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THE FREQUENCY OF ANEMIA ASSOCIATED WITH AEROBIC ACTIVITY

A Thesis

Presented for the

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Degree

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Brett J. Berry

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ABSTRACT

The purpose of this research project was to analyze hemoglobin concentration and daily iron intake for two different groups. The "high activity" group consisted of subjects who exercised aerobically four or more hours per week, whereas the "low activity" group consisted of subjects who exercised aerobically less than one hour per week. There were twenty males and twenty females in each group. The hemoglobin concentration was determined from a finger capillary blood sample. The iron intake was determined by analyzing a three day food record for daily ingested iron. The frequency of anemia in the "high activity" group was significantly greater than in the "low activity" group. There was no significant difference in the frequency of anemia when comparing females from the "high activity" to the "low activity" group. The hemoglobin concentration in males was significantly lower in the "high activity" (13.8 gm/100ml) compared to the "low activity" (15.4 gm/100ml) group, $t(38) = 4.28$, $p<.001$. There was no significant difference in the hemoglobin concentration between females from the "high activity" to the "low activity" group, $t(38) = 0$. There was no significant difference for males when comparing iron intake between the "high activity" and the "low activity" group, $t(30) = .29$. There also was no significant difference in iron intake for

females when comparing the "high activity" to the "low activity" group, t(33) = .52. The findings from this study indicate that "sports anemia" may be a problem among male athletes who exercise aerobically for more than four hours per week. It also suggests that the condition of "sports anemia" is more prevalent among males than females. It may be prudent for aerobically active males to have their hemoglobin concentration checked periodically for the condition of "sports anemia."

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CHAPTER I

INTRODUCTION

Background

In recent years the term "sports anemia" has emerged from obscurity to prominence. The changing exercise habits among the athletic population may be the reason for this change. With a high aerobic capacity being a most important outcome of an exercise program, it is easy to see why anything that would disrupt oxygen utilization would need to be examined.

Oxygen is carried by hemoglobin in the blood from the lungs to the working muscles. A low hemoglobin level would result in less oxygen being carried to the working muscles, resulting in suboptimal performance. Raw (1975) reported that an abnormally low hemoglobin content in blood can result in overall muscle weakness, heart pain (on exertion), and a general fatigue. Anemia could be a limiting factor in activities that depend upon a substantial rate of oxygen utilization.

In recent research Pate (1983) defined "sports anemia" in the following manner; hemoglobin concentration less than 14 gm/100ml for men, and 12 gm/100ml for women. Anything below these levels is also considered clinical anemia. A condition of clinical anemia will impair performance in aerobic type activities. However, it has been suggested by Pate (1983), that to follow the clinical anemia standards as the standards for "sports anemia" is a major mistake. Optimal viscosity of blood has been shown to be as high as 50% to 60% hematocrit in animal models, which corresponds to a hemoglobin concentration of 18 to 21 gm/100 ml. Pate classifies suboptimal hemoglobin level as anything below the population means, 16 gm/100ml for men, and 14 gm/100ml for women. Hemoglobin values below these levels could possibly impair aerobic performance.

There seems to be three possible causes of "sports anemia": plasma volume expansion, reduced hemoglobin synthesis and/or erythropoiesis, and increased destruction of red blood cells (Pate, 1983). In practical situations, the need for identifying the cause is not as important as diagnosing the anemia and correcting the condition. An increase in performance and a general overall better feeling should result when an anemic condition is corrected. The fact that "sports anemia" is apparent in a small percentage of individuals presents a problem with diagnosis. In the aerobic exercising population, anemia is also a factor that is not initially considered when the symptoms occur. Anemia and its symptoms could be factors associated with a decrease in performance and motivational setbacks that accompany aerobic exercise.

Changing exercise habits among the normal population has shifted the emphasis of fitness from sport skill acquisition to aerobic activities. Pate (1983) states that changes in exercising habits have led to the widespread recognition of many clinical conditions that were previously overlooked, with one such condition being "sports anemia." Since low hemoglobin levels are associated with anemia, a decreased capacity to carry oxygen to the working muscles is inevitable.

In contrast to Pate (1983), Williamson (1981) stated that the borderline anemic state is optimal for oxygen transport, and that the factors governing red blood cell production are fine tuned to meet the daily stresses the athlete imposes on his body. He added that a hematocrit level of 40%, hemoglobin 13 gm/100ml of blood, is optimal for oxygen transport. Pate (1983) reported that cardiovascular physiologists have tended to agree that the optimal hematocrit level is near the upper end of the normal range, i.e. near 45%. A hematocrit level of 45% corresponds to a hemoglobin concentration of 16 gm/100ml of blood.

Purpose

The general purpose of this study was to determine whether the frequency of anemia was different for "high activity" groups when compared to the "low activity" groups. A secondary purpose was to determine whether there was a significant difference in hemoglobin levels between "high activity" and "low activity" groups. Dietary iron intake from both groups was analyzed to see if this factor was related to any differences in the frequency of anemia in the above populations.

Hypotheses

1. The frequency of anemia in the "high activity" group will be significantly greater compared to the "low activity" group.
2. The hemoglobin concentration in the "high activity" group will be significantly lower compared to the "low activity" group.
3. There will not be a difference in iron intake between the "high activity" and "low activity" groups.

Operational Definitions

1. Sports Anemia - Hemoglobin levels less than 14 gm/100ml of blood for men, and 12 gm/100ml for women, Pate (1983).
2. Hemoglobin - The iron containing protein in humans which is the oxygen carrier in blood, Raw (1975).
3. "high activity" group - individuals who participate in aerobic activities four or more hours weekly.

4. "low activity" group - individuals who participate in aerobic activities less than one hour weekly.
5. Clinical Anemia - see sports anemia.

Assumptions

In this research project the following assumptions were made; (a) the subjects honestly and correctly filled out the identification form prior to being tested; (b) that the subjects honestly and correctly performed a Food Record Form; (c) if the subject was anemic, that it was not due to medical complications; (d) that hemoglobin levels were indicative of oxygen carrying capacity, and were related to the ability of the blood the deliver oxygen to muscles.

Limitations

In this research project the following limitations were made; (a) the "low activity" group, individuals who participate in aerobic type activity less than one hour per week, consisted of, but was not limited to, subjects who were enrolled in selected undergraduate Physical Education activity courses at the University of Tennessee, Knoxville, i.e. bowling, weight training, golf, etc; (b) the inability to control variables that may have influenced the hemoglobin measurement, i.e. aerobic activity prior to testing, unknown iron supplementation in the diet, unknown medical complications that may have affected hemoglobin, etc.

Delimitations

In this research project the following delimitations were made; (a) the sample size consisted of twenty males and twenty females for both the "high activity" and "low activity" groups; (b) two distinct groups had their hemoglobin and dietary iron intake analyzed. This distinction is made on the difference in the amount of aerobic activity performed weekly; (c) a certain number of subjects came from undergraduate Physical Education activity courses at the University of Tennessee, Knoxville.

Importance of the Study

The major purpose of this study was to determine if there were a significant number of subjects in the "high activity" group who had hemoglobin values that were associated with clinical standards of anemia. A secondary purpose was to determine if hemoglobin levels are different for two distinct levels of participation in aerobic activity. Any significant differences in dietary intake of iron between the two groups were also analyzed.

Symptoms that are associated with anemia could eventually be corrected by seeking proper medical guidance. Muscle weakness, heart pain with physical exertion, and a general fatigue could be alleviated. Motivational problems associated with the above problems may also subside. The aerobically active individual, who once was clinically anemic, may find participating in aerobic activity somewhat more pleasant. Diagnosing "sports anemia" seems to be a procedure that is overlooked by many individuals who participate in aerobic activities. Discovering anemia and correcting the condition could bring about positive changes in an individual's exercise program.

CHAPTER II

LITERATURE REVIEW

Introduction

The first section of the review of the literature will be concerned with studies showing a decrease in hemoglobin due to exercise, and the negative effect of this on performance. The second section will emphasize studies in which a decrease in hemoglobin due to exercise is seen as an advantageous response. The final section will discuss the relationship between "sports anemia" and iron supplementation and nutrition. A summary will follow the final section of the review of the literature.

Chronic Exercise Decreases Hemoglobin and Performance

Blood loss associated with athletic participation has been documented for many years. Dickinson (1894) reported hematuria, blood in the urine, in 18 runners who completed a marathon race. The runners' urine samples were considered pathological due to the presence of red blood cells.

The majority of recent research in the area of "sports anemia" support Dickinson's findings that the hematological changes due to chronic exercise are a detriment to performance. Pate (1983) tentatively suggested these conclusions from these studies:

1. Mean hemoglobin concentrations are somewhat lower in endurance athletes than nonathletes.
2. The reported incidence of true anemia in the athletic populations is low, although the distribution of hemoglobin concentrations suggests that the incidence of anemia may be significant.
3. Many athletes, particularly those engaged in endurance activities, manifest hemoglobin concentrations that could be classified as suboptimal.

Pate is very specific when he discusses suboptimal hemoglobin levels for aerobic performance. He states that anything below the population means for hemoglobin, 16 gm/100ml for men and 14 gm/100ml for women, should be considered suboptimal. The problem with this statement is that what may be suboptimal for one person may not be for another. Since the hemoglobin concentration varies from individual to individual, it would seem very difficult to establish a single set of values to define suboptimal concentrations.

In a study by Davidson (1969) the predisposition of runners to hemolyze red blood cells in the capillaries of their feet was examined. In this study a group of runners, who had been identified as having elevated plasma free hemoglobin, reduced plasma haptoglobin, and hemoglobin in the urine, were compared to a group of runners who did not have these traits. The experimental group wore shoes in which blood from both the control group, placed in thin tubing in one shoe, and their own blood, placed in the other shoe, was analyzed for hemolysis. The control group wore shoes in which blood from both the experimental group, placed in thin tubing in one shoe, and their own blood, placed in the other shoe, was analyzed for hemolysis. During a three mile run the runners predisposed to hemolysis hemolyzed their own blood in addition to the control group's blood. The control group did not hemolyze their own red blood cells or those of the subjects with hemolysis. Davidson concluded that mechanical trauma was a cause of hemolysis. Davidson also reported many other cases, i.e. conga players, karate practitioners, soldiers, etc., who have had a significant decrease in hemoglobin possibly due to mechanical trauma. The issue that is presently open to discussion is whether or not a decrease in hemoglobin due to mechanical trauma can be extensive enough to cause anemia.

In a study by Martin et al. (1986) nine elite male distance runners were evaluated by monitoring selected blood chemistry variables and other physiological variables, i.e. cardiopulmonary performance, as they prepared for the 1984 Olympic Summer Games in Los Angeles. The authors found a reduction in two indices of iron stores and metabloism: serum ferritin (suggesting depletion of iron stores in bone marrow), and serum haptoglobin (suggesting intravascular hemolysis). The authors concluded that runners in serious training may deplete or lower their iron stores by five mechanisms. These mechanisms are:

1. Runners may consume less iron than untrained people.
2. Runners may lose a considerable amount of iron through sweat.
3. Myoglobin may be lost through renal filtration and excretion.
4. A possibility of hematuria may occur due to hemo-hemolysis and shunting-induced renal filtration with an increased glomerular pressure and hypoxia-induced glomerular permeablility.
5. An increased loss of blood may occur through the gastrointestinal tract in elite runners.

The above findings are limited to elite distance runners and ultimately cannot be generalized to the running population. The author's first explanation of iron depletion, runners consuming less iron than other people, is open to discussion. Elite runners, due to their large caloric expenditure, probably consume the recommended dietary allowance of iron. The cause of iron depletion for an elite runner, who is not on a restrictive diet, may be due to a reason other than nutritional, (Casoni et al., 1985), (Clement et al., 1982).

In a study by Casoni et al. (1985) blood samples were analyzed for hemoglobin, hematocrit, serum iron, and serum ferritin for the following groups of individuals; (a) 45 marathon runners, (b) 56 ultramarathon runners, and (c) 32 healthy sedentary subjects. The blood samples of the first two groups were drawn before and after competition in a run of each group's selected distance. The controls, the third group, also had their blood sampled at this time. The results showed that the hemoglobin concentrations and serum iron stores were lower in the runners than in the controls. The authors concluded that the lower hemoglobin in the runners may be due to the following reasons:

1. An increase in plasma volume rather than in red cell mass that has been documented in long distance runners.
2. The reduction of hemoglobin could be due to a reduced bone marrow erythropoiesis.
3. Intravascular hemolysis that occurred in the runners, and is suggested by the reduced haptoglobin concentrations.
4. A depletion of iron stores were also found among the runners, which is caused by a variety of reasons as suggested by Martin et al. (1986).

Even though the runners were on a diet rich in iron content, a reduction of iron stores were observed. The authors concluded that in runners, whatever the diet received, some iron deficiency occurs. This is in contrast to what Martin et al. (1986) concluded concerning iron ingestion in the diet of elite athletes.

In the above study by Casoni et al. (1985) there are two distinct areas in which conflicting findings are apparent. In the study by Martin et al. (1986) a high reticulocyte count was found in nine elite distance runners, which is suggestive of a positive erythropoietic response. This finding is the opposite of what Casoni et al. (1985) reported. In a study done by Ohri et al. (1983) the immediate effects of submaximal exercise (85% of maximal) on hemoglobin, hematocrit, platelet count, platelet aggregation and blood fibrinogen levels were examined. An increase in hemoglobin of 3.64% was found from pre to post exercise. This was due to the initial decrease in blood and plasma volumes, as reported by Kaltreider et al. (1940). In the study by Casoni et al. (1985) a lowered hemoglobin level was found in the runners after competition, which is the opposite of what Ohri et al. (1983) reported.

In contrast to the study by Ohri et al. (1983) is the study done by Oscai et al. (1968). In this study a group of men were put through 16 weeks of running on a regular basis. A increase in plasma volume, not equated with an increase in red blood cell mass and hemoglobin, was reported. These findings are similar to the results of Casoni et al. (1985). Pate (1983) reports that in some athletes, training may result in a greater increase in plasma volume than total hemoglobin. The issue at hand is that endurance runners seem to have an increase in total blood volume. This would ideally lead to an increase in stroke volume and maximal cardiac output. Pate (1983) reports that the reduced hemoglobin concentration and reduction in the blood's oxygen carrying capacity seem to offset this ideal increase in total blood volume. Pate further adds that the gross training response would be enhanced by avoiding the dilution of hemoglobin. This may be accomplished by iron supplementation.

In a study by Frederickson et al. (1983) the effects of a competitive season of cross country running on hemoglobin and packed red blood cell volume were analyzed. Blood was sampled at weeks 0, 1, 2, 4, and 8 of the competitive season and at weeks 1, 5, and 11 after the season. A control group of nonrunners also participated in this study. During the cross country season a training effect, signified by an increase in VO_2 max, was recorded for the runners. This was accompanied by a condition of "sports anemia." As a group, the runners hemoglobin concentration decreased significantly by 8.3%. The nonrunners did not show these results. The authors also found a subsequent increase in hemoglobin during detraining, back to preseason levels. The authors concluded that recovery from "sports anemia" may impose a demand on iron reserves, thus it may be prudent to assess iron status as well as hematological status before and during aerobic training.

The problem with the above study is the fact that the authors address the issue of "sports anemia" as a team or group reaction. There is the possibility that certain runners in the study never experienced "sports anemia." The authors also do not confront plasma volume changes as a possible cause of an increase or decrease in hemoglobin concentration.

A study by Falsetti et al. (1983) suggests that red blood cell indices may be decreased due to the hardness of the sole in a shoe a runner may wear. In this study 23 marathon runners had their blood samples analyzed prior to being assigned to a specific group. Two groups were formed in this study; (a) those who trained in a firm-sole running shoe, and (b) those who trained in a soft air-cushioned shoe. The subjects were randomly assigned to the above groups. The two groups trained in their respective shoes for three to four weeks before blood values were recorded. On the day of blood measurements both groups completed a 15-mile run on asphalt. The results showed a greater decrease in haptoglobin levels in the firm-shoe group than in the air-sole group. This finding suggests that running in air-sole shoes may actually decrease the hemolysis acquired in a running workout. The authors concluded that the air-cushioned shoes may diminish the effects of acute mechanical damage on red blood cells.

The authors of the above study did not evaluate the distance run by each individual during the pre blood measurement. There may have been mileage differences between individuals within each group during the three to four weeks prior to the blood sampling. The authors did not state whether the group's mileage was similar. This may present a problem when determining mechanical damage from one single blood measurement.

In a study done by Stewart et al. (1985) the magnitude of gastrointestinal bleeding among runners was examined. In this study a recently developed assay, termed HaemoQuant, was used to measure fecal hemoglobin. Stool specimens were collected from 24 runners who averaged approximately 40 miles of running per week, 24 to 48 hours before and for 5 consecutive days following a 6.2 to 26.2 mile race. Two stool samples were also collected on nonrunners who served as the control group. A blood sample was also taken from each runner after running and during the week following the race. A blood sample was taken from the control group within one week of the stool collection. The authors found mean fecal hemoglobin levels significantly increased in the runners from pre to post race as compared with the controls. Mean hemoglobin and hematocrit levels were significantly lower in the runners as compared to the nonrunners. This is suggestive of the findings by Pate (1983) and Casoni et al. (1985). The authors concluded that endurance training may cause gastrointestinal blood loss which could contribute to the anemia or iron deficiency noted in some endurance athletes. In their findings however they did not address the issue of frequency of anemia among the running group. This finding may only be applicable to certain individuals.

Some past studies on hemoglobin values in the exercising population have dealt specifically with Olympic teams. A study by Clement et al. (1977) analyzed, prior to the Olympic games, the hemoglobin values of the entire 1976 Canadian Olympic team. Mean values for each sport were calculated as was an overall average for the entire team. When compared to the Canadian general population, Australian Olympic team and Dutch Olympic team, the Canadian Olympic team, for both male and female athletes, had significantly lower hemoglobin values. The authors further stated that certain members of the Canadian Olympic team, who had hemoglobin levels below suboptimal levels, all performed poorly. The authors added that suboptimal hemoglobin values were less than 16 gm/100ml for men and 15.1 gm/100ml for women. The authors concluded that the suboptimal hemoglobin values for these athletes may have been due to inadequate dietary intake of protein and iron.

The above study tried to pinpoint the values which are to be considered suboptimal hemoglobin concentrations. This is similar to what was done by Pate (1983). The problem with this is that what may be suboptimal for one individual may not be for another. Clement et al. (1977) also point to an inadequate intake of dietary iron and protein as a possible cause for the Canadian athletes' lower hemoglobin values. This is interesting considering the authors had no information available on the actual diets of the Canadian Olympic team. It has been shown (Stewart et al., 1972) that athletes in training do not have an inadequate dietary intake of iron and protein.

In a study done by Stewart et al. (1972) the hemoglobin concentration and iron and protein intake of Australian Olympic athletes were examined. One week before the 1968 Olympic games began, 44 athletes had their hemoglobin analyzed and participated in a seven-day dietary recall. The authors found a significantly lower hemoglobin level in athletes who were to participate in events requiring greater endurance; track events greater than 800 meters, cycling, rowing, canoeing, pentathlon, boxing, hockey and basketball. The authors added that athletes who competed in the above events, and had suboptimal hemoglobin levels, performed poorly. The suboptimal hemoglobin levels were listed as less than 14.6 gm/100ml for women and less than 15.8 gm/100ml for men. The authors stated that none of the athletes in the study manifested anemic hemoglobin concentrations. They further added that iron and protein intakes were adequate in the athletes who were classified as having suboptimal hemoglobin levels.

In the above study the authors performed dietary recalls on the Olympic athletes while in Mexico City and who were under the supervision of the Australian coaches, trainers, etc. The athletes were only in Mexico City for one week prior to the games. In Australia the athletes may have been responsible for their own diet. Since anemia, or nutritionally affected hemoglobin values, is not an overnight occurrence, it may have been more appropriate to obtain dietary recalls when the athletes were eating on their own. The authors' findings are consistent with studies mentioned previously in erroneously classifying specific hemoglobin values as suboptimal.

In a study done by Radomski et al. (1980), hematological variations were observed in physically fit soldiers. Twenty-one soldiers marched 35 km a day for six days, working at 35% of their VO2 max. The workload was achieved by adjusting the weight of the backpack in each individual soldier. After four days of marching, significant decreases in hemoglobin, hematocrit and in red blood cells were recorded. These decreases continued to occur past day six of the march. During the post-march period, which consisted of two days of recovery, an increase in red blood cells and hematocrit values were observed with further decreases in hemoglobin values. The authors added that the hemoglobin values continued to decrease throughout the recovery days, and was 12% lower on the last recovery day when compared to the first day of exercise. The authors concluded that "sports anemia" clearly can occur from sustained and repetitive submaximal exercise. They further added that it would appear essential to maintain or elevate hemoglobin levels in order to increase physical endurance and subsequently delay the onset of fatigue.

In the above study the daily exercise performed by the soldiers was much greater than the average exercising individual. The findings of the above study would be very hard to generalize to a larger population. The authors had a perfect opportunity to analyze physical performance in relation to a decrease in hemoglobin during this controlled march. It would have been interesting to see the effect of the lowered hemoglobin concentrations on physical performance. One distinct finding had to do with the fact that hemoglobin values continued to drop after exercise and into recovery. An athlete may think they are recovering from training while their hemoglobin concentration may actually be decreasing.

In a study by Rushall et al. (1980) hemoglobin variations of nine elite Canadian swimmers were analyzed during hard training, taper and rest. The results indicated a decrease in hemoglobin values during the hard training period. These lowered hemoglobin values returned towards normal levels during the taper off and rest period. The authors suggested that increased hemoglobin values in taper and rest could serve as an index of recovery from hard training. The authors added that six out of seven athletes measured after competition had higher hemoglobin values than those recorded during rest and taper. The authors added that the swimmers may not have achieved their best state, in terms of hemoglobin concentrations, until after competition.

In a second study done by the same authors the hemoglobin values of 37 elite swimmers, 18 males and 19 females, were recorded during maintenance training and taper during training camp for the Commonwealth Games. The results were not as clear cut as in the previous study. The authors concluded that both the males and females had erratic responses, and the results did not follow what was anticipated.

The above study exhibited the problems in evaluating the hemoglobin values of individual athletes. This may be the reason why the majority of the previously mentioned studies measured hemoglobin concentrations as a group. It also gives merit to the findings by Radomski et al. (1980) in which hemoglobin values continue to decrease even after rest has begun.

In reviewing the literature some interesting animal studies were found on the effect of anemia on physical performance. In a study done by Edgerton et al. (1972) the effect of induced anemia on physical performance in rats was analyzed. White rats were made anemic with an iron-deficient diet or by injections of a hemolytic agent, phenylhydrazine. The capacity of rats to run to exhaustion on a motor driven treadmill was observed after anemia had been determined. The results showed that the capacity of the rats to endure this run was directly related to their hemoglobin concentration and packed cell volume. On each occasion the rats ran for a significantly shorter time than did a group of rats which served as controls. The authors also found that the anemic rats, which were housed individually in cages with an activity wheel, were less active than their controls. This was evaluated by using a revolution counter on all the activity wheels. In this study, characteristics of individual rats, running ability, diet, weight,etc., were all controlled.

In another animal study (Clarkson, 1968) the hemoglobin values from winning racehorses were analyzed. After numerrous values were obtained, Clarkson acquired hemoglobin values from a general population of racehorses. The findings indicated that winning racehorses had a significantly higher hemoglobin concentrations than did the racehorses from a general population.

The problem with animal studies is the skepticism that is present when generalizing the findings to a human population. The first study did achieve a highly controlled setting, which is a advantage when observing the effects of anemia on physical performance. This is unlike many of the previously mentioned human studies in which control of the experiment was lacking. However, the second animal study lacked control conditions.

Many studies have analyzed the effect of reinfusion of red blood cells, "blood doping," upon physical performance. The vast majority of these have shown an increase in aerobic performance after the reinfusion of the blood. With the addition of red blood cells comes an increase in hemoglobin. It is for this reason some of the "blood doping" studies will be discussed in this review of the literature.

In a study by Williams et al. (1981) the effects of red blood cell infusion on 5-mile treadmill time and rated perceived exertion were analyzed. Twelve long distance runners undertook a series of four competitive 5-mile time trials on a treadmill. Four infusion conditions were utilized: pre-saline trial, post-saline trial (after 920 ml equivalent of saline solution), pre-blood trial, and post-blood trial (after 920 ml equivalent of whole blood). The results indicated the following when comparing the blood infusion trial to the other three trials:

1. A significantly higher hemoglobin level after whole blood infusion.
2. A significantly lower rated perceived exertion after the infusion of whole blood.

3. A significantly faster 5-mile treadmill time after the infusion of whole blood.

The authors concluded that the infusion of 920 ml of whole blood would increase performance in aerobic events.

In a study done by Freedson et al. (1981) the relationship between cardiac output and hemoglobin was analyzed. Twenty-eight females performed submaximum exercise on a cycle ergometer. A positive correlation between cardiac output and hemoglobin was observed when the subjects exercised at 88 Watts. However, a positive correlation was not observed when the influence of stroke volume was removed. In a second experiment the authors compared the VO2 max and cardiac output of 6 male subjects before and after blood donation. The subjects performed submaximum exercise (118 Watts) before and after giving blood. The findings showed that a mean decrease in hemoglobin of 18.6% caused a 6.2% decrease in VO2 max. The authors also found that cardiac output took 21 days to return to predonation levels. The authors concluded that individual differences in submaximum cardiac output are due, in part, to individual differences in hemoglobin.

In the above study the authors did not emphasize the fact that the higher hemoglobin values were also accompanied by larger blood volumes. The stroke volume will be increased by a larger volume of blood and a subsequent increase in pressure during the systole phase of the cardiac cycle, resulting in a larger amount of blood pumped per beat.

In a study similar to the one performed by Freedson et al. (1981), Ekblom et al. (1972) analyzed the response to exercise after blood loss and reinfusion. In this study submaximal and maximal work was done by seven subjects, 3 in group I and 4 in group II, before and after blood loss, and before (group I only) and after reinfusion of red cells four weeks later. The blood was drawn in the following manner; a single loss of 800 ml of blood for group I, sequential withdrawals of 400 ml of blood up to 1,200 ml for group II. The hemoglobin concentration decreased by 13% for group I and by 18% for group II, with both groups having an approximate decrease of 30% in physical performance capacity. After blood loss, maximal oxygen uptake decreased by 13% for group I and 18% for group II. Upon reinfusion of blood, the hemoglobin for group I increased by 13% as compared to the day before reinfusion. The overnight increase in physical performance capacity was 23%, with VO2 max increasing by 9%. The authors reported a correlation of r=.97 for the change in VO2 max in relation to the change in hemoglobin. The authors further added that maximal VE was unchanged in all situations in both groups, yet VO2 max increased up to 17%. Heart rate was higher for a given amount of work after blood loss. The authors feel that it was the change in hemoglobin, not blood volume, that caused the increase in both physical performance capacity and VO2 max.

The above study shows a relationship between hemoglobin and physical work capacity and VO2 max. Unlike a previously mentioned study, Freedson et al. (1981), and Ekblom et al. (1972) make no mention of hemoglobin affecting the actual cardiac output.

In a study by Buick et al. (1980) the effect of induced erythrocythemia on aerobic work capacity was analyzed. Eleven trained runners were studied in a double-blind design; (a) before blood withdrawal, (b) after recovery to a normal red blood cell count, (c) after reinfusion of 50 ml of saline solution, (d) following the reinfusion of 900 ml of preserved blood, (e) and after the return to normal levels of red blood cell count. The authors found no hematological differences between a, b, c, and e, but following reinfusion, hemoglobin was significantly higher. Maximum running time to exhaustion was significantly increased 24 hours after reinfusion, and again 7 days later. The VO2 max was significantly higher 16 weeks later despite the return of hemoglobin levels to normal values. The authors conluded that there is a distinct increase in VO2 max following induced erythrocythemia and suggest that limiting oxygen to the working muscles limits maximal aerobic capacity.

The above study further acknowledges the fact that increasing hemoglobin by the infusion of red blood cells increases the aerobic work capacity. A problem with the above study, and many like it, is the fact that a control group was not utilized and the subject population was very small.

In a study by Thomson et al. (1982), oxygen transport following the reinfusion of whole blood was examined. Four trained males performed a modified Balke treadmill test under controlled conditions after blood withdrawal of 1000 ml, and after reinfusion of the 1000 ml of blood. This study was 6 months in length, with the subjects performing the Balke treadmill test each week. Blood was withdrawn after the third month and reinfused after the six month. Following blood reinfusion the subject's VO2 max increased from a mean of 4.0 to 4.5 liters per minute. The authors concluded that the postreinfusion increase in VO2 max was due to an increased oxygen content supplied to the tissue by circulation. The absence of a control group in the above study may have been detrimental to the overall findings.

In summary, recent studies on "blood doping" have shown significant increases in physical work capacity and VO2 max. Williams (1981) reported that investigators who found a significant improvement in either VO2 max or endurance attributed it to increased hemoglobin concentrations that enriched the oxygen-carrying capacity of blood.

<u>Chronic Exercise Decreases Hemoglobin but not Performance</u>

This section of the review of the literature will summarize findings which suggest that a decrease in hemoglobin may be advantageous to aerobic work capacity.

In a review of the literature by Williamson (1981), many aspects of how a decrease in hemoglobin would enhance performance were discussed. Williamson pointed out many studies in which the authors concluded that a lower hemoglobin concentration was optimal for blood transportation due to the lower viscosity. Williamson then concluded that the borderline anemic state may be an adaptive state to maximize oxygen transport. He further added that no treatment is necessary for "sports anemia."

Williamson's review of literature has many problems associated with the overall conclusions. In light of the vast information on the effect of decreased hemoglobin on aerobic capacity, Williamson consistently evaluates studies in which the length of time exercising during a max test is not sufficient enough to elicit any significant changes in aerobic performance. In a study by Cotes et al. (1972) anemia was found to have no harmful effects on performance when students exercised. The exercise was performed for only four minutes. Williamson does not point out any studies in which extensive analysis was done on the effects of blood loss and reinfusion, i.e., Buick et al. (1980) and Williams (1981).

In a study by Pate et al. (1979) the effect of dietary iron supplementation were examined. Twenty-six women, from five different intercollegiate teams, completed the study. Early in each team's pre-season each subject had their hemoglobin, hematocrit, serum iron and total iron binding capacity analyzed. After this blood sampling subjects were randomly assigned to either a control or experimental group. Each day subjects in the experimental group ingested 167 mg of ferrous sulfate, which contained 50 mg of elemental iron. Pre and post blood samples showed that none of the twenty-six athletes was anemic, hemoglobin below 12 gm/100ml of blood. The overall effects of the iron supplementation was analyzed by comparing the means of each hematological variable between each group. The authors found that iron supplementation did not significantly affect hemoglobin or hematocrit. The authors added that it appears that anemia is rare among women athletes.

The problem with the above study is that pre-blood measurements, before iron supplementation, found none of the subjects anemic. It may be that people who are not anemic are not affected by iron supplementation.

In a study by Dressendorfer et al. (1981) the effects of a 20 day, 312 mile road race on hemoglobin concentration and hematocrit levels was examined. The runners, who were 23 to 60 years of age, averaged 60 miles per week prior to this race. Blood samples were analyzed on eight days during the race. The findings indicated the presence of a mild anemia, with gradual decreasing hemoglobin and hematocrit values as the race progressed. The authors stated that the mild anemia was not the result of an iron deficiency due to the elevated plasma iron levels. The authors concluded that no medical management was necessary in healthy males who show this type of anemia.

In their findings Dressendorfer et al. (1981) do not address the issue that the anemia could have been caused by factors other that iron deficiency, i.e. hemolysis, plasma volume expansion, inadequate resynthesis of hemoglobin, etc.

In a study done by Ehn et al. (1980) the iron status of athletes involved in intense physical activity was assessed. Over a period of two years, iron status, training programs, diets, and the general health of eight long distance runners were studied. The findings indicated that hemoglobin and serum iron did not differ from the general population. On the other hand the bone marrow showed only traces or a complete absence of iron, indicating latent iron deficiency. An iron loss of approximately 2 mg a day was found in the eight long distance runners. The authors stated however, that a balance was ultimately present due to a high daily dietary intake of iron. The authors also found no signs of bleeding, hemolysis, or increased excretion of hemoglobin in the urine. The authors concluded that the low absorption and increased elimination of iron seemed to be the reason for the depleted iron stores.

The above study is in contradiction to a finding in the study by Dressendorfer et al. (1981). The above study found latent iron deficiency with the addition of depleted iron stores. Dressendorfer et al. concluded that iron deficiency was not a problem due to elevated plasma iron levels. The studies by Ehn et al. (1980) and Dressendorfer et al. (1981) both have a potential drawback in the fact that they utilize a very limited and small group and no controls. Both studies do not address the idea of predisposition to the condition of "sports anemia," which is due to various reasons presented earlier in this literature review.

In a study by Wells et al. (1982) the changes in hematological variations were assessed in 10 runners, 6 male and 4 female, following a marathon. Blood samples were collected immediately before and after the race. Post race blood samples were taken at four intervals; immediately, four hours, eight hours, and twenty-four hours later. The authors concluded that the hematological findings in these collection periods for both male and female runners did not significantly differ from normal sedentary males and females.

The above study could have benefited by using a larger number of subjects and a control group of nonrunners. The authors found significant differences in hemoglobin in the post race blood samples, although their data show hemoglobin continually dropping form post race sample to sample. This is in agreement with the study done by Radomski et al. (1980) in which the hemoglobin continued to drop into the recovery period after heavy continuous physical aerobic exertion. The point at which the drop in hemoglobin becomes significant, as compared to pre-activity levels, is probably difficult to estimate and different for each individual.

Iron Supplementation/Nutritional Studies

Numerous studies have been performed to assess the effect of iron supplementation or nutritional changes upon aerobic work capacity. The increase in hemoglobin from such practices is assumed to increase the aerobic work capacity by altering or adding an element to the individual's diet.

In a study by Gardner et al. (1975) the cardiorespiratory, hematological and physical performances of anemic subjects was assessed following iron treatment. Twenty-nine anemic adults, 13 men and 16 women, were divided into an iron treatment and placebo group. Hematological, cardiorespiratory and physcial performance data were collected before, during and after treatment. A control group of 10 adults, 4 men and 6 women, was utilized. Hemoglobin levels for the iron treatment group significantly increased for both males and females, whereas the placebo group had no change in hemoglobin concentration. Peak exercise heart rates while doing a 5 minute, 40cm step test were significantly reduced for the iron treatment group when compared with the placebo group which had no changes. No difference was found in oxygen consumption between the two groups while performing exercise, however, the iron group delivered 15% more oxygen per pulse than the placebo group. The authors concluded that these findings clearly support the concept that performance requiring high oxygen delivery is significantly affected by iron treatment.

The above study suggests that increasing hemoglobin, via iron supplementation, is advantageous to the overall aerobic work capacity of anemic individuals. The subjects used were all previously anemic, so predisposition to the problem of anemia was already apparent. That iron supplementation only enhances the aerobic performance of those who are anemic or susceptible to anemia is an issue that needs to be studied in further detail.

In a study by Clement et al. (1982), nutrition and its relation to hematological parameters was evaluated. In this study 52 middle distance runners had daily dietary intake and hematology studies performed. The results indicated that distance runners had a greater than expected frequency of latent iron deficiency. The authors stated that the presence of latent iron deficiency without anemia may reduce physcial work capacity and impair racing performance. The authors added that distance runners should ensure adequate dietary iron intake and routinely monitor hemoglobin levels and serum ferritin levels in blood.

The above study is in agreement with the study by Ehn et al. (1980) who found latent iron deficiency to be a prominent factor in eight long distance runners studied over two years. The study by Clement et al. (1982) could have possibly benefited by utilizing a control group of nonrunners. An interesting finding in the study by Clement et al. was the fact that 10.5% of the male runners were considered to be anemic, hemoglobin less than 14 gm/100ml, whereas there were no female runners anemic, hemoglobin less than 12 gm/100ml.

The effects of iron supplementation on female runners were evaluated in a study by Plowman et al. (1981). In this study 28 female cross country runners, 14 to 22 years of age, were divided into two groups. One group received a diet supplement of ascorbic acid, while the other group received a diet supplement of ascorbic acid plus elemental iron. Blood samples were taken before the cross country season and immediately afterwards. The results indicated that the iron supplemented group showed a significantly greater hemoglobin level than the other group at the time of the second blood sample.

In another study evaluating the effects of iron supplementation on hemoglobin levels in female athletes, Cooter et al. (1978) found that iron supplementation was of no significant value in raising hemoglobin levels. In this study 17 females, 10 athletes and 7 nonathletes, ages 18 to 24 received an iron supplement of 18 mg of iron or none at all. The nonathletes served as the control group. The authors concluded that since all of the groups' members remained in the normal range of hemoglobin values the iron supplement was of no value.

The difference in findings between the studies by Plowman et al. (1980) and Cooter et al. (1978) may have to do with the differences in iron ingested by the experimental group. In the study by Cooter et al. 18 mg of iron were utilized, as in comparison to the 234 mg used by Plowman et al, which is a substantial difference in the amount of iron ingested daily from one study to the next. Another possible area of difference is the addition of ascorbic acid with the iron intake in the study by Plowman et al. Vitamin C aids in the absorption of iron into the body. One last factor that distinguishes the Plowman et al. study from the Cooter et al. study is the fact that Plowman et al. used a time released iron supplement. This may possibly alter any side effects that accompany iron supplementation, and may have allowed for the usage of such a high dosage.

In a study by Nickerson et al. (1983) the effects of treating eleven female cross country runners with 200 mg of ferrous sulfate containing 60 mg of elemental iron was evaluated. This treatment was done three times daily for the length of the cross country season. The results indicated that despite running 8 to 11 km a day none of the subjects developed "sports anemia." Also evaluated in this study were the effects of iron treatment on two girls who had iron deficiency anemia. In both cases performance in running cross country increased. In one case the hemoglobin concentration increased 0.9 gm/100ml, and improvement by 40 seconds in the 3,200 meter run was recorded. Of ten girls who were iron deficient prior to treatment, five had increases of 0.5 gm/100ml or more after iron therapy. The authors concluded that iron deficiency anemia interferes with good performance in long-distance running.

The above study strengthens the belief of predisposition to "sports anemia" in the fact that only 5 out of ten girls had significant increases in their hemoglobin concentrations. All were given iron supplements, yet only 50% recorded significant differences in hemoglobin concentrations. The above study may have benefited by using a control group, and by studying the effect of iron supplementation on a larger population.

Summary

There is considerable evidence demonstrating hematological variations during aerobic training. The actual severity of this problem is not well understood at this point in time. While research indicates a possible decrease in performance with a decrease in hemoglobin, very few researchers stress the importance of screening aerobically active people for "sports anemia."

The importance of diagnosing the "sports anemic" condition may be more important than actually diagnosing the cause of this condition. Widespread hemoglobin screening of aerobically active people may have to be done before becoming too involved with a search for the possible causes of "sports anemia." It would be important to initially exclude any medical or nutritional problems that would affect the hemoglobin concentration.

Screening for "sports anemia," excluding medical and nutritional deficiencies as possible causes, and correcting the condition would seem to be the most practical course to pursue. However, an obvious question appears to be, is "sports anemia" prevalent enough to perform widespread screening of aerobically active individuals.

CHAPTER III

METHODOLOGY

Subjects

The subjects involved in this research project came from two groups. The "high activity" group consisted of individuals who participated in aerobic endurance activities four or more hours weekly. This group was composed of twenty males and twenty females between the ages of eighteen and sixty. Running, swimming, and cycling clubs were the largest contributors to this group.

The "low activity" group consisted of, but was not limited to, subjects from selected undergraduate physical education courses at the University of Tennessee, Knoxville, i.e. bowling, golf, weight training, etc.. Each participated in aerobic endurance activities less than one hour weekly. This group consisted of twenty males and twenty females between the ages of eighteen and sixty.

The subjects were required to fill out an identification form prior to the actual testing. This form is found in Appendix A. The subjects were also required to read and sign an informed consent form prior to actual testing. This form contained the specific risks, benefits, and mechanics of the testing to be performed. This form is found in Appendix B. The subjects were also required to perform a three-day dietary recall. This form was used to analyze dietary iron intake. This form simply lists types and amounts of foods eaten for three consecutive days.

Materials/Apparatus

To analyze hemoglobin, a Sigma hemoglobin kit was utilized. In this procedure, hemoglobin reacts with Drabkin's Reagent to form cyanmethmoglobin. The absorption of light at 530-550nm is proportional to the hemoglobin in the blood sample. A stable freeze-dried methemoglobin preparation was used for the construction of the calibration curves. Absorption was measured on a Bausch & Lomb Spectronic 20 colorimeter/spectrophotometer. Construction of the calibration curves was done on a weekly basis and checked daily to see if calibration was correct.

Dietary intake of iron was analyzed by using a three day food record form. All foods eaten, and amounts, were listed on this form. Iron amounts in each food could then be determined and listed for each subject.

Procedures

A standard method to screen for anemia is to measure the hemoglobin content within a blood sample. A capillary blood sample, taken from the subject's finger, was used to measure hemoglobin levels in blood. The procedure involved sterilizing the subject's finger with an alcohol swab, followed by a prick of the finger with a sterile lancet. The blood sample was then drawn into capillary pipets. The blood was then mixed in a test tube with Drabkin's Reagent. This mixture was then analyzed for absorption of light to determine hemoglobin content, on a Bausch & Lomb colorimeter/spectrophotometer.

All subjects were required to fill out a Food Record Form after testing for hemoglobin content. This form was filled out for three days and was used to screen out nutritionally anemic individuals in the "high activity" group. The recommended dietary allowances for iron intake were used as a normal range in this procedure. The form used for this process is the standard Food Record Form developed and used by the Nutrition and Food Science Department at the University of Tennessee, Knoxville. The subject was also be asked if they were aware of any anemic conditions in their family due to reasons other than nutritional.

Subjects in both groups were involved in the above stated procedures. There were no differences in procedures between the two groups.

The risks involved with the procedures in this research project were minimal. The subjects were given precise instructions concerning the mechanics of obtaining a capillary blood sample. Each subject was seated at a table to reduce the chance of injury that could occur if the subject were to faint while obtaining the blood sample. The subject was also required to sit for twenty minutes following the procedure to assure no after-effects.

The anonymity of the subjects and confidentiality of the data were met in the following manner. The subjects were assigned a number that corresponded to their capillary blood sample and Food Record Form. This number was used throughout the research project as a means of identifying a particular blood sample and Food Record Form. The "high activity" group was identified by using the letter A, with a number behind the A representing the particular blood sample and Food Record Form. An odd number represented male subject, an even number a female subject. For example, the tenth male subject from the "high activity" group was labeled A19. The "low activity" group had the letter B preceding the number. Male and female subjects in the "low activity" group were assigned the same numbers as in the "high activity" group.

The capillary blood samples were taken in a laboratory located in the Health, Physical Education, and Recreation building at the University of Tennessee, Knoxville. Some capillary blood samples were taken in the field where subjects participated in their activity of interest, i.e. at a swimming facility. The dietary Food Record Forms were analyzed by computer in the Nutrition and Food Sciences Department at the University of Tennessee, Knoxville. The software used for this procedure is entitled "Computer Programs for Analysis of Food Record Forms."

Design

This research project incorporated an Ex post facto design. An attempt was made to see if differences that existed in the hemoglobin values of subjects were due to differences in their aerobic activity level.

Internal/External Validity

Threats to internal validity were controlled in the following manner. Since there was no treatment period, present history was not a threat. Past history was controlled by assuming the subjects responded correctly to the identification form, specifically the amount of time spent per week participating in aerobic activities. The threat to instrumentation was controlled by checking calibration daily, and constructing new calibration curves weekly. The same individual administered the hemoglobin test and analyzed all Food Record Forms. The threat to selection bias was controlled by assuming the subjects answered the questions on the identification form correctly.

There was only one applicable threat to external validity in this research project, the reactive effects of the experimental arrangements. Since the individuals who are anemic presumably participate in real-world activities in real-world settings, the findings can be generalized to other situations. The subjects chosen were representative of a larger population.

Statistical Analysis

A Chi-square test of independence was performed to see if the number of subjects found anemic in the "high activity" group was different when compared to the "low activity" group. This procedure was performed separately for males and females of both groups.

An independent t-test was used to see if there was a significant difference in hemoglobin values between the "high activity" and "low activity" groups. Since there is a normal difference in hemoglobin values between males and females, the above procedure was performed separately for males and females of both groups.

The dietary Food Record Forms were analyzed to obtain the iron intake in each subject's diet. Values for iron intake were obtained for all subjects. An independent t-test was performed to see if there was a significant difference in the iron intake between the "high activity" and "low activity" groups. Since there is a difference in the recommended daily allowances of iron for males and females, the above procedure was performed for both males and females of both groups. Subjects who were nutritionally anemic, and were in the "high activity" group, were eliminated from the Chi-square test of independence procedure.

CHAPTER IV

RESULTS

In analyzing differences in the frequency of anemia between the "high activity" and "low activity" groups a Chi-square test of independence was utilized. This procedure was performed separately for both males and females in each group. There were twenty males and females in both groups. There was no significant difference in the frequency of anemia between the "high activity" and "low activity" groups, within the female population. There were five females who were anemic, hemoglobin less than 12 gm/100ml, in the "high activity" group, as opposed to four in the "low activity" group. The frequency of anemia among the males was significantly greater for the "high activity," compared to the "low activity" group, $x^2(1) = 10.15$, $p<.005$. There were ten males who were anemic, hemoglobin less than 14 gm/100ml, in the "high activity" group, as compared to one in the "low activity" group.

An independent t-test was used to see if there was a difference in hemoglobin values between the "high activity" and "low activity" groups. The female "high activity" group ($M = 12.8$, $s = 1.19$, $n = 20$) was not significantly different from the "low activity" group ($M = 12.8$, $s = .81$, $n = 20$), $t(38) = 0$. The male "high activity" group ($M = 13.9$ s

= 1.02, n = 20) had a significantly lower hemoglobin value than did the males in the "low activity" group (M = 15.4, s = 1.19, n = 20), $t(38) = 4.28$, $p<.001$. (See Table 1.)

An independent t-test was performed to see if there was a significant difference in iron intake between the "high activity" and "low activity groups. The female "high activity" group (M = 12.98, s = 4.11, n = 19) was not significantly different from the "low activity" group (M = 12.38, s = 2.63, n = 16), $t(33) = .52$. The male "high activity" group (M = 16.36, s = 4.48, n = 18) was not significantly different from the "low activity" group (M = 15.96, s = 3.40, n = 14), $t(30) = .29$. (See Table 1.)

TABLE 1

Means, Standard Deviations, and t-Test for Hemoglobin Concentration and Iron Intake

	"High Activity"		"Low Activity"	
	Hemoglobin gm/100ml M(s)	Iron mg/day M(s)	Hemoglobin gm/100ml M(s)	Iron mg/day M(s)
Males	13.8(1.02)*	16.4(4.48)	15.4(1.19)*	16.0(3.40)
Females	12.8(1.19)	13.0(4.11)	12.8(.81)	12.4(2.63)

*p<..001

CHAPTER V

DISCUSSION OF RESULTS

The first hypothesis of this research project stated that the "high activity" group would have more subjects who were anemic compared to the low activity group. This hypothesis was accepted for the males, but was rejected for the females. Ten males in the "high activity" group, as opposed to one in the "low activity" group, were clinically anemic. The ten males from the "high activity" group, all of whom participated in aerobic activities four or more hours per week, did not record inadequate dietary iron intake values. These ten males may have a condition of "sports anemia," i.e., hemoglobin concentration less than 14 gm/100ml in aerobically active people. Unlike Pate (1983), where the incidence of true anemia in the athletic population was reported to be low, the incidence of anemia in the male athletic population in this study is significantly high. The findings from this research project are in agreement with a study by Frederickson et al. (1983) who found "sport anemia" to be present in a significant number of cross country runners during the season.

Within the female population there were no significant differences in the frequency of anemia when comparing the "high activity" group to the "low activity" group. The findings from this research project are similar to the findings by Clement et al. (1982) who found no female distance runners to be anemic, whereas 10% of the male distance runners were anemic. These studies, together with the findings from this study, suggests that males are affected more by the condition of "sports anemia."

The second hypothesis of this research project stated that there would be a significant difference in hemoglobin concentrations between the "high activity" and "low activity" groups. This hypothesis was rejected for the females. In fact, the two groups of females had equal mean values for the hemoglobin concentration.

The second hypothesis was accepted for the males, in that the "high activity" group showed a significantly lower hemoglobin concentration than the "low activity" group. The findings in this study would indicate that much more work needs to be done examining "sports anemia" in male athletes. For whatever reason, past research has seemed to make the deduction that "sports anemia" is a problem that only has a significant impact on females athletes. This may be due to the fact that most research projects examined only female athletes.

The third hypothesis of this research project stated that there would not be a significant difference in iron intake between the "high activity" and "low activity" groups. This hypothesis was accepted in that there were no significant differences in iron intake between the "high activity" and "low activity" groups for both males and females. There were also no anemic male subjects in the "high activity" group who recorded an inadequate iron intake value, lower than 10 mg of iron daily. However, the females from both the "high activity" and "low activity" groups recorded mean values (M = 12.98, M = 12.38) which were significantly lower than the recommended daily allowance, 18 mg of iron. The findings for both males and females are similar to those found by Clement et al. (1982). Clement et al. found a significant number of females, 90% of his population of 52, who had iron intake values lower than the recommended daily allowance of 18 mg. Clement et al. also found that of the 52 males in his study, only 2% recorded inadequate iron intake values.

The findings from this study indicate that "sports anemia" may be a problem among male athletes who exercise aerobically for more than four hours per week. It suggests that the condition of "sports anemia" is much more prevalent among males than females. It may be prudent, for males more than females, for aerobically active individuals to have their hemoglobin concentration checked periodically for the condition of "sports anemia."

The findings also indicate that the dietary intake of iron was adequate among the males in the "high activity" group. Based on this, iron intake would not be a factor that is associated with the "sports anemia" found in this study. However, females from both groups recorded values which are considered inadequate. Since the frequency of anemia was not significant for females when comparing the "high activity" to the "low activity" group, iron intake may not be a factor that contributes to "sports anemia" in females.

In this research project there were 5 out of 40 males who recorded optimal hemoglobin concentrations, that is, according to Pate (1983), greater or equal to 16 gm/100ml. There were also 5 out of 40 females who recorded optimal hemoglobin concentrations, greater or equal to 14 gm/100ml. These findings suggest that classifying optimal hemoglobin concentrations are more complicated than past researchers, Pate (1983), Clement et al. (1977), Stewart et al. (1972), have indicated. To label a certain concentration as sub-optimal for everyone seems to be ludicrous, considering hemoglobin concentration is different for most individuals. There may be a certain hemoglobin concentration in which suboptimal performance occurs when below this value. This value however, seems to be different for each individual, and clearly seems to be be, for the majority of people, lower than the past stated suboptimal concentrations.

In the future there needs to be more research performed on gender differences in the frequency of "sports anemia" in the athletic population. At the present time there are no concrete findings that suggest "sports anemia" may affect one gender more than the other.

There is a need for future research to be performed in the area of iron supplementation on athletes who suffer from "sports anemia." The increase in performance due to iron supplementation in anemic athletes needs to be examined. It is apparent from past research (Pate et al., 1979) that iron supplementation does not significantly increase hemoglobin in athletes who are not anemic.

There is also a need for more studies to examine the theory suggested by Davidson (1969) that "sports anemia" may be caused by a predisposition factor. There must be a reason why one individual develops "sports anemia" and another individual does not, when all pertinent factors are being controlled.

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APPENDIXES

APPENDIX A

IDENTIFICATION FORM

NAME____________________________

Do not fill in
ID No.______

AGE__________

SEX: Male Female

ADDRESS:

PHONE:

How many hours per week do you participate in aerobic type activities?

Has any member of your family ever been diagnosed as being anemic?

APPENDIX B

INFORMED CONSENT FORM

The project you are participating in involves research in the area of anemia due to physical activity, specifically aerobic endurance activity. The purpose of this research is to determine if there is a relationship between a high level of physical activity and anemia.

I understand that there are two groups involved in this research: Group A - individuals who participate in aerobic type of activities more than four hours weekly.

Group B - individuals who are enrolled in undergraduate physical education courses at the University of Tennessee, Knoxville, and participate in aerobic activities less than one hour per week.

I understand that my participation consists of giving a capillary blood sample, and that this type of blood sample is drawn from the finger. I understand that the duration of my participation will be the time it takes to give a capillary blood sample. I understand that I will be asked to give a dietary recall. The capillary blood sample will be taken using a blood lancet. The prick will be made after the finger is sterilized with an alcohol swab. Appropriate bandaging will be made after the sample is collected.

I understand that the risks involved include possible infection of the area pricked, soreness in the finger used in the procedure, and the possibility of fainting. The risks of fainting and infection are very small. There is some pain associated with the finger prick in the procedure.

I understand that the procedure involved in this research will let me know if I am anemic. If I am anemic I will benefit by consulting a physician and having this condition corrected.

I understand that the information from my tests may be used for research publications. I understand that a number will be used as a means of personal identification during the research period. I further understand that my identity will not be revealed and that I may withdraw my consent at any time.

I understand that my participation in this research project is voluntary, and that I may discontinue my participation at any time without penalty.

SUBJECT: ______________________________ Date__________

WITNESS: ______________________________ Date__________

Brett J. Berry - Student
7700 Gleason Rd. #34R
Knoxville, Tn. 37919

Edward T. Howley - Advisor
Health, Physical Education and Recreation

APPENDIX C

STATISTICAL DATA

Hemoglobin Concentration

	High Activity		Low Activity	
	Males	Females	Males	Females
1.	13.6	14.0	15.9	13.8
2.	14.4	13.3	16.8	14.1
3.	11.8	13.3	17.4	12.8
4.	15.2	13.9	16.8	13.5
5.	14.5	13.8	15.8	12.9
6.	13.6	14.6	15.6	14.0
7.	14.9	11.6	15.9	12.1
8.	12.8	12.5	14.0	12.7
9.	14.8	12.1	17.2	11.7
10.	14.7	11.1	15.1	12.2
11.	13.1	11.5	14.9	11.9
12.	14.9	12.2	16.8	12.0
13.	15.1	14.3	14.2	12.9
14.	13.6	13.3	15.6	13.4
15.	13.4	13.1	14.3	13.2
16.	12.9	13.4	14.0	11.4
17.	13.5	10.2	15.1	11.9
18.	14.6	11.8	13.3	13.8
19.	15.2	14.0	15.1	12.4
20.	12.3	12.3	14.2	12.7
Mean=	13.8	12.8	15.4	12.8
s=	1.02	1.19	1.19	.81

Iron Intake - mg/day

	High Activity		Low Activity	
	Males	Females	Males	Females
1.	15.1	12.9	17.3	9.0
2.	19.1	12.4	21.3	16.0
3.	12.8	8.6	15.5	14.6
4.	19.2	17.2	14.1	12.9
5.	12.9	17.8		11.8
6.	13.8	12.3		11.6
7.	12.8	16.4		15.0
8.	16.7	12.8	20.3	17.0
9.	18.2	22.2	16.0	
10.	16.2	7.9	18.0	10.2
11.	27.7	12.0	14.8	12.2
12.	10.6	13.6		12.8
13.		18.5		
14.		6.4	11.6	7.9
15.	21.3	11.5	14.5	
16.	15.0	10.9	15.5	
17.	15.2	15.1		15.1
18.	23.4	10.6	15.2	10.0
19.	13.7	7.6	8.9	9.8

20. 10.8		20.5	12.2
Mean=16.4	13.0	16.0	12.4
s=4.48	4.11	3.40	2.63

VITA

Brett J. Berry was born in New Orleans, Louisiana on April 20, 1960. He attended elementary school in that city and was graduated from Holy Cross High School in June 1978. In May 1982 he received a Bachelor of Science Degree in Physical Education from Tulane University in New Orleans. In the spring of 1983 he accepted a graduate teaching assistantship at the University of New Orleans, and began study towards a Master's Degree.

In the fall of 1983 he began teaching on the high school level in New Orleans, Louisiana. After two years of teaching he entered graduate school at the University of Tennessee, Knoxville, in September 1985. He received a Master of Science Degree with a major in Physical Education in June 1986.

The author is a member of Alpha Sigma Lambda and the American College of Sports Medicine.