8. Supplement Intake: A Comparison of Studies

reference	sport	N	% using supplements
This study	Tennis	40	75%
Nowak et al (8)	Basketball	10	50%
Khoo et al (83)	Triathlon	10	80%
Nieman et al (84)	Running	54	70%
Deuster et al (85)	Running	51	53%

CONCLUSION AND SUMMARY

This study was conducted to investigate the dietary practices of professional women tennis players to determine the quality and quantity of their general diets and to compare their dietary intake with other women athletes who do not travel as extensively to compete in their respective sport. The study was conducted with 40 professional women tennis players from various countries with a wide cultural background. The nutrition section of The Health Habits and History Questionnaire (100) was used to collect the data.

The analysis of the questionnaire indicated that the mean caloric intake was 2026 kcal. The mean percentage of kcal from carbohydrates, protein and fat was 50.6%, 17.1%, and 31.3%, respectively. The mean percentage of carbohydrate was lower than the recommendation for endurance athletes (2); the fat intake was higher; and the mean intake per g/kg of protein was in the recommended range (5). The mean intake of vitamin and minerals was over 100% of the RDA, but some of the individual intakes were below the RDA. Thirty of the subjects took one or more vitamin and mineral supplements daily. The use of supplements resulted in 200% or higher of the RDA in daily intakes of vitamin A, vitamin C, vitamin E, thiamin, iron and calcium.

The comparison of the professional women tennis players with other women athletes revealed all were in the recommended range of 1600 to 2400 kcals for nonathletic women. The mean percentage of kcal from carbohydrates was lower than the recommendation (2) in 80% of the groups. The mean percentage of total kcal from protein ranged from 12 to 16%. Eighty percent of the groups had mean percentage of kcal from fat that were above the recommendation (7). Sixty percent of the groups had levels of vitamin C in amounts greater than the RDA; 40% had levels of calcium in amounts above the RDA; and only 10% percent met the RDA for iron.

The nutrient deficiencies found in the professional women tennis players diets could have been due to under reporting of food intake and cultural differences in food habits not on the questionnaire. Some of the women noted they took supplements at different times of the year depending upon their tournament schedule.

Although this study used a questionnaire to collect data, the results were comparable to the other studies referenced where diet recalls and food records were used.

In summary, the results from this study show that the diets of professional women tennis players compared to that of other women athletes of various sports found in the Literature.

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APPENDIX A

HEALTH HABITS AND HISTORY QUESTIONNAIRE

	OFFICE USE
1. How old are you? _____ years	18 _ _
2. How tall are you? _____ feet _____ inches Weight?_____	43_ _ _ _ _ _
3. During the past year, have you taken any vitamins or minerals? 1. ___no, 2.___yes, fairly regularly 3. ___Yes, but not regularly	43 _
IF YES:	

What do you take fairly regularly? NUMBER of PILLS per DAY, WEEK, etc.

MULTIPLE VITAMINS:			OFFICE USE
One-a-day type	____ pills per _____		44 _ _ _
Stress-tabs type	____ pills per _____		47 _ _ _
Therapeutic, Theragran type	____ pills per _____		50 _ _ _
OTHER VITAMINS:		Milligrams or IUs per pill?	
Vitamin A	____ pills per _____	_____IU per pill	53 _ _ _ _
Vitamin C	____ pills per _____	_____mg per pill	57 _ _ _ _
Vitamin E	____ pills per _____	_____IU per pill	61 _ _ _ _
Calcium or dolomite	____ pills per _____	_____mg per pill	65 _ _ _ _

OTHER (What?) 1 __Yeast 2__Selenium 3__Zinc 4__Iron
5 __Beta-carotene 6__Cod liver oil 7__Other _____ 69 _

Please list the brand of multiple vitamin/mineral you usually take:
_____

FOR OFFICE USE
Q10, mg or IU: 1=50-100 2=200-250 3=400-500 4=1000 5=5000 6=10,000
7=20,000-25,000 8=50,000 9=Unk

Version 02.1, March, 1987. GEN.ALL.YR.2

OFFICE USE

4. Are you on a special diet?
1 ___ No 2 ___ Weight loss 3 ___ For medical condition 4 ___ Vegetarian 5 ___ Low salt
6 ___ Low cholesterol 7 ___ Weight gain

70 __

5. How often do you eat the following foods from *restaurants* or *fast food places?*

RESTAURANT FOOD	1 Almost every day	2 2-4 times a week	3 Once a week	4 1-3 times a month	5 5-10 times a year	6 1-4 times a year	7 Never, or less than once a year
Fried chicken							
Burgers							
Pizza							
Chinese food							
Mexican food							
Fried fish							
Other foods							

72 __
73 __
74 __
75 __
76 __
77 __
78 __

6. This section is about your *usual* eating habits. Thinking back over the past year, how often do you usually eat the foods listed on the next page?

First, check (✓) whether your usual serving size is small, medium or large. (A small portion is about one-half the medium serving size shown, or less; a large portion is about one-and-a-half times as much, or more.)

Then, put a *NUMBER* in the most appropriate column to indicate *HOW OFTEN*, on the average, you eat the food. You may eat bananas *twice a week* (put a *2 in the "week"* column). If you never eat the food, check "Rarely/Never." Please DO NOT SKIP foods. And please BE CAREFUL which column you put your answer in. It will make a big difference if you say "Hamburger once a day" when you mean "Hamburger once a week"!

Some items say "in season." Indicate how often you eat these just in the 2-3 month time when that food is in season. (Be careful about overestimating here.)

Please look at the *example* below. This person

1) eats a medium serving of cantaloupe once a week, in season.
2) has ½ grapefruit about twice a month.
3) has a small serving of sweet potatoes about 3 times a year.
4) has a large hamburger or cheeseburger or meat loaf about four times a week.
5) never eats winter squash.

C 79 80

EXAMPLE:

	Medium Serving	Your Serving Size			How often?				
		S	M	L	Day	Week	Month	Year	Rarely/ Never
Cantaloupe (in season)	¼ medium		✓			1			
Grapefruit	(½)		✓				2		
Sweet potatoes, yams	½ cup	✓						3	
Hamburger, cheeseburger, meat loaf	1 medium					4			
Winter squash, baked squash	½ cup								✓

PLEASE GO TO NEXT PAGE

FOR OFFICE USE

On the following two pages, code the four characters for each food as follows:

S-1	No.	De-1
M-2	Times	Wk-2
L-3		Mo-3
NS-9	NS-99	Yr-4
		Nev-5
		NS-9

If respondent places a checkmark in the "How often" columns, do not impute "01", once. Instead, code "99", Not Stated. If respondent does not check a portion size, do not impute medium, but code "9".

FRUITS & JUICES	Medium Serving	Your Serving Size S	M	L	How often? Day	Week	Month	Year	Rarely/Never	OFFICE USE
EXAMPLE - Apples, applesauce, pears	(1) or ½ cup		✓			4				
Apples, applesauce, pears	(1) or ½ cup									11 ____
Bananas	1 medium									15 ____
Peaches, apricots (canned, frozen or dried, whole year)	(1) or ½ cup									19 ____
Peaches, apricots, nectarines (fresh, in season)	1 medium									23 ____
Cantaloupe (in season)	¼ medium									27 ____
Watermelon (in season)	1 slice									31 ____
Strawberries (fresh, in season)	½ cup									35 ____
Oranges	1 medium									39 ____
Orange juice or grapefruit juice	6 oz. glass									43 ____
Grapefruit	(½)									47 ____
Tang, Start breakfast drinks	6 oz. glass									51 ____
Other fruit juices, fortified fruit drinks	6 oz. glass									55 ___✓___
Any other fruit, including berries, fruit cocktail	½ cup									59 ____
VEGETABLES		S	M	L	Da	Wk	Mo	Yr	Nv	
String beans, green beans	½ cup									63 ____
Peas	½ cup									67 ____
Chili with beans	¾ cup									71 ____
Other beans such as baked beans, pintos, kidney beans, limas	¾ cup									75 ____ D 79 80
Corn	½ cup									11 ____
Winter squash, baked squash	½ cup									15 ____
Tomatoes, tomato juice	(1) or 6 oz.									19 ____
Red chili sauce, taco sauce, salsa picante	2 Tblsp. sauce									23 ____
Broccoli	½ cup									27 ____
Cauliflower or brussel sprouts	½ cup									31 ____
Spinach (raw)	¾ cup									35 ____
Spinach (cooked)	½ cup									39 ____
Mustard greens, turnip greens, collards	½ cup									43 ____
Cole slaw, cabbage, sauerkraut	½ cup									47 ____
Carrots, or mixed vegetables containing carrots	½ cup									51 ____
Green salad	1 med. bowl									55 ____
Salad dressing, mayonnaise (including on sandwiches)	2 Tblsp.									59 ____
French fries and fried potatoes	¾ cup									63 ____
Sweet potatoes, yams	½ cup									67 ____
Other potatoes, including boiled, baked, potato salad	(1) or ½ cup									71 ____
Rice	¾ cup									75 ____ E 79 80
Any other vegetable, including cooked onions, summer squash	½ cup									11 ____
Butter, margarine or other fat on vegetables, potatoes, etc.	2 pats									15 ____
MEAT, FISH, POULTRY & MIXED DISHES		S	M	L	Da	Wk	Mo	Yr	Nv	
Hamburgers, cheeseburgers, meat loaf	1 medium									19 ____
Beef—steaks, roasts	4 oz.									23 ____
Beef stew or pot pie with carrots, other vegetables	1 cup									27 ____
Liver, including chicken livers	4 oz.									31 ____
Pork, including chops, roasts	2 chops or 4 oz.									35 ____
Fried chicken	2 sm. or 1 lg. piece									39 ____
Chicken or turkey, roasted, stewed or broiled	2 sm. or 1 lg. piece									43 ____
Fried fish or fish sandwich	4 oz. or 1 sand.									47 ____
Tuna fish, tuna salad, tuna casserole	½ cup									51 ____
Shell fish (shrimp, lobster, crab, oysters, etc.)	(5) ¼ cup or 3 oz.									55 ____
Other fish, broiled, baked	4 oz.									59 ____
Spaghetti, lasagna, other pasta with tomato sauce	1 cup									63 ____
Pizza	2 slices									67 ____
Mixed dishes with cheese (such as macaroni and cheese)	1 cup									71 ____

	Medium Serving	Your Serving Size S	M	L	How often? Day	Week	Month	Year	Rarely Never	OFFICE USE
LUNCH ITEMS										
Liverwurst	2 slices									75 ____ F 79 80
Hot dogs	2 dogs									11 ____
Ham, lunch meats	2 slices									15 ____
Vegetable soup, vegetable beef, minestrone, tomato soup	1 med. bowl									19 ____
Other soups	1 med. bowl									23 ____
BREADS / SALTY SNACKS / SPREADS		S	M	L	Da	Wk	Mo	Yr	Nv	
Biscuits, muffins, burger rolls (incl. fast foods)	1 med. piece									27 ____
White bread (including sandwiches), bagels, etc., crackers	2 slices, 3 cracks									31 ____
Dark bread, including whole wheat, rye, pumpernickel	2 slices									35 ____
Corn bread, corn muffins, corn tortillas	1 med. piece									39 ____
Salty snacks (such as chips, popcorn)	2 handfuls									43 ____
Peanuts, peanut butter	2 Tblsp.									47 ____
Butter on bread or rolls	2 pats									51 ____
Margarine on bread or rolls	2 pats									55 ____
Gravies made with meat drippings, or white sauce	2 Tblsp.									59 ____
BREAKFAST FOODS		S	M	L	Da	Wk	Mo	Yr	Nv	
High fiber, bran or granola cereals, shredded wheat	1 med. bowl									63 ____
Highly fortified cereals, such as Product 19, Total, or Most	1 med. bowl									67 ____
Other cold cereals, such as Corn Flakes, Rice Krispies	1 med. bowl									71 ____
Cooked cereals	1 med. bowl									75 ____ G 79 80
Sugar added to cereal	2 teaspn.									11 ____
Eggs (1 egg = small)	2 eggs = medium									15 ____
Bacon	2 slices									19 ____
Sausage	2 patties or links									23 ____
SWEETS		S	M	L	Da	Wk	Mo	Yr	Nv	
Ice cream	1 scoop									27 ____
Doughnuts, cookies, cakes, pastry	1 pc. or 3 cookies									31 ____
Pumpkin pie, sweet potato pie	1 med. slice									35 ____
Other pies	1 med. slice									39 ____
Chocolate candy	small bar, 1 oz.									43 ____
Other candy, jelly, honey, brown sugar	3 pc. or 1 Tblsp.									47 ____
DAIRY PRODUCTS		S	M	L	Da	Wk	Mo	Yr	Nv	
Cottage cheese	½ cup									51 ____
Other cheeses and cheese spreads	2 slices or 2 oz.									55 ____
Flavored yogurt	1 cup									59 ____
Whole milk and bevs. with whole milk (not incl. on cereal)	8 oz. glass									63 ____
2% milk and bevs. with 2% milk (not incl. on cereal)	8 oz. glass									67 ____
Skim milk, 1% milk or buttermilk (not incl. on cereal)	8 oz. glass									71 ____
BEVERAGES		S	M	L	Da	Wk	Mo	Yr	Nv	
Regular soft drinks	12 oz. can or bottle									75 ____ H 79 80
Diet soft drinks	12 oz. can or bottle									11 ____
Beer	12 oz. can or bottle									15 ____
Wine	1 med. glass									19 ____
Liquor	1 shot									23 ____
Decaffeinated coffee	1 med. cup									27 ____
Coffee, not decaffeinated	1 med. cup									31 ____
Tea (hot or iced)	1 med. cup									35 ____
Lemon in tea	1 teaspn.									39 ____
Non-dairy creamer in coffee or tea	1 Tblsp.									43 ____
Milk in coffee or tea	1 Tblsp.									47 ____
Cream (real) or Half-and-Half in coffee or tea	1 Tblsp.									51 ____
Sugar in coffee or tea	2 teaspn.									55 ____
Artificial sweetener in coffee or tea	1 packet									59 ____
Glasses of water, not counting in coffee or tea	8 oz. glass									63 ____

67 0 2 2 0 6 9 . . . I 79 80

7. Are there any foods not mentioned which you ate at least once a week, even in small quanities. Please take a look at the list of following foods and write in any applicable ones:

FOOD:	Your Serving Size S	M	L	How Often? Day	Wk	OFFICE USE CODE	AMOUNTS
						11	_ _ _ _ _ _
						17	_ _ _ _ _ _
						23	_ _ _ _ _ _
						29	_ _ _ _ _ _
						35	_ _ _ _ _ _
						41	_ _ _ _ _ _

Veal, lamb	01	Onions	41
Tofu	03	Summer squash	42
Mixed dish w/meat	04	Asparagus	43
Mixed dish w/chicken	05	Sweet green peppers	44
Chinese dishes	06	Sweet red peppers	45
Mexican dishes	07	Bean sprouts	46
Seafood Creole	08	Avocado, guacamole	47
Refried beans or bean burritos	09	Beets	48
Polish/Italian Sausage	10	Pineapple or pineapple juice	61
Cream soups	11	Prunes or prune juice	62
Noodles	12	HI-C	63
Pancakes, waffles	21	Cranberry juice cocktail	64
Instant breakfast, metrecal	22	Grapes	65
Pudding	23	Mangoes	66
Milkshake	24	Papayas	67
Other dairy products	25	Honeydew or cassaba melon	68
Other dessert, sweet	26	Lemons or lemon juice	69
Sour cream, dips	31	Nuts and seeds	70
Diet salad dressing	32	Bran _	71
Catsup	33	Other vegetable/fruit	79
Green chilies, jalapenos	34	Other not mentioned here	88

	Seldom/Never	Sometimes	Often/Always		
8. How often do you eat the skin on Chicken?	_____	_____	_____	47	_
How often do you eat the fat on meat?	_____	_____	_____	48	_
How often do you add salt to your food?	_____	_____	_____	49	_
How often do you add pepper to your food?	_____	_____	_____	50	_

	OFFICE USE Code	Amounts
9. How often do you use fat or oil in cooking? For example, in frying eggs, meat or vegetables _____times per _____ day week month	51	_ _ _
10. What do you usually cook with? 1___Don't know or don't cook. 2___Soft margarine. 3___Stick margarine. 4___Butter. 5___Oil. 6___Lard, fat-back, bacon fat. 7___Pam or no oil.	54	_ _
11. What kind of fat do you usually add to vegetables, potatoes, etc? 1___Don't add fat. 2___Soft margarine. 3___Stick margarine. 4___Butter. 5___Half butter, half margarine. 6___Lard, fatback, bacon fat.	56	_ _
12. If you eat cold cereal, what kind do you most often?_____	58	_ _ _
13. Not counting salad or potatoes, about how many vegetables do you eat per day or per week. _____ per _____ Vegetables day, week	61	_ _ _
14. Not counting juices, how many fruits do you usually eat per day or per week? _____ per _____ Fruits day, week	64	_ _ _

THANK YOU VERY MUCH for taking the time to fill out this information. The answers you have given will be critical in completing this study to analyze the dietary habits of the woman athlete and can be of great value in determining the proper dietary guidelines for greater athletic performance. Your participation is sincerely appreciated.

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VITA

Laura Hinshaw was born in Fort Wayne, Indiana on September 11, 1958. In May, 1981, she received a Bachelor of Science Degree in Administrative Dietetics from Purdue University, and in March 1994, she received a Masters of Science Degree in Human Nutrition and Foods from Virginia Tech. Her employment experience has been in institutional food service, the organization of a restaurant and as a nutrition consultant. She has participated in nutrition seminars and has given sports nutrition lectures to professional and amateur athletes. Career goals for the future are in nutrition education, research and sports nutrition.

Laura Hinshaw