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Body composition, dietary intake, and iron status of female collegiate swimmers

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Body composition, dietary intake, and iron status of female collegiate swimmers

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Signatures have been redacted for privacy

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LIST OF ABBREVIATIONS

BMI	Body Mass Index
CT	Computed Tomography
DXA	Dual Energy X-ray Absorpitometry
ELISA	Enzyme-Linked Immunosorbent Assay
Hb	Hemoglobin
Hct	Hematocrit
ISU	Iowa State University
LBM	Lean Body Mass
MCV	Mean Corpuscular Volume
MRI	Magnetic Resonance Imaging
RBC	Red Blood Cell
RDA	Recommended Daily Allowance
TfR	Transferrin Receptor
TIBC	Total Iron Binding Capacity
WHR	Waist to Hip Ratio

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ABSTRACT

The purpose of this study was to determine the effect of training on body composition, dietary intake, and iron status of female collegiate swimmers and whether nutrition attitudes are correlated to dietary choices.

Measurements were obtained on 24 eumenorrheic Iowa State University female collegiate swimmers (swimmers, n=18; divers, n=6) at preseason, before competition, and after 16-weeks of training. Training consisted of 3 days/week on dryland (resistance, strength, flexibility; 1.5 hours/day) and 6 days/week in-water (7,000-11,000 yards/day; nine, 2 hour sessions/week). Body composition was assessed using dual-energy x-ray absorptiometry (DXA). Changes were documented in body composition, regional fat and lean tissue distribution, dietary intake, and iron status using paired t-tests. We also examined the relationship between dietary changes and nutrition attitudes using correlation analyses.

There were decreases in BMI ($P=0.05$), waist circumference ($P\leq 0.0001$), hip circumference ($P\leq 0.0001$), whole body fat weight ($P=0.0002$), and percentage body fat ($P\leq 0.0001$); lean weight ($P=0.028$) increased. We found no significant change in regional lean distribution, but documented a decrease in fat at the waist ($P=0.0002$), hip ($P=0.0002$), and thigh ($P=0.002$). Energy intake at preseason averaged 2403 ± 864 $kcal \cdot day^{-1}$ with macronutrient composition of 62% carbohydrate, 13% protein, and 24% fat; no changes were noted from preseason to late season. Dietary fiber ($P=0.036$), iron ($P=0.015$), vitamin C ($P=0.029$), vitamin B_6 ($P=0.032$), and fruit exchanges ($P=0.003$) increased. A higher nutrition attitude score was correlated with a higher intake of calcium ($P=0.02$), milk exchanges ($P=0.04$), and fruit exchanges ($P=0.019$). We documented an increase in hemoglobin (Hb) ($P=0.046$) and hematocrit (Hct) ($P=0.014$) and a decrease in serum transferrin receptor ($P\leq 0.0001$).

In summary, after 16-weeks of training, female collegiate swimmers decreased overall body fat and increased lean weight. Dietary quality improved with an increase in dietary fiber, iron, vitamin C, vitamin B_6, and fruit exchanges, as well as a decrease in fat exchanges. A more positive nutrition attitude score was correlated with higher intakes of calcium, milk, and fruit. Iron status improved with an increase in Hb, Hct, and a decrease in serum TfR. Additional studies to evaluate body composition and iron status in relation to dietary intake in female collegiate swimmers are warranted.

CHAPTER 1. GENERAL INTRODUCTION

Thesis Organization

This thesis consists of a general introduction including objective, hypotheses, specific aims, limitations, and significance. The second chapter is a review of the literature relevant to physical training in swimmers and divers, body composition, dietary intake, and iron status. The third chapter is a manuscript entitled "Body composition, dietary intake, and iron status in female collegiate swimmers". The final chapter is a general conclusion. It is followed by references cited in the review of literature and appendices.

Objective, Hypotheses, Specific Aims, Significance, and Limitations

Objective The purpose of this study is to determine the effects of physical training and nutrition education/counseling on body composition, dietary intake, and iron status.

Hypothesis 1 Physical training for 16 weeks (preseason to late season) in female collegiate swimmers will decrease body fat, increase energy intake, and decrease iron stores.

Specific Aim 1 To determine the effect of training on female swimmers with respect to body composition, dietary intake, and iron status by assessing:

a. total body composition (lean mass, fat mass), regional fat distribution, and regional lean distribution;
b. carbohydrate, protein, fat, dietary fiber, and alcohol intake; and
c. hemoglobin, hematocrit, serum ferritin and transferrin receptor.

Hypothesis 2 Nutrition education/counseling will improve the nutrient intake and significantly correlate with behavior and attitude scores of female collegiate swimmers during a 16-week training period.

Specific Aim 2 To assess the effect of group nutrition education and individual counseling on dietary intake of female swimmers and the relationship of intake with behavior and attitude by assessing:

a. micronutrient (calcium, magnesium, potassium, iron, zinc, copper, vitamin E, vitamin C, and vitamin B_6), caffeine, and food group intake; and
b. the correlation of behavior and attitude inventory scores at postseason with nutrient intake

Significance and Limitations of Proposed Study

Numerous studies have shown that body composition, dietary intake, and iron status play a role in physical performance. The majority of studies on body composition focus on correlating physical performance with whole body composition (Meleski et al., 1985; Meleski et al., 1982; Siders et al., 1991). This study examines whole body composition as well as regional fat and lean distribution. This author is unaware of other studies examining competitive female swimmers' regional fat and lean distribution.

It is well known that nutrition plays a key role in attaining peak physical performance. Several researchers have examined the diets of swimmers (Sharp, 2000; Grandjean, 1986). Two previous studies have also shown that Iowa State University female students had sufficient energy intakes (Eller, 1995) but their intakes of dairy products, fruits, and vegetables were lower than recommended based on the Food Guide Pyramid (Eller, 1995; Kundrant, 1993). Hence, there is good rationale to provide nutrition intervention to help improve food choices and nutrition attitudes in these female collegiate swimmers.

Another important predictor of performance in athletes is iron status. Lukaski et al. (1996) showed that serum ferritin is reduced in female swimmers. Other researchers (Brigham el al., 1993; Selby et al. 1986) have shown compromised iron status in collegiate swimmers. Brigham et al. (1993) prevented a decline in iron status during swimmers' competitive season with iron supplementation (39 mg/day), in addition to mean dietary intakes of 16.3 mg/day.

There are several inherent limitations in the study design and methodology. The athletes in this study were all training, with no age-matched, non-training group used as a control. An age-matched, training group not taking supplements was also not used as a control. It is often difficult to find appropriate controls for athletes in training. However, we have used the literature as a basis of comparison. The sample size of this competitive group of female collegiate swimmers and divers was also small. A larger number would have provided greater statistical power to detect small changes. Another limitation was in regards to supplement use, as we used self-reporting to check compliance. This makes it difficult to distinguish between whether supplement use or dietary intake was the root cause of any changes we observed. Lohman (1996) determined that dual energy x-ray absorptiometry (DXA) is limited by its inability to differentiate between subcutaneous adipose tissue (SAT) and visceral adipose tissue (VAT). The gold standard method for assessing regional fat distribution is computed tomography (CT). The use of DXA for regional analysis is a novel technique that has not been validated by CT. Also, skeletal landmarks defining waist, hip, and thigh regions have not yet been firmly established. Nonetheless, DXA was employed in this study, since it is rapid and safe (minimal radiation), as well as provided a highly reproducible measure of fat and lean mass. Another limitation is that the questions from our nutrition attitudes scale were adapted from Shannon and Pelican (1984), and we did not have a large enough sample size to estimate reliability on the adapted scale.

CHAPTER 2. REVIEW OF LITERATURE

Physical Training in Swimmers and Divers

Swimmers commonly train twice per day in the pool, covering up to 16,000 m per day, 6 days per week. Training is often done at submaximal speeds to develop aerobic adaptations and swimming mechanics. It is mixed with supramaximal interval training to develop speed and physiologic capacities specific to the race distance in which the swimmer competes (Sharp, 2000).

Effects on Body Composition

Regular training generally results in a decrease in body fat and an increase in lean body mass (LBM), quite often without a change in body weight (Parizkova, 1977). Many studies have been conducted to test whether or not these results occur in swimmers. Katch et al. (1969) found no significant changes in body composition of female collegiate swimmers over 16 weeks of training. Johnson et al. (1989) also found no changes in body composition of female collegiate swimmers over 25 weeks of training. Ballor (1996) indicated that changes in body composition through physical training only manifest themselves over extended periods of time.

In contrast, several other studies have shown a decrease in body fat and an increase in LBM in female swimmers with training (Barr et al. 1991; Lukaski et al. 1990; Meleski et al. 1985; Siders et al. 1991; Wade, 1976). Despite these decreases in body fat, body fat percentages of female swimmers average 15-22% (Sharp, 2000). This is 4-6% higher than age- and ability-matched endurance runners (Novak et al. 1977; Thorland et al. 1983). Sharp (2000) reviewed some of the possible explanations for the higher body fat percentages in swimmers than runners. One is an increase in postexercise appetite among swimmers, whereas Haari and Kuusela (1986) reported a somewhat anorexic effect directly after exercise in runners. In contrast, swimmers typically experience appetite stimulation after exercise, although this theory has not been documented in the literature. Sharp (2000) suggested another possible explanation, that fuel utilization is less in swimmers than other athletes. In contrast, Flynn et al. (1990) reported that the respiratory exchange ratio was increased, indicating that fat oxidation is greater after swimming than running. More research is needed to determine whether this difference in body fat between swimmers and runners can be attributed to differences in appetite, energy expenditure, fat oxidation, or other factors.

When examining regional fat distribution using skinfold thicknesses, swimmers have lower body fat and greater LBM in the upper extremities (arms and trunk) as compared to lower extremities (legs) (Avlonitiou et al. 1997). Meleski et al. (1982) also showed that female swimmers have lower tricep and subscapular skinfold thicknesses compared with United States reference data on females. These results illustrate that regional fat and lean distribution are modified according to the training regimen and athletic sport.

Effects on Dietary Intake

Energy: The previously described intensive training for competitive swimmers has a significant impact on the demand for energy. Many studies have examined the relationship between energy demand and energy intake. Trappe et al. (1997) measured the total energy expenditure of five highly trained elite female swimmers to be 23.4 ± 2.1 MJ·day^{-1} (5593 ± 495 kcal·day^{-1}). Energy intake estimated from the two day diet records averaged 13.1 ± 1.0 MJ·day^{-1} (3136 ± 227 kcal·day^{-1}). This resulted in an energy imbalance of -43 ±2%. The macronutrient intake profile was 68% carbohydrate, 21% fat, and 11% protein.
Sharp (2000) reviewed several studies examining the energy demands of swimming training and energy intake. One study by Van Handel et al. (1984) used diet records to examine the energy intakes of 14 female competitive swimmers. The females' energy intakes averaged 9.6 MJ·day^{-1} (2300 kcal·day^{-1}), with a range between 6.3 and 13.8 MJ·day^{-1} (1500-3300 kcal·day^{-1}). The women reported 53% of energy from carbohydrate and 30% of energy from fat. Sharp (2000) also described a study by Berning et al. (1991) who reported energy intakes of adolescent developmental level swimmers attending a training camp. The females average energy intake was 15.0 MJ·day^{-1} (3580 kcal·day^{-1}). The authors observed that the distribution of energy among micronutrients was not different from the general population, prompting them to conclude that these swimmers consumed too much fat and inadequate carbohydrate.

From the studies reviewed by Sharp (2000), female competitive swimmers ranging in age from 16-23 years typically consume about 10.9 MJ·day^{-1} (2600 kcal·day^{-1}). When compared to the energy requirement proposed by Sherman and Maglischo (1992), female swimmers maintain a negative energy balance [10.9 MJ·day^{-1} (2600 kcal·day^{-1}) average intake versus 14.2-16.8 MJ·day^{-1} (3400-4000 kcal·day^{-1}) estimated energy requirement]. Some explanations for this high negative energy balance may include either underreporting or underconsumption of food intake by the subjects. The energy demands of swimming are high and sufficient energy may be difficult to obtain on reporting days. Underreporting of food intake is common among female athletes (Trappe et al., 1997), perhaps providing some explanation for our reported low energy intake.

The American Dietetic Association position paper on nutrition and athletic performance (2000) recommends that during times of high-intensity training, adequate energy needs to be consumed to maintain body weight, maximize training effects, and maintain health. Low-energy intakes can result in loss of muscle mass, menstrual dysfunction, loss or failure to gain bone density, and increased risk of fatigue, injury, and illness.

Carbohydrate: Carbohydrate intake is important to maintain the concentration of blood glucose during exercise and to replace muscle glycogen. Recommendations for athletes range from 6 to 10 g/kg body weight per day (American Dietetic Association 2000) or between 500 and 800 grams/day (Maglischo, 1993). It would require consuming a diet providing 16.8 $MJ \cdot day^{-1}$ (4300 $kcal \cdot day^{-1}$) with 50% of the energy from carbohydrate to consume 500 g/day. Hickson (1993) reviewed the numerous factors interrelated with carbohydrate utilization and exercise including exercise duration, exercise intensity, training state, initial glycogen stores, participation of specific muscle groups, and circulating substrate and hormonal concentrations. Chronic glycogen depletion from high intensity training and inadequate carbohydrate ingestion can result in poor performance.

Sharp (2000) reviewed a study by Costill et al. (1988b) examining muscle glycogen stores of male collegiate swimmers before and after swimming 2743 or 5486 m. The results show a large loss of muscle glycogen during a single training session. Furthermore, glycogen repletion was only 52% complete after an 8-hour recovery and ingestion of 112 g of carbohydrate. Sharp concluded that when one considers that many swimmers perform this kind of training on a daily basis, and in many instances twice per day, the probability of chronic glycogen depletion is great, especially considering the incomplete glycogen repletion in the 8-hour recovery period.

Sharp (2000) also examined a number of studies that have shown improved endurance performance when carbohydrate was ingested at frequent intervals during exercise. Carbohydrate ingestion during activity may improve blood glucose maintenance during exercise and/or spare muscle glycogen for later in the performance when carbohydrate stores tend to become depleted. From the studies reviewed by Sharp (2000), carbohydrate ingestion during exercise was not effective in improving average performance late in swimming practice. However, some individuals benefited who had a drop in blood glucose concentration during training. Another area of interest is the timing of carbohydrate ingestion after training. Ivy et al. (1988) showed that muscle glycogen resynthesis is accelerated when carbohydrate is ingested 1-2 hours after the exercise is stopped.

Protein: An increase in protein catabolism occurs during exercise, particularly in the face of glycogen depletion (Lemon and Mullin, 1980). As discussed previously, competitive swimmers are often glycogen depleted. This may result in increased protein catabolism requiring compensation with extra dietary protein. In addition, the relatively low energy intake that has been reported in swimmers may also trigger an increase in protein catabolism (Sharp, 2000). The American Dietetic Association (2000) reports increased protein requirements in highly active people. The protein recommendation for endurance athletes is 1.2 – 1.4 g/kg body weight per day, whereas those for resistance and strength-trained athletes may be as high as 1.6 – 1.7 g/kg body weight per day. Sharp (2000) reported needs at 1.5 g/kg for endurance and 2-3 g/kg for resistance training. Competitive swimming involves both endurance and resistance exercise; protein needs thus lie somewhere between 1.5-2 g/kg/day (Sharp 2000). Van Erp-Baart et al. (1989) reported that the typical young adult female competitive swimmer in the Netherlands consumes approximately 50-60 grams protein per day, translating into 0.9-1.2 g/kg/day.

Fat: As reported above, the energy derived from fat in the athletes' diet has not been reported to be different than that of the general population. The American Dietetic Association (2000) reported that fat intake should not be restricted, because there is no performance benefit in consuming a diet with less than 15% of energy from fat, compared with 20% to 25% of energy from fat. Fat is important in the diets of athletes as it provides energy, fat-soluble vitamins, essential fatty acids, and satiety.

Effects on Iron Status

Whereas the biological importance of iron is well established, there is a paucity of information about the influence of physical training on iron status (Lukaski et al., 1990). Iron deficiency is common in the United States, and those who exercise may be at particular risk for low iron stores and anemia. Several causes of exercise-induced iron deficiency have been identified. They include increased fecal and urinary iron losses, considerable iron loss in sweat, intravascular hemolysis, decreased absorption of dietary iron, and low dietary iron intake (Brigham et al., 1993).

Let us examine first the dietary iron intake of female athletes and swimmers. Nutritional analysis of female distance runners revealed an average intake of 12.5 mg

(Clement et al., 1984), which is below the recommended daily allowance (RDA) of 18 mg. The average western diet supplies 5 – 7 mg of iron per 1000 kcal. Thus, intakes below 2000 kcal are often associated with low dietary iron intakes (Newhouse et al., 1988). Of 25 female collegiate swimmers, mean iron intake was 16.3 ± 6.3 mg/day: reported daily intakes ranged from 6 – 41 mg. Fifteen of the 25 subjects had iron intakes ≥ 15 mg/day. Only one subject consumed <10 mg/day (Brigham et al., 1993). Lukaski et al. (1990) reported the mean dietary iron intake for 16 female collegiate swimmers to be 13.8 ± 1.3 mg/day preseason and 14.2 ± 1.3 mg/day postseason. Although it is reported above that swimmers are consuming on average greater than 2000 kcal/day, these studies show that dietary iron intake of female athletes may fall below the RDA.

Various results have been found when examining the effects of physical training on iron status. The literature suggests that women engaged in intensive physical training may be susceptible to iron deficiency anemia. Wirth et al. (1978) found no significant change in serum iron or hemoglobin (Hb) concentration of 17 college-age women after ten weeks of physical training. When the authors compared their results to those of Bottiger et al. (1971) and Kilbom et al. (1971b), they determined that there is an iron cost of physical training. However, serum iron concentration will decrease only if the iron cost exceeds iron stores.

Lukaski et al. (1990) compared 16 female collegiate swimmers at preseason and postseason with an age-matched control group. This study saw no significant changes in hematocrit (Hct) or Hb among athletes during training or in controls. However, the swimmers had slightly lower concentrations of Hct and Hb, but still within the normal range. Serum ferritin concentrations among the female swimmers declined slightly after training but were not indicative of iron deficiency. Total iron binding capacity (TIBC) declined significantly in the swimmers and control groups, indicating a slight reduction in iron transport. The authors concluded that the observed changes reflected minor fluctuations associated with time and activity, since the measurements of iron status were within the normal range. Their findings indicated that intensive swimming training did not result in a decrease in iron status when dietary iron intake was $\geq 67\%$ of the RDA.

Newhouse and Clement (1988) reviewed 21 studies involving 3730 subjects (primarily runners). Only one of the studies did not show a high incidence of low Hb concentration. There was also a consistent incidence of lower than normal serum ferritin. These findings tend to be exacerbated by repeated seasons of training.

Cook (1994) reported a moderate decrease in body iron reserves in the early weeks of intense aerobic training. This is best explained by a mobilization of storage iron required for an expanding red blood cell (RBC) and muscle mass. Overt iron deficiency in the highly conditioned athlete is unusual, although some reduction in storage iron is a common finding.

The other area worth mentioning is the effect of iron supplementation during physical training on iron status. Brigham et al. (1993) examined the effect of iron supplementation on iron status in 25 female collegiate swimmers throughout a competitive season. At preseason, 17 of the swimmers had serum ferritin stores <12 μg/day, while 5 swimmers had Hb <12 g/dl. The swimmers were then split into a control group and an experimental group that received 39 mg per day of elemental iron as a supplement. The experimental group had 24% of subjects with an increase in Hb concentration and 68% of the subjects with an increase in ferritin concentration. The control group had a decrease in Hb despite a diet containing 16.3 mg per day of dietary iron. The authors concluded that iron supplements may be necessary for athletes at-risk for iron deficiency.

Body Composition: Overall, Regional Fat and Lean Distribution

Definitions

Overall body composition contains the major compartments of fat free mass, fat mass, total body water, bone mineral content, and fluid (Van Loan, 1996). Age, gender, ethnicity, and exercise affect these body compartments. Fat free mass, formerly referred to in this thesis as lean body mass, is all of the body's nonfat tissues. This includes the fat free portion of bone, muscle, organs, and connective tissue. The fat mass is often referred to in terms of percentage of total body mass that is composed of fat (percentage body fat). Overall body composition is a useful tool for the athlete, particularly the female athlete for two reasons. One is that the female athlete may be at-risk of being underweight. Sinning (1996) describes how body composition can be used to set a minimum weight for the individual athlete that is based on fat free mass. The second reason body composition is useful for the athlete is to determine if one is overfat. An athlete may be overweight by common height and weight tables in the sense that they have higher than average muscle mass. Being overweight in this sense does not necessarily deter from performance, as being overfat has been shown to impair performance. The female athlete is at particular risk for eating disorders and over-training. Evaluating body composition and body weight should be the first step in the nutritional counseling of the female athlete (Sinning, 1996).

Regional body composition is defined as the variation in anatomical distribution of major components of the body mass (Malina, 1996). Two terms are often heard in relation to regional body composition. "Distribution" refers to the absolute or relative amount of a tissue in different regions or compartments of the body. "Patterning" is used to characterize a specific pattern of tissue distribution. For example, a central or truncal pattern is described as a greater accumulation of subcutaneous adipose tissue on the trunk compared to the extremities. An android pattern is a relatively greater accumulation of adipose tissue over the abdomen compared to the hips. The opposite of android is the gynoid pattern, with more adipose tissue distributed over the hips than the abdomen.

Two types of adipose tissue are described in the literature. Visceral adipose tissue is the internal or deep fat that lies around the visceral organs. Subcutaneous adipose tissue is the external or outer fat located underneath the skin. Numerous studies have examined fat distribution and type of fat in relation to chronic diseases such as non-insulin-dependent diabetes mellitus (Bjorntorp, 1991), cardiovascular disease (Lapidus, 1989), Cushing's syndrome, and colon and breast cancer. This author is not aware of any studies investigating regional body composition and physical performance in swimmers.

Assessment Methods

Anthropometric Measurements

Body circumferences. Circumference or girth measurements may serve as an index of total body fatness and regional fat distribution. Typical sites include the abdomen, right thigh, and right upper arm. Circumference measurements of the waist (abdominal circumference) and hip (gluteal circumference) have been shown to correlate with visceral fat (Groff, 1995). Reproducibility of measurements may be as low as 2% (Groff, 1995; van der Kooy, 1993) with appropriate training and practice. A ratio of waist and hip circumferences was calculated from waist and hip measurements. Ratios greater than 0.8 in women and 0.95 in men indicate a health risk (Groff, 1995). A limitation of the waist-to-hip ratio (WHR) is that it cannot distinguish between subcutaneous adipose tissue and visceral adipose tissue in the abdominal region (Bonora et al., 1995). The WHR has been found to be more valid in women than men in determining regional fat distribution (Mueller et al., 1991).

Skinfold thicknesses. Skinfold thicknesses are the most widely applied of field techniques for measuring body composition (Wilmore and Costill, 1994). The method is portable, inexpensive, and highly reproducible when performed by a trained anthropometrist.

This approach is based upon two assumptions: the thickness of the subcutaneous adipose tissue reflects a constant proportion of the total body fat and the sites selected for measurement represent the average thickness of the subcutaneous adipose tissue (Lukaski, 1987). The skinfold measurement is based on a double fold, which includes two layers of skin and subcutaneous tissue. Five anatomical sites (triceps, subscapula, iliac, abdomen, and thigh) have been shown to be highly predictive of whole body fatness and regional fat distribution (Groff et al., 1995). Additional sites include the pectoral (chest), midaxillary, and calf. These measurements are often taken on the right side of the body to compare to other reference data.

The skinfold measurements taken at various sites can be entered into one of numerous equations to predict percentage body fat. Sinning (1996) reported that an equation developed by Jackson et al. (1980) was more accurate than other equations for determining percentage body fat in women athletes. This equation is Body Density = 1.096095 – 0.0006952 [(triceps+abdominal+suprailiac+thigh skinfolds (mm))] + 0.0000011 [(sum of skinfolds)^2] – 0.000074 [age(years)]. There are also ratios that provide a relative estimate of regional fat distribution. Gynoid distribution is represented by smaller ratios, and android by larger ratios. The trunk-to-extremity ratio [(subrascapular + suprailiac + abdominal)/(triceps + biceps + medial calf)] and the upper-to-lower body ratio [(biceps + triceps + subscapular)/(suprailiac + thigh + medial calf)] are useful as estimates of regional fat distribution.

Radiologic Measurements

Computed Tomography. Computerized or computed tomography (CT) can differentiate among lean, fat, and bone tissue (Forbes, 1999). The CT takes visual images to determine regional body composition, such as visceral organ mass, regional muscle mass, subcutaneous and internal fat, as well as bone density (Groff et al., 1995). Subjects lie face up on a moveable platform that passes through the instrument's circular gantry. Cross-sectional images are constructed as the x-ray detects differences in the physical density of tissues. The body composition results of the CT are highly reproducible (Groff et al., 1995). The CT's use, however, is limited by its expense and exposure to high doses of ionizing radiation (Groff et al., 1995; Forbes, 1999).

Magnetic Resonance Imagery. Magnetic resonance imaging (MRI) permits assessment of body composition including body fat, fat-free lean, bone, total body water, as well as the size of individual organs, large blood vessels, and muscles, but without exposure to radiation (Forbes, 1999). Groff et al. (1995) describes that MRI is based on the principal that atomic nuclei behave like magnets when an external magnetic field is applied across the body. The nuclei align with the magnetic field and absorb radio waves directed into the body. As the magnetic field is released, the activated nuclei emit radio signals that are used by a computer to relay an image. The reproducibility for visceral fat is 10-15%. However, MRI provided the least variability compared to other methods in determining adipose tissue distribution (Groff et al., 1995). An advantage of MRI is that it is non-invasive and safe, although its cost is quite high (Groff et al., 1995; Forbes, 1999).

Dual-Energy X-Ray Absorptiometry. Dual energy x-ray absorptiometry (DXA) is the most recent method for measuring total and regional body composition. It allows measurement of three major components of body composition: LBM, fat mass, and bone mineral content (Slosman et al., 1992). DXA replaced the older methods of single or dual photon absorptiometry by replacing the radioactive source with an x-ray tube and filter, that converts the polychromatic x-ray beam into low and high energy peaks. This has allowed a greater precision of measurement and estimation of soft tissue composition and bone mineral (Lohman, 1996). The radiation exposure for a whole body scan is relatively low, ranging from 0.5 mrem – 1.5 mrem. To put the dose into perspective, this is less than the radiation exposure on a transcontinental flight across the United States (4 to 6 mrems) and far less than the 25 – 270 mrem of a conventional chest x-ray or CT scan.

Three companies (Hologic, Lunar, and Norland) manufacture DXAs that are available commercially. Each company uses different configurations of hardware and software that make it unique, with the same overall goal of measuring bone mineral content and soft tissue composition. Some assumptions or areas of limitations need to be considered. One is the sensitivity to hydration status. Going et al. (1993) determined that changes in body composition during hydration were due to weight fluctuations alone. Normal hydration fluctuations of 1-2% of body weight do not affect DXA results. A second assumption is that measurements are not affected by the anteroposterior thickness of the body. In fact, subject size may well be a limitation of the DXA for those taller than 193 cm or wider than the scan area (58 to 65 cm). Accuracy may also be compromised for subjects with greater centrally located tissue thickness and those weighing more than 100 kg.

Numerous studies have examined the precision and accuracy of DXA as a noninvasive, clinical method to measure total body and regional body composition. Lohman (1996) reported that precision for overall percentage body fat is about 1.0%, which is comparable to other methods (hydrostatic weighing and bioelectric impedance). Results for regional body composition are somewhat less precise. Van Loan and Mayclin (1992) concluded that the DXA gave accurate values of fat free mass for both men and women compared to underwater weighing and total body water. Lukaski (1993) reported the accuracy and precision error of bone mineral content was 99% and <1%, respectively, and the reproducibility of soft tissue composition as 99%. Pritchard et al. (1993) found DXA to produce precise regional measurements of bone mineral content, fat mass, lean mass, and percentage of fat.

Dietary Intake and Food Behavior

Female College Students

The food consumption patterns of college students, especially women, have received attention because of their tendencies to skip meals, follow low-energy diets, and avoid certain types of nutritious foods. A study by Hernon et al. (1986) examined 192 women and 58 men with intakes >1,200 kcal, as well as 53 women with intakes <1,200 kcal per day. Those consuming less than 1,200 kcal per day appeared to consume a more nutrient dense diet, but only met the RDAs for protein, vitamin A, and ascorbic acid. They tended to eat less frequently by skipping midday meals and not eating after 8 PM. This group also showed a tendency to avoid desserts, fat, sugar, milk products, meat, eggs, legumes, bread, and cooked starchy foods. The males consuming >1,200 kcal met all the RDAs for 19 to 22 year old men, whereas the women in the higher energy intake group met all the RDAs except for iron.

Two studies have been conducted at Iowa State University (ISU) examining the dietary intakes of college women. Kundrat (1993) recruited 41 female students and analyzed three-day diet records prior to and after nutritional counseling. Prior to counseling, the mean energy intake was 1,891 kcal with a range of <1,000 to >2,000. Macronutrient breakdown was $14.3\pm3.0\%$ from protein, $55.8\pm6.5\%$ from carbohydrate, and $29.3\pm6.0\%$ from fat. Those reporting intakes of greater than 66% of the RDA for individual nutrients are considered adequate. The percentage of subjects reporting less than 66% of the RDA were as follows: 36.6% for calcium, 24.4% for iron, 9.8% for vitamin A, and 26.8% for vitamin C. It is also of interest to note that this study examined the distribution of dietary intake based on the five food groups. Only 14.6% of the subjects consumed three or more servings of fruit, only 2.4% consumed three or more servings of vegetables, and 17% consumed 3 or more cups of milk per day.

Eller (1995) also reported on the dietary intakes of 39 female ISU students. Mean total energy consumed daily was 1781, with the mean percentage of energy derived from protein, carbohydrate, and fat being 14.7%, 58.0%, and 25.9%, respectively. The percentage of subjects not meeting 66% of the RDA for individual nutrients were as follows: 43.6% for calcium, 25% for iron, 15.3% for vitamin A, and 33.3% for vitamin C. When evaluating the average daily servings per food group, the subjects were within the recommended intake for breads/cereals, fruits, and meat/protein. They only consumed a daily average of 1.3 ± 1.0 servings of vegetables and 1.5 ± 1.2 servings from the milk group.

Female Athlete

Dietary intake of the female athlete can vary markedly depend on the sport and, in some cases, within sports depending on the timing of their competitive season. Burke (1996) examined the results of thirty nutrient intake studies. These results indicate that most groups of female athletes have adequate nutrient intakes and appear to eat better than sedentary women both in terms of macronutrient and micronutrient goals. The exception is among groups or individuals whose focus is on achieving or maintaining a low percentage body fat. These athletes tend to consume low total energy that may not meet the energy cost of their training program, as well as the RDAs for various nutrients.

Short and Short (1983) examined the dietary intakes of several collegiate athletic teams at the Syracuse University from spring 1978 through fall 1981. The mean intake of the women's basketball and swim team members was more than 2,900 kcal. The swim team members may have had higher energy requirements due to double daily practices. Except for the dancers, only five women had diets poor in calcium. Average iron intake was low for all women.

Female Swimmers/Divers

Studies on swimmers consuming self-selected diets have recorded mean energy intakes of 3988, 2865, 2248, and 2594 for women and 4832 and 4226 for men (Grandjean, 1986). The male swimmers were determined to consume 2.6 meals per day with 1.0 or 1.2 snacks. Hawley and Williams (1991) reported on dietary intakes of 11 competitive female swimmers. The average energy intake was 2130 kcal with percentage of energy derived from carbohydrate, fat, and protein being 56.0, 28.0, and 16.2, respectively. This study showed that a significant percentage of the female swimmers had calcium (73%) and iron (82%) intakes below the RDA. Berning et al. (1991) reported similar results in 21 adolescent female swimmers. Mean energy intake was 3,573 kcal with 12.0% from protein, 47.9% from carbohydrate, and 41.4% from fat. Many of the females did not meet the RDA for calcium or iron, although they did consume more than the RDA for vitamins A and C, thiamin, riboflavin, and niacin.

Nutrition Attitudes of College Students

Attitude towards nutrition may have a direct or indirect relationship on eating behavior. Two studies in elderly subjects (Matheson et al., 1991; Shannon and Pelican, 1984) indicated that positive nutrition attitudes were strong predictors in nutrition knowledge and the number of dietary changes. Eller (1995) examined the nutrition attitudes of 39 female ISU college students. The potential score range was 1 through 5, and the actual score range was 3.2 to 5.0, with a mean of 4.0. Over three-fourths (76.9%) of the subjects scored in the upper half or above 3.6. A higher score represents a more positive attitude towards nutrition. It appears that the majority of these subjects had a positive attitude towards nutrition. However, when correlating attitudes with the Food Guide Pyramid score, there was not a significant relationship as would be expected.

Barr et al. (1991) examined the nutrition attitudes, anthropometric measures, and dietary intakes in 14 female collegiate swimmers. To assess attitudes, subjects completed the 26-item version of the Eating Attitudes Test. This test includes three subscales: "dieting" reflects subjects' perceptions of concern about body weight and the extent to which they engage in dieting behavior; "bulimia" reflects their perceptions of bulimic tendencies (binge eating, purging, and preoccupation with food); and "oral control" reflects perceptions of conscious control of food intake and ability to resist pressure from others to eat. Higher total scores suggest disordered eating, and scores of 20 or more indicate eating attitudes found in those with anorexia. Subjects had a mean age of 19.8 ± 1.2 years, a mean height of 168 ± 6 cm, and a mean weight of 63 ± 8 kg. The mean value for body mass index (BMI) was 22.1 ± 2.0 and calculated body fat was 21.9%. The mean scores on the EAT-26 were 10.1 ± 6.9, with only one subject scoring above 20. The author reported that the swimmers' scores were similar to those of the female controls, suggesting that the sport neither predisposed nor protected them from the "normal" degree of concern about dieting and body size typical of women in western cultures. No significant relationships were seen between eating attitudes and energy intakes. Some correlations with attitudes and BMI were observed. Swimmers with a higher BMI, even though within normal limits, were more concerned about body size and more likely to engage in dieting behavior.

Iron Status

Iron plays an important role in exercise as it is required for the formation of Hb and myoglobin, oxygen binding proteins. Iron plays a role in oxygen transport to all tissues. It is incorporated into electron transport enzymes involved in energy production. Because iron is so important in these processes, iron stores help to ensure a sufficient supply of iron. Growth, pregnancy, lactation, and blood loss may increase the demand for iron stores. Many premenopausal women (20-30%) have scant or no iron stores (Puhl, 1987). This is mainly attributed to high iron losses from menstruation. Maintenance of iron stores depends on a balance between dietary intake/absorption and losses.

One of the most prominent nutrient deficiencies observed in athletes, especially female athletes, is iron depletion or low iron stores. Data on the impact of iron depletion on exercise performance is limited. However, iron deficiency anemia exhibited by low Hb concentrations can negatively affect physical performance (American Dietetic Association, 2000). This has been observed in decreases in maximal oxygen uptake, work capacity, and endurance time. Intracellular iron stores may impact the respiratory capacity of muscle. The high incidence of iron depletion in athletes is attributed to poor energy intake; avoidance of meat, fish, and poultry that contain the readily available heme form of iron; vegetarian diets with poor iron bioavailability; and/or increased losses in sweat, feces, urine, or menstrual blood (Newhouse and Clement, 1988; Clement and Sawchuk, 1984; Brigham et al., 1993).

Sports Anemia in Females

Sports anemia has been referred to as an anemic or borderline anemic state in physically active individuals, particularly athletes (Carlson et al., 1986). "Sports anemia" has been used to describe both (1) decreases in RBC count and Hct and Hb concentration in training studies and (2) low-normal or suboptimal values of these hematological indices in descriptive studies of athletes (Puhl, 1987). Researchers are in agreement that "sports anemia" is not always a clinical anemia. One reason for this is that when the hematologic values are within normal range, decreases from training that occur are relatively small. The RBCs also tend to be of normal size and contain normal amounts of Hb, conditions that are not seen in iron deficiency anemia. The condition is reported in previously sedentary individuals who start a training program, in fit individuals who participate in daily submaximal activities, and in those individuals who participate in prolonged severe exercise and endurance training. It may only appear during the initial phases of exercise or be present on a continual basis. Sudden changes in training intensity may also trigger sports anemia (Carlson et al., 1986). Several etiologies of sports anemia have been proposed including: hemolysis, hematuria, gastrointestinal bleeding, and an increase in plasma volume.

Hemolysis is the breakdown of RBCs (Mosby's, 1994). This occurrence has been described in the Japanese literature (Yoshimura, 1970) as the drop in Hb that occurs as an acute response to exercise. It appears that the hemolysis or destruction of erythrocytes is caused by a stress reaction to strenuous muscular activity. Adrenaline secretion is promoted by the stress and accelerated contraction of the spleen, which causes the hemolysing factor to flow out into the circulating blood.

Hematuria is defined as the abnormal presence of blood in the urine (Mosby's, 1994). In a review article (Carlson et al., 1986), it suggests that hematuria may be due to direct renal trauma in contact sports. However, when comparing contact and non-contact sports, 55% of athletes participating in football and crew had hematuria, whereas 80% of athletes participating in swimming and track experienced hematuria. The authors concluded that the duration of activity and the amount of exertion had just as much effect as direct renal trauma. Carlson et al. (1986) describe two possible theories of hematuria without kidney trauma. One is that renal vasoconstriction may result in an increased filtration pressure and stasis in glomerular capillaries, which favors an increased filtration of protein through the glomerular membrane. The other theory is that interference with the kidney's autoregulation of blood flow during exercise leads to vasodilation of arterioles in muscle, leading to increase blood flow. Meanwhile, there may be decreased blood flow to or vasoconstriction of renal blood vessels. The consequent renal ischemia may result in hematuria.

Gastrointestinal bleeding has been observed in long distance runners. Possible causes could include irritation to local lesions, such as hemorrhoids, or gut ischemia. This author is not aware of any studies that have examined gastrointestinal bleeding in swimmers.

Carlson et al. (1986) reported that plasma volume has been found to decrease during the initial stages of short-term exercise. However, during prolonged periods of exercise, plasma volume typically increases. This may cause false anemia results by increasing plasma volume enough to produce sufficient hemodilution, such that low-normal Hb may emerge as an anemic concentration. An increase in plasma volume without a reduction in absolute cell mass does not produce a true anemia.

Swimmers/Divers

The iron status of swimmers and divers reported in the literature is not different from other endurance athletes, such as runners, as reported earlier. Selby and Eichner (1986) reported the iron status of nine collegiate swimmers and 23 competitive masters' swimmers (aged 24 to 40 years). Of the 15 females, one had a Hb concentration below 13 g/dl with normal mean corpuscular volume (MCV) and ferritin concentration. One woman had iron deficiency anemia with a Hb of 10.7 g/dl, MCV of 72 fl, and ferritin concentration below 5 μg/L. There were significant differences in Hb concentrations in those swimming less than and greater than 10,000 yards per week, with respective means of 14.9 g/dl and 14.3 g/dl. The authors concluded that swimmers share with runners an "anemia" that is probably mainly dilutional.

Brigham et al. (1993) also examined the iron status of 25 female collegiate swimmers. The mean values at the beginning of the season were Hct ($40.1\pm1.9\%$), Hb (135 ± 10 g/L), ferritin (12.0 ± 8.2 μg/L), and plasma iron (15.1 ± 5.3 μM). A decrease in Hb (127 ± 10 g/L) but increase in ferritin (14.4 ± 6.7 μg/L) and plasma iron (16.6 ± 2.3 μM) were observed after 5 weeks of training.

Indices of Assessment

When describing indices of iron status, they can be categorized into four subgroups: storage iron indices, transport iron indices, RBC indices, and tissue iron availability. The four main iron compartments are affected progressively with increasing deficits in body iron. A deficiency in storage iron occurs first, followed by deficits in iron transport, and RBCs. Figure 1 shows the sequential stages of iron status, iron indices, and range of values at each stage.

Storage Iron Indices: Serum ferritin is the major iron storage protein in the body. It provides a quantitative measure of total iron in the storage compartment. Iron stores have no physiological function per se, but serve as a buffer against increasing iron demands, such as occurs with pregnancy or in blood loss(Cook et al., 1992). Storage depletion in of itself is not a liability, but represents an increased risk of developing iron deficiency. Therefore, serum ferritin is a better index of iron sufficiency than iron deficiency.

The immunologic method most often used to measure serum ferritin is the enzyme-linked immunosorbent assay (ELISA) because of its simplicity and shelf-life (Cook et al., 1992; Konijn et al., 1982; Anderson and Kelly, 1981). The mean concentration of serum ferritin in healthy adults is between 12 and 250 μg/L (Jacobs et al., 1970). Depletion

	Normal	Early Negative Iron balance	Iron Depletion	Iron Deficient Erythropoiesis	Iron Deficiency Anemia

	Normal	Early Negative Iron balance	Iron Depletion	Iron Deficient Erythropoiesis	Iron Deficiency Anemia
Reticuloendothelial marrow iron	2–3+	1+	0–1	0	0
Transferrin iron binding capacity (µg/dL)	330±30	330–360	360	390	410
Plasma ferritin (µg/L)	100±60	<25	20	10	<10
Iron absorption (%)	5–10	10–15	10–15	10–20	10–20
Plasma iron (µg/dL)	115±50	<120	115	<60	<40
Transferrin saturation (%)	35±15	30	30	<15	<15
Sideroblasts (%)	40–60	40–60	40–60	<10	<10
Erythrocyte protoporphyrin (µg/dL)	30	30	30	100	200
Erythrocytes	Normal	Normal	Normal	Normal	Microcytic Hypochromic
Serum transferrin receptors	Normal	Normal–high	High	Very high	Very high
Ferritin iron	Normal	Normal–low	Low	Very low	Very low

Figure 1. Sequential changes in iron status with iron depletion. From Groff JL, Gropper SS. Advance Nutrition and Human Metabolism. Third Edition. Belmont, CA: Wadsworth/Thomson Learning, 2000. Adapted from Victor Herbert. Recommended dietary intakes of iron in humans. Am J Clin Nutr 1987;45:679-86.

of iron stores is seen at concentrations below 12 μg/L (Cook et al., 1992; Jacobs et al., 1970). Studies have demonstrated that 1 μg/L serum ferritin corresponds to 8-10 mg of storage iron in an average sized adult. Serum ferritin is influenced by age, sex, presence of chronic infection or inflammation, pregnancy, leukemia, and liver disease (Cook et al., 1992; Harrison, 1977). Newhouse and Clement (1988) reported that athletes may have falsely elevated serum ferritin values for a number of days following hard exercise.

Transport Iron Indices: A reduction of plasma iron is preceded by fully depleting body iron stores. Plasma iron is often measured with transferrin, its specific transport protein. Transferrin saturation is the most informative expression of plasma transport. Normal values for transferrin saturation are $35 \pm 15\%$. It is the plasma iron expressed as a percentage of TIBC, which is the amount of added iron that can be specifically bound by plasma. The major limitation of transferrin saturation is its wide diurnal variation in plasma iron concentration. Healthy subjects may vary as much as 100% during a 24-hour interval (Cook et al., 1992). Transferrin saturation values have been found to be more useful in screening for iron overload than for iron deficiency.

Red Blood Cell Indices: Since the largest proportion of body iron is contained in blood, measurement of Hb concentration is important in the detection of overt iron deficiency. Hemoglobin values are affected by numerous factors including age, sex, race, infection, inflammation, protein-energy malnutrition, plasma expansion, cigarette smoking and deficiencies of vitamin B_{12} or folate. The major drawback of Hb as measure of iron status is its low specificity. For example, one cannot distinguish between iron deficiency anemia or anemia due to another cause. As a major index of iron status, Hb is only affected after other iron stores have been fully depleted. Hematocrit is expressed as a percent volume of packed RBCs. The usefulness of Hct is limited as it is affected by all the factors mentioned above for Hb. Furthermore, early in iron deficiency a near-normal Hct can exist with a slightly reduced Hb.

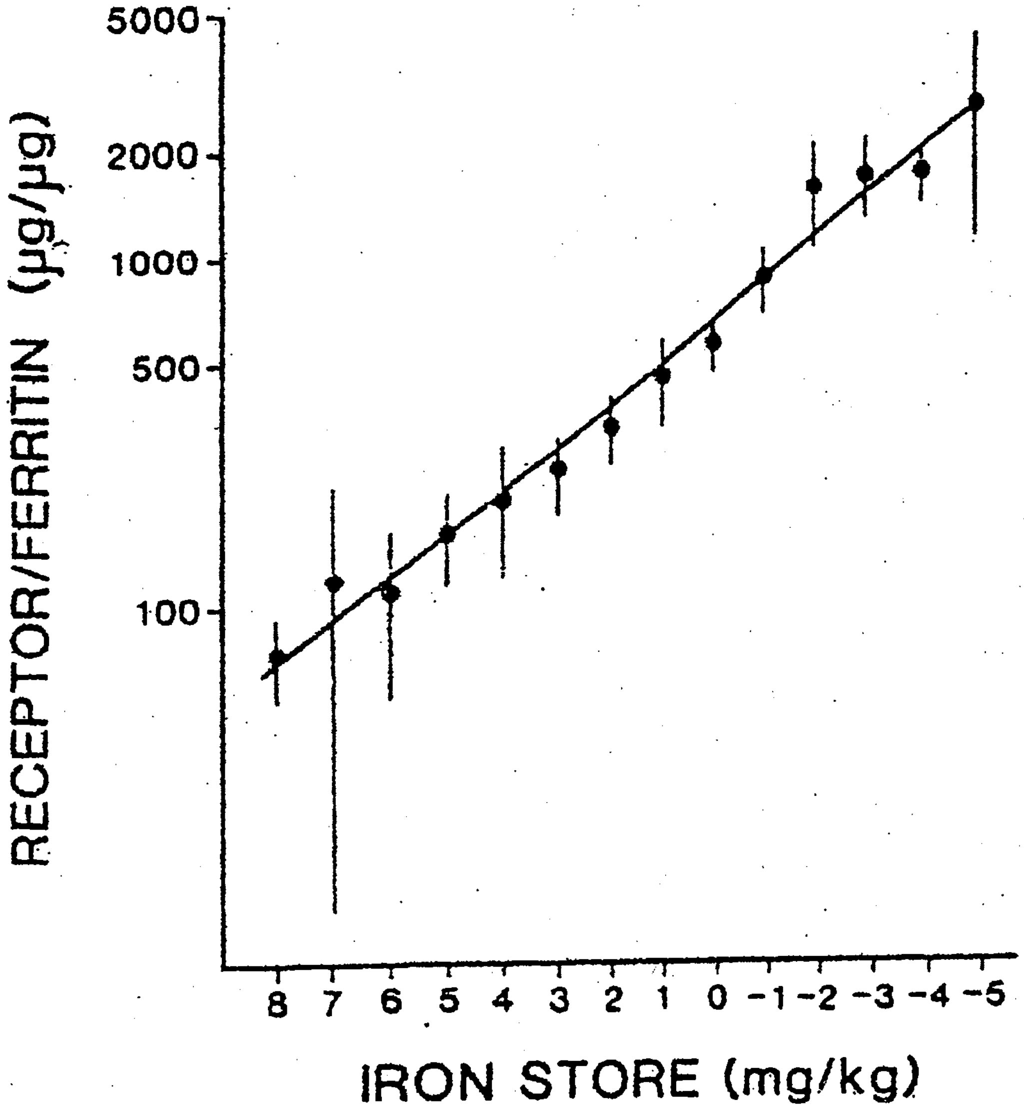
Mean corpuscular volume measures the size of the RBC. This is a reliable index of Hb synthesis. Values below 80 femtolitres indicate iron deficient erythropoiesis (Cook et al., 1992). Its main limitation is the time required after the onset of iron deficiency for the concentration to become abnormal. Because the lifespan of circulating red cells is greater than three months, several weeks must elapse before enough microcytic cells are released to affect the MCV.

Tissue Iron Availability Indices: Serum transferrin receptor (TfR) is the newest measure of tissue iron availability. The protein's key role is receptor-mediated endocytosis, the process by which transferrin iron is delivered to the cytosol. When a cell perceives an increased need for iron, an up-regulation of TfR occurs which allows the cell to compete more effectively for circulating transferrin iron. The mean normal value is 5.6 ± 1.2 mg/L (Cook et al., 1992), with iron deficiency described as serum TfR values greater than 8.5 mg/L. The serum receptor may be elevated with an increase in RBC production, but iron deficiency is the only condition in which increased serum TfR is combined with a low level of red cell production. The serum TfR is useful because it not only identifies iron deficiency, like serum ferritin, but it measures the severity of iron deficiency (Ahluwalia, 1998).

Multiple Indices: Due to the limited usefulness of Hb concentration in determining iron status due its low sensitivity and specificity, combining different measurements provides us with a clearer picture of iron status. One such combination is Hb and serum ferritin. Iron deficiency is ruled out if both measurements are normal; if both are low, iron deficiency can be identified. If Hb is normal and serum ferritin is low, the individual is at-risk for iron deficiency. Further assessment is needed if Hb is low and ferritin is normal. Another option is Hb and serum TfR. Iron deficiency can be excluded if both are normal, whereas a normal Hb and raised serum TfR reflects mild iron deficiency. Serum ferritin and serum TfR may be the most advantageous combination. It portrays the entire spectrum of iron status, ranging from normal to severe iron deficiency. The serum ferritin measures iron stores and the serum TfR measures the deficit in tissue iron. Cook et al. (1992) reported a study in which body iron could be accurately assessed from the serum ferritin and TfR, either used separately or expressed as a ratio. The combination of these two measurements portrays the entire spectrum of iron status ranging from normal to severe iron deficiency. The ratio can be used to accurately assess body iron (Figure 2).

In summary, this review of literature demonstrates that body composition, dietary intake, and iron status play a role in physical performance. The manuscript "Body composition, dietary intake, and iron status of female collegiate swimmers" reports on the changes in regional fat and lean distribution during a competitive swimming season, as well as the relationship between nutrition attitudes and dietary intake.

Figure 2. Relationship between iron stores and serum transferrin receptor/ferritin ratio during phlebotomy. The vertical bars represent ± 2 SEM. From Cook JD, Skikne BS, Baynes RD. Screening strategies for nutritional iron deficiency. Nutritional Anemias 1992;30:164.



CHAPTER 3. BODY COMPOSITION, DIETARY INTAKE, AND IRON STATUS OF FEMALE COLLEGIATE SWIMMERS

A paper to be submitted to Medicine & Science in Sports & Exercise

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ABSTRACT

Purpose: To determine the effect of training on body composition, dietary intake, and iron status of female collegiate swimmers and whether nutrition attitudes are correlated to dietary choices.

Methods: Measurements were obtained on 24 eumenorrheic Iowa State female collegiate swimmers (swimmers, n=18; divers, n=6) at preseason and after 16-weeks of training. Training consisted of 3 days/week on dryland (resistance, strength, flexibility; 1.5 hours/day) and 6 days/week in-water (7,000—11,000 yards/day; nine, 2 hour sessions/ week). Body composition (whole body and regional) was assessed using dual-energy x-ray absorptiometry (DXA). Changes in body composition, regional fat and lean tissue distribution, dietary intake, and iron status were determined using paired t-tests. We also examined the relationship between dietary changes and nutrition attitudes.

Results: During the 16-week training period, there were decreases in BMI (P=0.05), waist circumference ($P \leq 0.0001$), hip circumference ($P \leq 0.0001$), whole body fat weight (P=0.0002), and percentage body fat ($P \leq 0.0001$); lean weight increased significantly (P=0.028). No significant change was found in regional lean distribution, but we documented a decrease in fat at the waist (P=0.0002), hip (P=0.0002), and thigh (P=0.002). Energy intake at preseason averaged 2403 ± 864 $kcal \cdot day^{-1}$ with macronutrient composition of 62% carbohydrate, 13% protein, and 24% fat; we observed no changes at late season. An increase was observed in dietary intakes of dietary fiber (P=0.036), iron (P=0.015), vitamin C (P=0.029), vitamin B_6 (P=0.032), and fruit exchanges (P=0.003). A higher nutrition attitude score was correlated with a higher intake of calcium (P=0.02) and milk (P=0.04) and

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fruit exchanges (P=0.019). We documented an increase in hemoglobin (Hb) (P=0.046) and hematocrit (Hct) (P=0.014) and a decrease in serum transferrin receptor ($P \leq 0.0001$).
Conclusion: During the 16-week training season, female collegiate swimmers had a decrease in overall body fat and an increase in lean weight. Dietary quality improved with an increase in dietary fiber, iron, vitamin, C, vitamin B_6, and fruit exchanges, as well as a decrease in fat exchanges. A more positive nutrition attitude score was correlated with higher intakes of calcium, milk, and fruit. Iron status improved with an increase in Hb, Hct, and a decrease in serum TfR. Additional studies to evaluate body composition and iron status in relation to dietary intake in female collegiate swimmers are warranted.

Key Words: SWIMMERS, REGIONAL FAT & LEAN DISTRIBUTION, NUTRITION ATTITUDES

INTRODUCTION

Numerous studies have shown that body composition, dietary intake, and iron status play a role in physical performance. Several studies have shown a decrease in body fat and an increase in lean body mass (LBM) in female swimmers with training (Barr,1991; Lukaski et al., 1990; Meleski and Malina, 1985; Siders et al., 1991; Wade, 1976). In contrast, various studies have shown that there were no significant body composition changes with training intervals less than 25 weeks (Ballor, 1996; Johnson et al., 1989; Katch et al., 1969). Although a few studies have examined regional fat distribution using skinfold thicknesses (Avlonitou et al, 1997; Meleski et al., 1982), dual energy x-ray absorptiometry (DXA) has not been used to assess change in regional fat distribution or regional lean distribution in swimmers undergoing intense training. In this study, we used DXA to assess whole body composition as well as regional fat distribution and regional lean distribution changes in female collegiate swimmers from preseason to late season.

It is well known that nutrition plays a key role in attaining peak physical performance. Several researchers have reviewed the dietary intake of swimmers (Grandjean, 1986; Sharp, 2000), with studies indicating that energy intake is less than their estimated energy requirement (Sherman and Maglischo, 1992; Trappe et al., 1997; Van Handel et al., 1984). Previous studies of Iowa State University female students have shown sufficient energy intakes (Eller, 1995), but lower than recommended intakes of dairy products, fruits, and vegetables based on the Food Guide Pyramid (Eller, 1995; Kundrat, 1993). Two studies in elderly subjects (Matheson et al., 1991; Shannon and Pelican, 1984) revealed that positive nutrition attitudes were strong predictors of nutrition knowledge and the number of dietary changes. In contrast, a study of 39 female college students (Eller, 1995) did not show a correlation with attitude or consumption of the recommended servings from the Food Guide Pyramid categories.

Iron plays an important role in exercise, as it is required for the formation of hemoglobin (Hb) and myoglobin, oxygen binding proteins. Thus, examining iron status is important because it may be a predictor of performance in athletes. Compromised iron status, exhibited by a decline in Hb, hematocrit (Hct), and serum ferritin during a training season has been shown in several studies (Brigham et al., 1993; Lukaski et al., 1996; Shannon and Pelican, 1984). The use of serum transferrin receptor (TfR) to measure tissue iron availability is a useful tool because, like serum ferritin, it not only identifies iron deficiency, but it measures the severity of iron deficiency (Ahluwalia, 1998). This study examined the effect of physical training on body composition, dietary intake, and iron status of female collegiate swimmers. We hypothesize that physical training for 16 weeks (preseason to late season) in female collegiate swimmers will decrease body fat, increase energy intake, and decrease iron stores. We also hypothesize that female collegiate swimmers with a more positive nutrition attitude score will consume a more nutrient-dense diet.

METHODS

Subjects

The subjects included 24 healthy, female, eumenorrheic Iowa State University swimmers (n=18) and divers (n=6). They participated in a 16-week training period from early October to early February. The training consisted of dryland and in-water training. Dryland training included resistance, strength, and flexibility exercises for 1.5 hours/day, 3 days/week. In-water training occurred 6 days/week for nine, 2-hour sessions per week. Distances covered were 7,000–11,000 yards per day. The subjects were responsible for their own meals either in the dormitory or off campus. Each of the subjects was provided with a multivitamin/mineral supplement containing 18 mg of iron and instructed to take one/day to reduce variability. Each subject obtained information regarding the study, asked questions, and written informed consent was obtained. This study was approved by the Human Subjects Review Board at Iowa State University.

Data collection and measurement

Anthropometric measurements (APPENDIX A) were taken at preseason (baseline) before competition and at late season, two weeks before the end of the season championship competition. Body weight was measured with a balance beam scale (Health-o-meter, Inc.; Brideview, IL) to the nearest 0.1 kg with the subject standing erect in light indoor clothing. Standing height was measured with a stadiometer to the nearest 0.1 cm with the subject wearing no shoes, standing erect with hands on hips, with heels together against a wall. Body Mass Index (BMI) was calculated for each swimmer as body mass (kg)/height (m^2). Waist and hip circumferences were measured to the nearest tenth of a centimeter with a non-elastic tape measure. The waist circumference was measured at the narrowest portion of the waist between the rib cage and the umbilicus. The hip circumference was measured at the maximum girth around the hips and buttocks. The waist-to-hip ratio was determined by dividing the waist circumference by the hip circumference.

Changes from preseason to late season in whole body composition and regional lean and fat distribution were assessed using DXA (QDR 2000+; Hologic, Inc; Waltham, MA). The same two (KBH and DLA) trained researchers performed the whole body scans and analyzed them according to the manufacturer's Operator's Manual (1992). Analysis of regional fat and lean tissue was completed by a single trained research assistant (HLP), using the DXA regional analysis protocol developed and modified by Farrell-Lee (1995). The whole body DXA scan is viewed in a different mode, whereby the mid-region is subdivided into three regions (waist, hip, and thigh) based on bony landmarks as illustrated in Figure 1. The waist region extended superiorly from the superior edge of the second lumbar intravertebral disk to the most lateral edge of the anterior superior iliac crests. The hip region extended superiorly from the most lateral edge of the anterior superior iliac crests to the most inferior edge of the ischial tuberosities. The thigh region extended superiorly from the most inferior edge of the ischial tuberosities to the approximate midpoint between the ischial tuberosities and the inferior margins of the medial femoral condyles. The lateral edges of each region were extended distally to encompass all tissue. The estimated fat and lean mass of each area were automatically calculated from the DXA data.

Blood samples at baseline and late season were analyzed for various biochemical indices (serum glucose, albumin, serum iron, total iron binding capacity [TIBC], transferrin saturation, ferritin, transferrin receptor (TfR), Hb, Hct, serum lipid profile, and circulating minerals). Quest Diagnostics (St, Louis, MO), a certified clinical laboratory, preformed serum analysis of indices other than Hb, Hct, ferritin, and TfR. Serum ferritin and TfR were analyzed in serum frozen at –80°C. The Hb concentration was determined in whole blood immediately after the blood samples were drawn using the HemoCue system (HemoCue, Inc, Mission Viejo, CA). The serum ferritin and TfR concentrations were determined with the use of enzyme-linked immunoassay kits (RAMCO Laboratories, Houston).

At baseline, a trained graduate research assistant (and registered dietitian) administered a health and medical history (APPENDIX B) and a nutrition history (APPENDIX C). The questionnaires provided information on personal and family medical history, menstrual history, chronic or acute conditions or diseases, use of prescription and nonprescription drugs, eating habits, history of eating disorders, and use of supplements (vitamins, minerals, herbals). The information was gathered and analyzed to provide a basis for nutrition counseling. The athletes were required to discontinue their own supplement use and instead provided multivitamin/mineral supplements containing 18 mg of iron and instructed to take one/day to reduce individual variability. A questionnaire (APPENDIX D) was administered late season to assess attitudes towards nutrition and healthy eating. This attitude instrument included 19 questions adapted from Shannon and Pelican (1984), evaluating changes throughout the training season. The subjects were instructed to complete 3-day food records at baseline and late season. Two-dimensional food portion visual aids (Nutrition Consulting Enterprises, Morgan/Posner, 1981; Framingham, MA) (APPENDIX E) were provided to assist subjects in quantifying portion sizes. The food records were analyzed using the Nutritionist V computerized nutrient database program (Version 1.5, 1998; San Bruno, CA).

Throughout the training season, the same registered dietitian met with the swimmers individually and as a group to provide nutrition counseling and education. The female swimmers were educated on their estimated energy requirements, individualized meal plans highlighting deficiencies and excesses, use of the food guide pyramid, an adequate training diet, and the need for sufficient fluid, calcium, and iron.

Statistical analyses of data

Statistical analyses were performed with SAS (version 8.0; 20); results were considered statistically significant at $P \leq 0.05$. The descriptive statistics includes means for normally distributed data (age, body size and composition, dietary intake, Hb, Hct, transferrin saturation, serum iron, TIBC, serum TfR) and medians for nonnormally distributed data (dietary fat, alcohol, exchanges; serum ferritin, and the ratio of serum TfR/ferritin). To detect differences in body size, body composition, dietary intake, and iron indices from pre- to late season, nondirectional paired t-tests were used. Pearson correlation coefficients were used to determine the relationship between nutrition attitude scores and dietary intake of various nutrients or food groups.

RESULTS

Subjects, Body Size, and Overall Body Composition

Age and anthropometric data of the subjects are presented in **Table 1**. The female collegiate swimmers ranged in age from 18 to 21 years. The swimmers and divers were combined into one group as they were not significantly different in the values presented, with the exception of the waist-to-hip ratio. Swimmers had a lower waist-to-hip ratio than divers ($P<0.05$). Several body composition variables changed significantly over the 16-wk training period. BMI ($P<0.05$), waist circumference ($P\leq0.0001$), hip circumference ($P\leq0.0001$), fat weight ($P=0.0002$), and percentage body fat ($P\leq0.0001$) decreased, whereas overall lean body weight ($P=0.028$) increased. Although there were significant changes in fat and lean weight, total body weight did not change significantly throughout the season. None of the athletes were smokers and all reported good-to-excellent health.

Regional Fat and Lean Distribution

Swimmers and divers were not significantly different from each other at most regional fat and lean distribution sites. However, divers had a higher thigh lean mass than swimmers ($P=0.03$). The means for swimmers and divers combined are reported in **Table 1**. A significant decrease in fat mass at the waist ($P=0.0002$), hip ($P=0.0002$), and thigh ($P=0.002$) was documented after 16 weeks of training. No significant change in regional lean distribution with training was observed.

Nutrient and Dietary Intake

The subjects consumed an average of 3 meals and 1 snack per day. Twelve of the subjects lived on campus and used Iowa State University for their food service, and twelve lived off-campus. One subject reported being a lacto-ovo vegetarian. Dietary intake of macronutrients, selected micronutrients, caffeine, and food group exchanges are reported in **Table 2**. Energy intake at preseason averaged 2403 ± 864 $kcal\cdot day^{-1}$, with a macronutrient composition of 62% carbohydrate, 13% protein, and 24% fat. Energy intake at late season, although not significantly different, averaged 2356$\pm$768 kcal·day^{-1}, with a macronutrient composition of 65% carbohydrate, 14% protein, and 23% fat. The food group exchanges exhibited a shift in dietary quality between preseason and late season, with an increase in fruit exchanges (P=0.003) and a decrease in fat exchanges (P=0.019). An increase was also observed for dietary fiber (P=0.036), iron (P=0.015), vitamin C (P=0.029), and vitamin B_6 (P=0.032).

Nutrition Attitudes

The frequency of responses to each nutrition attitude question is reported in **Table 3**. The nutrition attitude score reflects the mean response to the nutrition attitude questionnaire. The range of scores was 1-5 with higher scores indicating more positive attitudes. The mean nutrition attitude score was 3.86$\pm$0.31. **Figure 2** shows the distribution of attitude scores. Pearson correlation coefficients for selected variables indicated the highest correlation of positive attitudes with calcium intake (P=0.02), milk exchanges (P=0.04), and fruit exchanges (P=0.019). The nutrition attitude score was not significantly correlated with energy, protein, iron, vitamin C, vegetable, bread, fat, or meat exchange intake.

Iron Status

Indices of iron status are reported in **Table 4**. No changes were observed in transferrin saturation, serum iron, or TIBC. Significant increases in Hb (P=0.046) and Hct (P=0.014) were observed, whereas serum TfR ($P \leq 0.0001$) and serum ferritin (P=0.057; albeit NS) decreased from preseason to late season. Because the slight decrease in serum ferritin was inexplicable, we explored post-hoc, using multiple regression analysis, those factors that might have contributed to this change. The decrease in serum ferritin was unrelated to energy, protein, fat, iron, vitamin C, or meat exchange intake, as well as BMI, lean weight, or fat weight. Median values for serum ferritin at preseason and late season were below that of the normal range of values, 12-250 µg/L, reported by Jacobs et al. (1970). Forty-six percent of the subjects at preseason and 58% at late season had serum ferritin values less than 12 µg/L.

DISCUSSION

Various results have been reported in the literature in regards to the effects of physical training on body composition. Katch et al. (1969), Johnson et al. (1989), and Ballor (1996) have reported no significant changes in body composition, whereas several other studies have demonstrated a decrease in body fat and an increase in LBM in female swimmers with training (Barr, 1991; Lukaski et al., 1990; Meleski and Malina, 1985; Siders et al., 1991; Wade, 1976). Parizkova (1977) reported that regular training generally results in a decrease in body fat and an increase in LBM, quite often without a change in total body mass. Our results are consistent with the latter findings, demonstrating a decrease in body fat mass and an increase in LBM over a 16-week training period.

The literature has reported that the average body fat percentages of female swimmers ranges from 15-22% (Sharp, 2000). Although we reported a significant decrease in body fat percentage, our results were slightly higher than these published values. Further study of body composition changes in relation to dietary habits of collegiate swimmers offseason, after their training regimens have been completed, may provide insights as to why swimmers have higher than average percentages of body fat. Alternatively, swimmers, as well as other athletes, may self-select into specific sports, making it difficult to determine whether the sport itself induces changes in body composition, or certain body types gravitate to particular sports.

Avlonitiou et al. (1997) and Meleski et al. (1982) have reported lower body fat and greater LBM in the upper extremities of female swimmers compared to age-matched controls. These results illustrate that regional fat and lean distribution are modified according to the training regimen and athletic sport. This author is unaware of other studies using DXA to report regional fat and lean distribution in female swimmers. Our results using the DXA showed a decrease in fat at the waist, hip, and thigh, which is consistent with the decrease in waist and hip circumference measurements, as well as a small decrease in body weight with training. Although there was an increase in overall LBM, regional lean mass in the waist, hip, and thigh areas did not increase. Further study of the upper extremities using DXA and skinfold thicknesses may provide greater explanation of changes in regional fat and lean distribution. However, we are not convinced that regional analysis, other than the mid-region using the alternate mode, of whole body DXA scans is sufficiently reproducible and hence we did not determine whole body subregion composition.

The energy intake observed in this study (2356 ± 768 kcal$\cdot$day^{-1}, late season) is consistent with that reported from female swimmers in previous studies (Sharp, 2000; Van Handel et al., 1984). The relationship between energy demand and energy intake in female swimmers has consistently demonstrated that they are in negative energy balance (Sharp, 2000; Trappe et al., 1997). The question that remains to be answered is how total body weight decreases slightly during a 16-week period of apparent negative energy balance. Some explanations may include underreporting of food intake by the female athletes, underconsumption by the female athletes, or an adaptation to fuel utilization. Trappe et al (1997) reports on the theory of adaptation to fuel utilization or an increase in metabolic efficiency. In studies using doubly labeled water and/or whole body calorimetry in female endurance runners and cyclists, a decreased energy requirement was an invalid explanation for the negative energy balance. The energy demands of swimming are high and may be difficult to obtain on reported days. The food records were kept for 3 days by our subjects, who may have consumed more on non-reporting days, reducing the energy imbalance. Underreporting of food intake is common among female athletes (Trappe et al., 1997), perhaps providing some explanation for our low reported intake of energy. Ballor (1996) explains that aerobic training has an inconsistent effect on body weight, because it generally stabilizes at some level for all individuals, particularly when body weight is already at a minimum level. Gender, exercise status, percentage of fat in the diet, distribution of muscle fiber types, as well as number, type, and distribution of adipocytes play a role in determining the level at which body weight may plateau. Further investigation needs to be conducted in these important areas.

A significant increase in selected nutrients and exchanges shows a shift in dietary quality. This may be due to the nutrition counseling and education that the swimmers received, although a direct link cannot be established because we did not examine change in dietary intake in relation to change in nutrition attitude over time. However, we did note an increase in dietary iron, vitamin C, and vitamin B_6 from preseason to late season. Nonetheless, the Recommended Daily Allowance (RDA) for each nutrient was already being met at preseason. Also, the RDA for each reported nutrient except zinc was met at late season.

The mean nutrition attitude score reported is 3.86, which indicates a positive nutrition attitude. The range of mean scores was from 3.3 to 4.7, indicating a neutral to highly positive attitude. The swimmers who scored higher on the nutrition attitude instrument consumed more milk exchanges and calcium, as well as more exchanges of fruit, substantiating the hypothesis that those with a more positive nutrition attitude will consume a more nutrient-dense diet. A limitation is that the questions from our nutrition attitudes scale were adapted from Shannon and Pelican (1984), and we did not have a large enough sample size to estimate reliability on the adapted scale.

The observed increase in Hb and Hct is not consistent with the hypothesis that physical training may induce iron deficiency. These changes may also be related to the improved dietary intake during the 16-week training period. Dietary intake of iron and vitamin C, which increases iron absorption, both increased during the training season. However, the increase in Hb and Hct may also have been related to the use of the multivitamin/mineral supplements containing 18 mg of iron. These were provided because many of the swimmers were taking their own supplements prior to preseason and we wanted to ensure that all the athletes would have similar supplement intakes. Compliance to supplement use was self-reported, an inherent limitation of the study, precluding any direct conclusion between supplement use and iron status.

Serum TfR is the newest measure to assess tissue iron availability. It is a specific and sensitive assay to measure iron status. An up-regulation of TfR occurs when cells perceive an increased need for iron, allowing the cell to compete more effectively for circulating transferrin-bound iron (Ahluwalia, 1998). The mean value is 5.6 ± 1.2 mg/L (Cook et al., 1992), with iron deficiency described as serum TfR values greater than 8.5 mg/L. The decrease in TfR we observed after the 16-week training period does not fit the hypothesis that the female athlete is at-risk of developing sports anemia with physical training. Our results may be explained by previously documented observations that TfR decreases as Hb and Hct increase, which may be due to improved dietary intake and/or use of multivitamin/mineral supplement.

The subjects were iron-depleted at preseason, as evidenced by below normal serum ferritin concentrations. The decrease in serum ferritin was not significant, nor was it related to the above-mentioned dietary or body composition factors. Thus, it is likely that the modest decrease (albeit NS) in ferritin may have been due to a training effect, suggestive of some mobilization of iron stores for hemoglobin synthesis. The provided mulitvitamin/mineral supplements, along with improved dietary intake of iron and vitamin C, may have prevented a decline in iron status of these subjects.

CONCLUSION

In summary, female collegiate swimmers experienced a decrease in body fat and an increase in lean mass after a 16-week training season. Dietary quality improved with an increase in dietary fiber, iron, vitamin C, vitamin B_6, and fruit exchanges, as well as a decrease in fat exchanges. A more positive nutrition attitude score was correlated with higher intakes of calcium, milk exchanges, and fruit exchanges. Iron status improved with an increase in Hb, Hct, and a decrease in serum TfR. Additional studies to evaluate body composition and iron status in relation to dietary intake in female collegiate swimmers are warranted.

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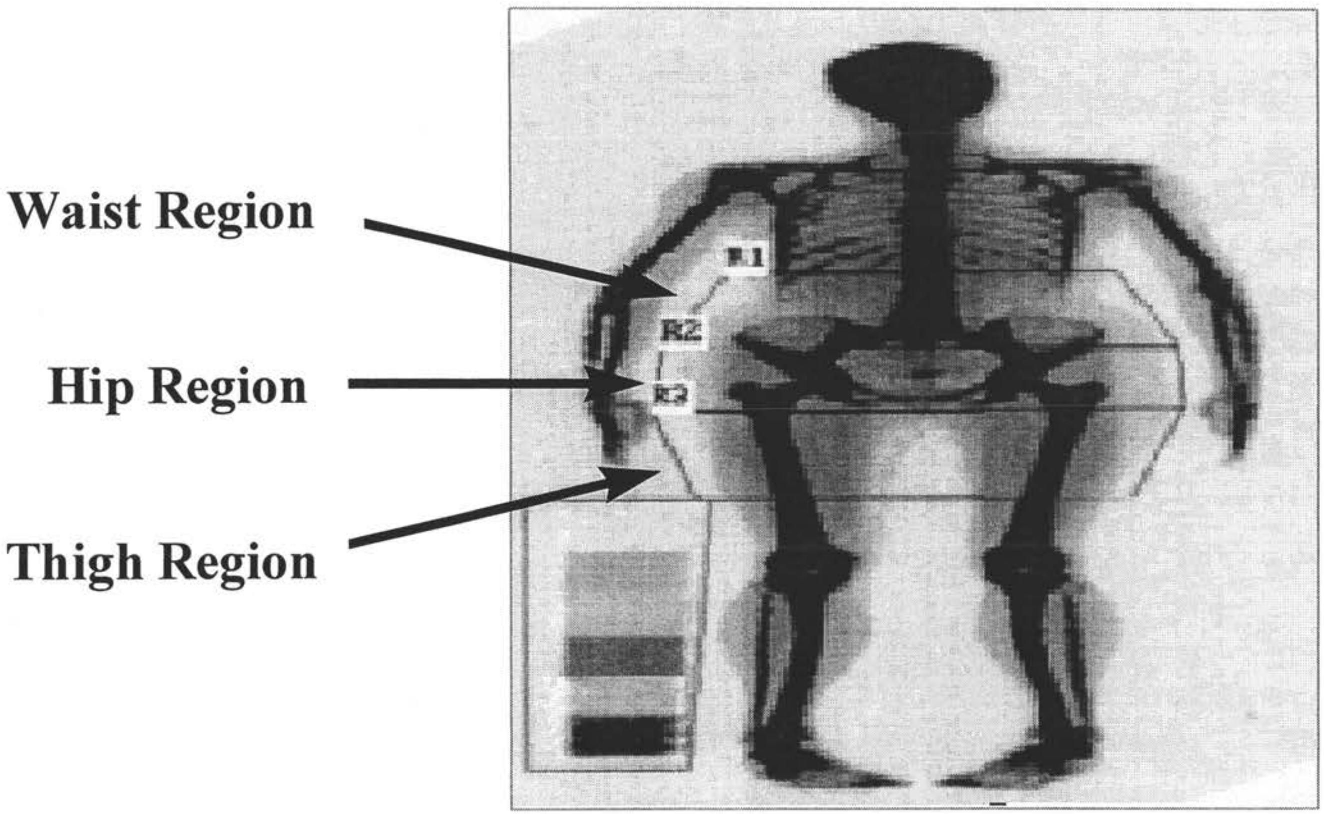

Figure 1. Regional analysis of whole body dual-energy x-ray absorptiometry scan. Waist, hip. and thigh regions were manually set based on skeletal landmarks following the regional DXA analysis protocol developed and modified by Farrell-Lee (1995).

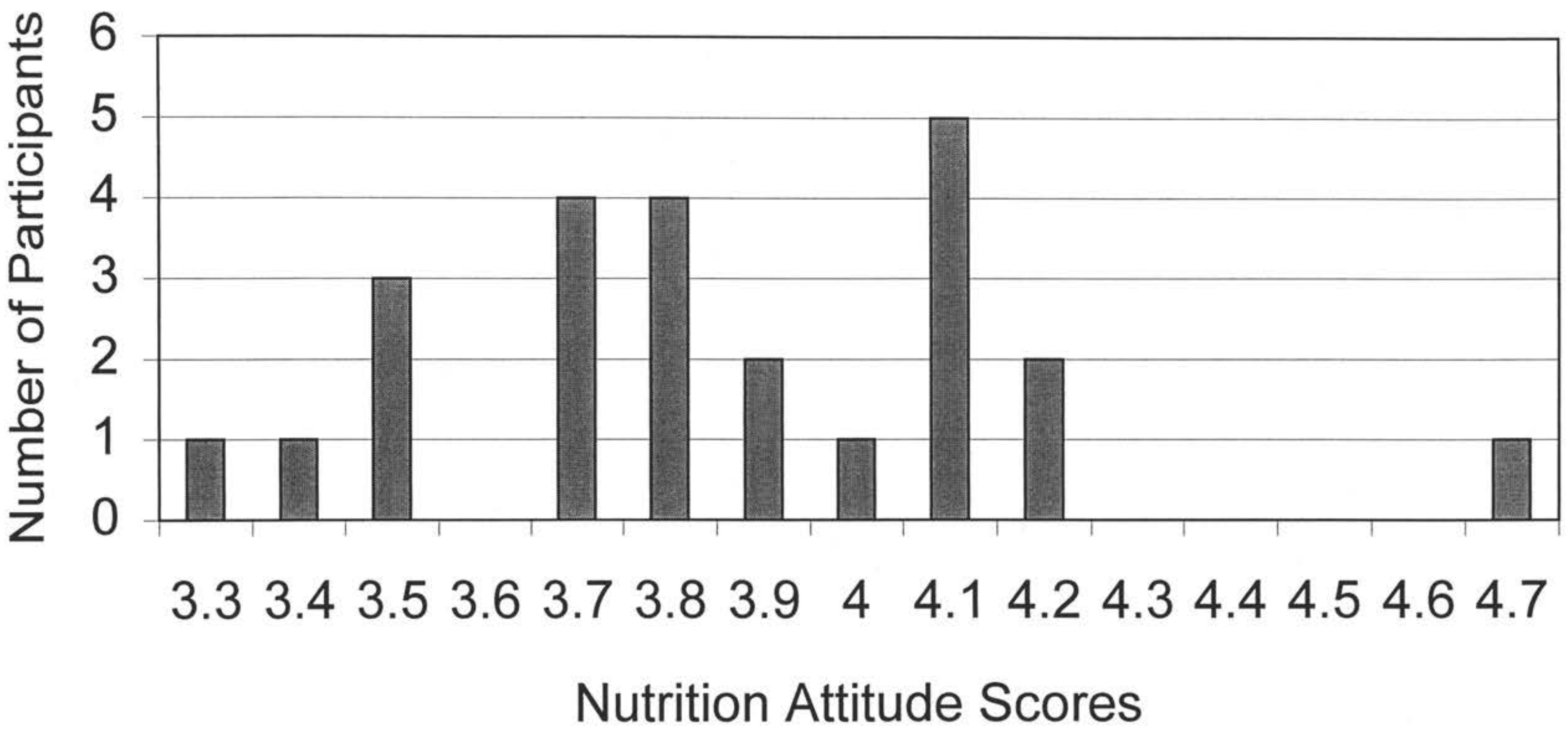

Figure 2. Average postseason nutrition attitude scores of collegiate swimmers and divers (n=24). Range of average scores (1-5) with higher scores indicating more positive attitudes.

Table 1. Age at Menarche, Age, Body Size, Body Composition, and Regional Fat Distribution of Female Collegiate Swimmers at Preseason and Postseason

Measure	Preseason[a] (n=24) (Mean ± SD)	Postseason[a] (n=24) (Mean ± SD)	P Value[b]
Age at Menarche (median [min, max] yrs)	13.0 [10.0, 18.0]		
Present Age (median [min, max] years)	19.5 [18.0, 21.9]		
Desired Body Weight (kg)	60.3 ± 4.7		
Maximum Non-pregnant Weight in Lifetime (kg)	64.8 ± 6.6		
Height (cm)	170.1 ± 6.7		
Weight (kg)	64.6 ± 6.5	63.3 ± 5.4	0.065
Body Mass Index (kg/m^2)	22.4 ± 2.4	21.9 ± 2.1	<0.050
Waist Circumference (cm)	70.2 ± 3.7	66.9 ± 3.3	≤0.0001
Hip Circumference (cm)	95.4 ± 5.3	91.7 ± 3.9	≤0.0001
Waist-Hip Ratio	0.74 ± 0.03	0.74 ± 0.08	0.71
Lean Weight[c] (kg)	47.2 ± 2.7	47.7 ± 2.4	0.028
Fat Weight[c] (kg)	15.3 ± 4.9	14.0 ± 4.5	0.0002
Percentage Body Fat[c] (%)	24.1 ± 5.7	22.4 ± 5.6	≤0.0001
Regional Fat and Lean Distribution using DXA[c]			
Waist Fat (kg)	1.86 ± 0.88	1.58 ± 0.76	0.0002
Hip Fat (kg)	2.79 ± 0.80	2.53 ± 0.71	0.0002
Thigh Fat (kg)	2.80 ± 0.78	2.58 ± 0.65	0.002
Waist Lean (kg)	6.41 ± 0.77	6.43 ± 0.76	0.825
Hip Lean (kg)	6.52 ± 0.53	6.67 ± 0.62	0.11
Thigh Lean (kg)	6.68 ± 0.46	6.76 ± 0.35	0.24

[a] 16 week period from preseason to postseason (September to February)

[b] Nondirectional paired t-tests were used to detect differences from pre- to postseason.

[c] Lean weight, fat weight, percentage body fat, and regional fat distribution were determined using dual-energy x-ray absorptiometry (DXA). One subject was removed from the regional analysis (n=23) due to technical difficulties.

Table 2. Dietary Intake of Macronutrients, Selected Micronutrients, Caffeine, and Food Group Exchanges[a] of Female Collegiate Swimmers at Preseason and Postseason[b]

Measure	**Preseason** (n=24) (**Mean** ± SD)	**Postseason** (n=24) (**Mean** ± SD)	**P Value**[c]
Energy (kcal)	2403 ± 864	2356 ± 768	0.27
Protein (gm)	79.0 ± 29.0	82.6 ± 28.3	0.53
Protein Percent (%)	13.3 ± 2.4	14.1 ± 2.4	0.26
Carbohydrates (gm)	365.2 ± 108.2	380.5 ± 115.7	0.47
Carbohydrate Percent (%)	62.2 ± 7.2	65.1 ± 6.7	0.12
Fat (median [min, max] gm)	53.7 [27.6, 163.0]	53.2 [24.6, 158.9]	0.17
Fat Percent (%)	24.3 ± 5.9	22.6 ± 5.9	0.25
Alcohol[d] (median [min, max] gm)	15.1 [2.8, 88.8]	28.1 [0, 28.1]	0.065
Dietary Fiber (gm)	17.0 ± 4.4	20.4 ± 6.2	0.036
Calcium (mg)	1131.2 ± 611.1	1230.7 ± 699.1	0.47
Magnesium (mg)	245.6 ± 87.6	288.5 ± 120.2	0.052
Potassium (mg)	2546.5 ± 1085.6	2979.7 ± 1399.3	0.057
Iron (mg)	16.3 ± 5.3	19.7 ± 7.9	0.015
Zinc (mg)	9.3 ± 4.2	9.9 ± 5.1	0.61
Vitamin C (mg)	106.8 ± 111.8	155.2 ± 101.8	0.029
Vitamin B_6 (mg)	1.6 ± 0.6	1.9 ± 0.8	0.032
Caffeine (mg)[e]	48.2 ± 45.8	44.6 ± 47.1	0.51
Exchanges:			
Bread (median [min, max])	9.25 [4.8, 15.5]	9.75 [2.0, 17.5]	0.13
Fruit (median [min, max])	2.1 [0, 6.2]	3.0 [0, 8.0]	0.003
Vegetable (median [min, max])	0.33 [0, 2.7]	0.33 [0, 3]	0.31
Milk (median [min, max])	1.5 [0, 4.3]	1.67 [0, 8.2]	0.083
Meat (median [min, max])	3.25 [0.8, 12.3]	3.83 [1.2, 8.2]	0.72
Fat (median [min, max])	5.25 [1.5, 25.2]	5.25 [0.8, 15.8]	0.019

[a] Assessment was based on a three-day food diary, analyzed using Nutritionist V.

[b] 16 week period from preseason to postseason (September to February)

[c] Nondirectional paired t-tests were used to detect differences from pre- to postseason.

[d] Refers to 9 women preseason and 1 postseason who reported alcohol intake.

[e] Refers to 18 women preseason and 16 women postseason who reported caffeine intake.

Table 3. Participants' responses to items in the nutrition attitude scale (n=24)

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It is difficult for me to gain access to nutritious foods.*	7	10	3	4	
I have nutritious foods available to me when I am hungry.		2	2	17	2
Eating a nutritious diet is important in preventing disease.			1	12	11
I should be concerned about the foods I eat, even if I take vitamin and/or mineral supplements.			1	10	13
Eating vegetables and fruits will not improve the nutritional quality of my diet.*	14	8	1		1
I make an effort to include adequate amounts of vegetables and fruits in my diet to improve its nutritional quality.		4	1	16	3
I consume too many sweets and/or soda pop.*	2	6	4	10	2
I consume adequate sources of dietary calcium.		4	4	11	5
I consume too many high fat foods.*	3	14	6	1	
Eating a healthy diet has improved my performance.		1	12	10	1
Consuming a nutritious diet off-season will affect my athletic performance next season.			2	13	9
Eating adequate carbohydrates will help enhance my performance.			3	16	7
Eating a nutritious diet is not an important part of my training regimen.*	1	1		11	11
Drinking adequate amounts of fluid benefits my athletic performance.				12	12
I realize that I need to consume lots of food to meet my energy demands during season.	1	2	2	11	8
My caloric intake is inadequate during training to meet my increased needs.*	7	10	3	4	
I plan to eat a healthy diet off-season.	1			10	13
I do not make an effort to consume adequate amounts of fluids.*	6	15	2	1	
I have modified my diet to help enhance athletic performance during this swim season.		4	4	12	4

*Denotes items with reversed scoring, such that strongly disagree indicates a more positive nutrition attitude.

Table 4. Indices of Iron Status

Measure	**Preseason**[a] (n=23) (**Mean** ± SD)	**Postseason**[a] (n=23) (**Mean** ± SD)	**P Value**[b]
Hemoglobin[c] (g/L)	132.0 ± 7.2	134.8 ± 9.1	0.046
Hematocrit[c] (%)	42.2 ± 1.9	43.5 ± 2.1	0.014
Transferrin Saturation (%)	26.6 ± 12.3	26.2 ± 10.9	0.88
Serum Iron (μg/dL)	88.4 ± 37.6	89.8 ± 39.1	0.88
Total Iron Binding Capacity (μg/dL)	341.2 ± 42.1	347.4 ± 50.5	0.46
Serum Transferrin Receptor (mg/L)	6.2 ± 1.9	4.5 ± 1.2	≤0.0001
Serum Ferritin[d] (median [min, max] μg/L)	11.0 [1.6, 50.2]	9.4 [1.5, 33.1]	0.057
Serum Transferrin Receptor/Ferritin Ratio[d]	581 [124, 5128]	510 [116, 2703]	0.38

[a] 16 week period from preseason to postseason (September to February)

[b] Nondirectional paired t-tests were used to detect differences from pre- to postseason.

[c] n = 22 subjects

[d] n = 22 subjects, one outlier was removed

CHAPTER 4. GENERAL CONCLUSIONS

In summary, female collegiate swimmers experienced a decrease in body fat and an increase in lean mass after a 16-week training season. Dietary quality improved with an increase in dietary fiber, iron, vitamin C, vitamin B_6, and fruit exchanges, as well as a decrease in fat exchanges. A more positive nutrition attitude score was correlated with higher intakes of calcium, milk exchanges, and fruit exchanges. Iron status improved with an increase in Hb, Hct, and a decrease in serum TfR. Additional studies to evaluate body composition and iron status in relation to dietary intake in female collegiate swimmers are warranted.

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APPENDIX A: ANTHROPOMETRIC MEASUREMENTS

Body circumferences:

Measurements should be taken with the subject standing and weight evenly distributed, heels together, abdomen relaxed. The circumferences are taken on a horizontal plane with a flexible, non-elastic tape measure. The waist circumference is made below the rib cage and above the umbilicus at the narrowest site. Hip circumference should be measured at the site of greatest circumference around the hips and buttocks. Upper arm circumference is taken at the midpoint between the acromial process of the shoulder and the elbow. Calf circumference is measured at the widest girth.

Skinfold Thicknesses:

The subjects should be standing and relaxed. All measurements should be repeated two to three times and an average used. The triceps fold should be measured vertically at the back of the upper arm halfway between the tip of the shoulder (acromial process) and the tip of the elbow. The biceps fold is measured at the same level as the triceps over the anterior portion of the arm. The subscapula measurement is an oblique fold just below the tip (interior angle) of the scapula. The suprailiac is also a slightly oblique fold measured just above the hip bone with the fold lifted to follow the natural diagonal line at this point. The abdomen is measured vertical approximately 1 inch from the umblicus. The thigh fold is measured vertically at the midpoint of the thigh between the knee cap and the inguinal crease of the hip. The calf fold is measured about 1 cm proximal to the point of maximal calf girth on the lateral side of the leg.

APPENDIX B: HEALTH AND MEDICAL HISTORY QUESTIONNAIRE

Wellness Center
Student Health Center, Room 2015
Iowa State University
Ames, Iowa 50011
(515) 294-1868

Subject ID:
Name:
Address:

Telephone:
Date of Birth:
Date of interview:

Health and Medical History Questionniare

I. Overall Health

A. How would you rate your present health condition?
1. Poor______ 2. Fair________ 3. Good _______ 4. Excellent ________
B. How many days in the past six months have you been sick enough to stay in bed?
__________ Please explain____

C. Weight History
1. Usual weight range _________________
Recent increase/decrease in weight?__________ Amount_____________
Time Course________________
Reason____
2. What were your **maximum** (non-pregnant) and **minimum** weights as an adult and how old were you?
Maximum weight & age______ Minimum weight & age________________
3. What is your **desired** weight for the present?______________________

D. Do you have an eating disorder, such as anorexia or bulimia?
1. No, never______2. Not now, but previously_____3. Currently_______
Explain:____

E. Smoking History: 1. No, never _________2. Not now, but ______ no. years ago for ______ years 3. Yes, currently smoking for ______ years:______no of packs or cigs per day

II. Reproductive Health

A. Menstrual History
1. Age of menarche (start of menstrual cycle) in years ___________
2. List any comments relating to irregular periods:_______________________
3. Are you or have you been amenorrheic for reason other than pregnancy?
____
4. How often are your menstrual periods?____________ How many days do they last?__________________
5. Do you have a history of premenstrual syndrome or tension?_____________________________________

B. Oral Contraceptive (OCA) Use
1. Never ________ 2. Yes, in the past ________ at what age(s)? __________ & how long ______________
3. Yes, currently ________ If yes, reason for taking __________________
Type (name) of OCA ________________________
Dosage ____________ & how long ______________

III. Bone Health

A. Have any members of your family had osteoporosis or crush fractures (i.e., unexplained fractures,
"humped back", wrist fractures, hip fractures, etc.)? Please explain.
1. No awareness _________ 2. Possible____________ 3. Definite_________
One close relative ___________ More than one close relative __________
Other ______________

B. Have you ever had any type of bone fracture? Explain _______________

C. Have you modified your diet as a preventive measure against bone disease?
Explain_______________________

D. Have you ever had your bone mineral tested? ________________
1. If yes, do you know what type of analyzer was used?__________________
2. For your age, do you know if your bone mineral was: above________
below_______ or average________

IV. Medical History

A. **Allergies/Asthma**
1. No____ 2. During childhood___ 3. Yes, since childhood___ 4. Yes, since adulthood___
Explain____
Type of Medication(s)____
Current dosage_________________ Years taken______________________
Ever taken steroids (i.e., prednisone)?________________________
Long term antibiotics (i.e., tetracycline)?______________________
How does this condition affect your activity?_________________________

B. **Arthritis**
1. No __________2. Yes _________
Type____
Type of Medication(s)____
Current dosage______________ Years taken________________________
Ever taken steroids (i.e., prednisone)?________________________
How does this condition affect your activity? ________________________

C. **Cardiovascular Disease (HTN, ↑Lipids, CAD)**

Personal history of cardiovascular problems:
1. None known______ 2. Yes ____________ Kind?___________________
3. Yes: uncontrolled__________4. Yes: modified diet___________________
5. Yes: medications_____________6. Yes: surgery______________________
7. Do you know your most recent blood pressure?_______________________
8. Yes: exercise program______________9. Yes: combined program______
Give details____
Type of Medication(s) ____
Current dosage________________ Years taken_____________________
How does this condition affect your activity?_________________________

Family history of cardiovascular disease
1. None ____________________________
2. One parent ____
3. Both parents ____

Comments_______________

D. **Cancer**

Personal history of cancer: 1. No________ 2. Yes__________

If yes, when?______________________

Type ______________________

Medication or Treatment ______________________

E. **Diabetes**

1. No record or indication__________ 3. Yes, well controlled__________
2. In past, but not now __________ 4. Yes, not controlled__________

Explain______________________

Type of Medication(s) ______________________

Current dosage__________ Years taken______________

How does this condition affect your activity?______________

F. **Gastrointestinal/Digestive Problems**

1. No record or indication______ 3. Yes, well controlled__________
2. In past, but not now ________ 4. Yes, not controlled__________

Explain______________________

Type of Medication(s) ______________________

Current dosage__________ Years taken______________

Ever taken steroids (i.e., prednisone)?______________

Currently taking antacids?______________

How does this condition affect your activity?______________

G. **Kidney Disease/Problems**

1. No record or indication_______3. Yes, well controlled__________
2. In past, but not now ________4. Yes, not controlled__________

Explain______________________

Type of Medication(s) ______________________

Current dosage__________ Years taken______________

How does this condition affect your activity?______________

H. **Liver Disease/Problems**

1. No record or indication__________3. Yes, well controlled__________
2. In past, but not now ________ 4. Yes, not controlled__________

Explain______________________

Type of Medication(s) ______________________

Current dosage____________ Years taken______________

How does this condition affect your activity?______________

I. **Parathyroid Disorder**

1. No record or indication________3. Yes, well controlled__________
2. In past, but not now _________4. Yes, not controlled__________

Explain______________________

Type of Medication(s) ______________________

Current dosage___________Years taken______________

J. **Respiratory Problems**

1. No record or indication_____ 3. Yes, well controlled__________
2. In past, but not now ________ 4. Yes, not controlled__________

Explain______________________

Type of Medication(s), such as steroids (i.e., prednisone)______________

Current dosage____________ Years taken______________

How does this condition affect your activity?________________________

K. **Thyroid Disorder**

1. No record or indication____________ 3. Yes, well controlled_____________
2. In past, but not now _____________ 4. Yes, not controlled______________

Hyper?_______________ Hypo?_______________

Explain____

Type of Medication(s) ____

Ever taken thyroid hormones (i.e., Synthroid)?__________________

Current dosage________________ Years taken______________________

How does this condition affect your activity?_________________________

IV. Medication or Drug Use

A. Previous or Present Use of Any of the Following (Specify):

1. anabolic steroids_______________ other steroids or hormones_____________
2. antacids______________________ other G.I. medications_________________
3. tetracycline antibiotics__________ other antibiotics_______________________
4. anticonvulsants________________ other meds for seizures________________
5. corticosteroids or glucocorticoids__________prednisone__________________
6. thiazide diuretics _______________ other diuretics ________________________
7. lipid lowering drugs _____________ others ______________________________
8. additional medications or drugs

____

APPENDIX C: NUTRITION HISTORY QUESTIONNAIRE

Wellness Center
Student Health Center, Room 2015
Iowa State University
Ames, IA 50011
(515) 294-1868

Subject ID:________________
Name:___________________
Address:________________
____
Telephone_______________
Date of Birth:
Interviewer:_______________
Date of interview: __________

NUTRITION HISTORY QUESTIONNAIRE

Modified/Specialized Diet(s) Followed Presently:

Type of diet:____

Reason for modified/specialized diet: ___________________________________

Recommended by____________ Length of time followed_________________

Indicate if you are: ___Non-Vegetarian ___Vegetarian: ____Lacto ____Lacto-Ovo ___Pure Vegetarian

Do you modify your diet due to religious reasons? _________________________

How would describe your diet?____

Food Patterns and Problems:

How many meals do you eat each day?______ How often do you eat between meals?_____________

How often do you skip meals? _______________________________________

Have you had recent changes in your appetite?______ Due to_______________

What foods do you avoid?____

Due to____

Do you have a history of problems digesting milk?_____ When?______

How long?_________

Have you been diagnosed with lactose intolerance?________ When?_________

By whom?__________________________

Have you been diagnosed with a food allergy?____________________________

Intake of Fats and Oils (past year):

How often do you consume fried foods?_________________________________

How often do you consume fast food?___________________________________

How often do you consume convenience snack foods?________________________

How often do you use the following as condiments (excluding fat free versions):

Butter/Margarine (Type, Amount, Times/Week or Month):___________________

Mayo/Salad dressings (Type, Amount, Times/Week or Month):_______________

Vegetable oil (Type, Amount, Times/Week or Month): ______________________

Nutritional Supplements (Type, Dose, Times/Week, No Years):

Vitamin Supplements____

Mineral Supplements____

Vitamin/Mineral Supplements____

Other Supplements (e.g., cod liver oil, protein powder)_______________________

DAILY INTAKE *(Typical Weekday)*

Time	*Food/ Description (ingredients, preparation method)*	*Serving Size*

Sodium Intake (Amount of Salt Used/day): in cooking___________
at the table____________ **TOTAL** ____________

Beverages Consumed (Servings or cups per day):

Coffee: reg________ decaf__________ ***Cocoa***:__________
Tea: reg__________ decaf/herb _________
Soda: reg(+caf)_________ diet(+caf)__________ reg(caf free)___________
diet(caf free)____________
Milk (cups/day): reg(3.5%)______ low fat(2%)____ skim(1% or <1%)_________

During what period(s) of life have you been a milk drinker? *(Check all that apply)*

_____1. Child _____2. Teenager _____3. Young adult (20-29)

_____4. Adult (30-39)_____5. Middle-aged adult (40-59) _____6. Never

If you excluded milk during any part of your life, was (is) this due to digestive problems? (Explain): ____

Milk (cups/day): child_______ teenager_______ young adult (20-29)_______
adult (30-45)_______ present _______

Yogurt (cups/day): child_______ teenager_______ young adult (20-29)_______
adult (30-45)_______ present________

Juice (Specify type & cups/day): ____________________________________

Calcium-Fortified Juice (Specify type & cups/day): ________________________

Other: ____

Alcoholic Beverages (yes/no): ___________ If yes, please specify:

	Type	Times/Week or Mo	Serving Size	No Servings	Total/Week or Mo
Beer:	Reg				
	Lite				
	Dark				
Wine:	White				
	Red				

Rose

(Blush)

Mixed Drink (specify):

Other (specify):

How did your food or beverage intake differ from the above during your childhood and teenage years?

APPENDIX D: LATE SEASON QUESTIONNAIRE

Name_______________________________

How would you rate your present health condition?
1. Poor_____ 2. Fair ______ 3. Good _________ 4. Excellent ________

How many days since the beginning of the swim season have you been sick enough to stay in bed? _________Explain____

Have you experienced either irregular or absent menstrual periods during your swim season?________ Explain ____

If you suffer from premenstrual syndrome or tension, have you noticed any changes throughout this swim season? Explain ____

Have you had any changes in oral contraceptive use since the start of your swim season?_______Explain ____

What is your desired weight for the present? ______________

How many meals do you eat each day? __________ How many snacks?_______________
How often do you skip meals? __________________________

Have you had any recent increases or decreases in your appetite?___________________
Explain__________________________ Due to ________________________________

As a result of nutrition counseling/education, what changes have you made in your food intake? Please check the appropriate column and circle daily or weekly:

	More	No change	Less
Daily or weekly servings of dairy foods	____	________	____
Daily servings of breads/cereals/grains	____	________	____
Daily or weekly servings of fruits	____	________	____
Daily or weekly servings of vegetables	____	________	____
Daily or weekly servings of meat/protein foods	____	________	____
Daily or weekly servings of sweet/sugary foods or beverages	____	________	____
Daily or weekly servings of high calcium foods	____	________	____
Daily or weekly servings of high fiber foods	____	________	____
Daily or weekly servings of high fat foods	____	________	____

Are there any changes you have made in your food intake that are not listed in the table above? ______Explain____

DAILY INTAKE (Typical Weekday)

Time	Food/Description (ingredients, preparation methods)	Serving Sizes

Read the following statements and check the box that best describes your attitude towards the statement throughout your swim season:

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
It is difficult for me to gain access to nutritious foods.					
I have nutritious foods available to me when I am hungry.					
Eating a nutritious diet is important in preventing disease.					
I should be concerned about the foods I eat, even if I take vitamin and/or mineral supplements.					
Eating vegetables and fruits will not improve the nutritional quality of my diet.					
I make an effort to include adequate amounts of vegetables and fruits in my diet to improve its nutritional quality.					
I consume too many sweets and/or soda pop.					
I consume adequate sources of dietary calcium.					
I consume too many high fat foods.					
Eating a healthy diet has improved my performance.					
Consuming a nutritious diet off-season will affect my athletic performance next season.					
Eating adequate carbohydrates will help enhance my performance.					
Eating a nutritious diet is not an important part of my training regimen.					
Drinking adequate amounts of fluid benefits my athletic performance.					
I realize that I need to consume lots of food to meet my energy demands during season.					
My caloric intake is inadequate during training to meet my increased needs.					
I plan to eat a healthy diet off-season.					
I do not make an effort to consume adequate amounts of fluids.					
I have modified my diet to help enhance athletic performance during this swim season.					

APPENDIX E: USE OF THE TWO-DIMENSIONAL FOOD PORTION VISUAL

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USE OF THE TWO-DIMENSIONAL FOOD PORTION VISUAL

The correct use of the Food Portion Visual (FPV) is important to assure accurate and reliable estimates of portion sizes from your food records. The FPV has two sides, each of which contains a specific set of visual shapes. Edible portions of foods may be measured by volume in fluid ounces (Side A), by weight in ounces or grams (Side B), or in standardized portions. Visuals are not intended to depict any one food, but rather each model is designed to represent the portion size of many foods. A letter/number code (i.e., A2, B3) for each model may be used to simplify recording. For example, to describe a medium sized biscuit, you could indicate: *biscuit -B2.*

Side A of Food Portion Visual -Volume Models

Side A of the FPV contains shapes for estimation of food portion sizes that are measured in fluid volume. *Quarter (1/4), half (1/2), and three-quarters (3/4)* marks appear on several of the volume models to help you indicate what portion of the full container you consumed. The top mark indicates a full glass, bowl, or cup. Various sizes and shapes of glasses are represented by A4, A5, A6, A7, and A8; bowls are represented by All and A15; cups are represented by A9 and AlO; spoons are represented by Al, A2, and A3. The mounds (Al2, Al3, A16, and A17) should be used for foods that are served on a plate. For example, to describe a medium plate of pasta with sauce, you could record: *spaghetti -A13* and *tomato sauce - 1/2 A9;* a *scoop of ice cream - A17.* The wedge models (A14, A18, A19) should be used for foods that are served by wedges (i.e., pies and some cakes). The following list indicates those foods which should be estimated using Side A:

<u>Volume Models (Side A)</u>
Baked Goods (pies, layered cakes)
Beans or Peas (chili, lentils)
Beverages (milk, cream, coffee, tea, juice, soda, beer, wine, mixed drinks, other beverages)
Butter, Margarine, Peanut Butter
Canned Goods (fruits, vegetables, soups)
Casseroles, Stews
Cereals (cooked, ready-to-eat)
Cheeses - soft (cottage, cream, ricotta) and grated (pannesan, roniano)
Condiments (catsup, powdered creamer, salt, sugar, soy sauce, chutney)
Frozen Desserts (ice cream, ice milk, frozen yogurt, sherbet)
Fruits - frozen and canned
Grains (rice, barley)
Mayonnaise, Salad Dressing, Sauces, Gravy

Nuts, Seeds (peanuts, almonds, cashews, sunflower seeds)
Snacks (chips, pretzels, popcorn)
Vegetables - canned, fresh cooked, frozen cooked, raw (i.e., salads)

Side B of Food Portion Visual - Weight Models

Side B of the FPV contains shapes for estimation of food portion sizes that are measured in weight. The weight side depicts discs (Bl, B2, B3, B4, *B5),* squares (B1, B2, B3, B4, *B5),* rectangles (B1, B2, B3, B4, B5), and a sphere (B6). The size of the food you consume may be described by using any of the discs, squares, or rectangles. Note that the disc, square, and rectangle in the same vertical column each have identical letter/number codes since they represent the same weight (disc Bl = square B1 = rectangle B1). Although these models do not resemble any meat you've ever eaten, they should be used to estimate edible portions of meats, fish, cheese, and some breads and cakes. For these foods, you will need to indicate the disc, square, or rectangle that most closely resembles your portion size (B1, B2. B3, etc.). To estimate the thickness of the food item, use the measure bars (1 through 6) in the upper left corner of Side B. It is important to indicate whether you have consumed the meat with or without the fat since this will greatly influence the calculations. For example, to describe a piece of meat that approximates the square B4 and is the thickness of measure bar *5,* you would record: *steak without fat - square B4 X 5.* The following list indicates those foods which should be estimated using Side B:

Weight Models (Side B)
Baked Goods (biscuits, pancakes, muffins, quickbreads, rolls, crackers, cookies, sheet cakes)
Cheeses - hard (brick, cheddar, mozzarella, muenster, Swiss, etc.)
Cold Cuts, Sliced Meats, Sausage
Meats: Beef, Lamb, Pork, Fish, Poultry (except parts)

Standardized Portion Sizes
Standardized portion sizes should be used to describe the foods you consume whenever possible. For example, to describe a dinner including a pork chop, baked potato, brussel sprouts, carrot sticks, canned pears, and a glass of milk, you would record: *1 pork chop (without fat), 1 medium baked potato with soft tub margarine - Al, 6 brussel sprouts, 1 raw carrot, canned pears in light -syrup (with juice) - 2 halves, 2% milk - A8 X 1.5.* The following list indicates foods that are described in standardized portions:

Standardized Portion Sizes
Bacon - commercial slices
Baked Goods (bagels, commercial crackers, donuts, English muffins, tortillas, waffles)
Bread - commercial slices
Cheese - commercial slices (American)
Chicken Parts (breast, leg, thigh, wing)
Eggs
Fish (sardines, shellfish, sticks)
Fresh Fruit
Hotdogs

Lamb Chops
Pork Chops
Pot Pies
Vegetables . whole (asparagus spears, brussel sprouts, carrot, celery stalk, potato, tomato, etc.)

Please do not hesitate to call *[(515)* 294-1868] if you have questions as you are keeping your food diaries. You should leave a voice mail message and a nutritionist will be glad to return your call ASAP. Remember, the more accurately you record your food intake, the more accurate will be the results you receive from your dietary analysis.