The Demonstration and Evaluation of Hemoglobin and Hematocrit Testing as Support Services in Preparing Elite Swimmers for Serious Competition

---

A Thesis

Presented to

the Faculty of University Schools

Lakehead University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in the

Theory of Coaching

---

by

James Douglas Busch

April, 1982

ABSTRACT

These studies demonstrated and evaluated the usefulness of hemoglobin concentrations (Hb gm%) and hematocrit percentages (Hct %) in the preparation of elite swimmers for serious competition. Study 1 monitored Hb and Hct levels of nine male swimmers during two months of hard training, tapering, and post-competition rest. Study 2 monitored Hb and Hct levels of the 18 male and 19 female members of the 1978 Commonwealth Games Swimming Teams during maintenance training before competition. Weekly variations were observed during hard training in Study 1. Reduced work load and/or coach determined iron supplementations seemed to increase Hb and Hct levels in most athletes. It was concluded that Hb and Hct screening is a feasible and beneficial support service in the preparation of elite swimmers for competition. For a limited number of individuals more extensive services are required.

ACKNOWLEDGEMENTS

The author wishes to acknowledge a great debt of gratitude to Dr. B. S. Rushall for his invaluable assistance and guidance in advising this thesis.

An expression of appreciation is also extended to Dr. S. Magwood for his assistance.

Thanks are also due to the coach, Mr. D. Talbot, and the swimmers, without whose co-operation this thesis could never have materialized.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Purpose

The purpose of this thesis was to demonstrate and evaluate hemoglobin (Hb) and hematocrit (Hct) tests as support services in the preparation of elite swimmers for serious competition.

Significance

It has been shown that elite Canadian athletes have significantly lower Hb concentrations than is desirable (Clement, Asmundson & Medhurst, 1977). Since Hb is related to maximal oxygen uptake and consequently aerobic performance, and Hct percentage is also related to aerobic work, it would be valuable to assess these two items in athletes in training. This would allow corrective steps to be taken to avoid athletes entering serious competitions with hematological impairments. These assessments would serve a diagnostic purpose which could be used to enhance coaching decisions.

This study was an exploratory project to generate new information about the physiological preparation of elite athletes for competition. It also attempted to ascertain the plausibility of repetitive testing of Hb concentrations and Hct percentages during training. The testing could locate problems through the provision of sensitive data. If changes occurred during preparations for competition this information might contribute to coaching decisions with regard to work load, diet

and rest.

Other features assessed were the practicality and acceptances of repetitive blood tests on entire teams of elite athletes. Since the methods to be employed had to be as convenient as possible and needed to provide information as quickly as possible, appropriate procedures were selected with these criteria in mind.

A case study approach to evaluate and demonstrate the employed methods was adopted. This was followed to ensure that any idiosyncratic responses could be located and possibly accounted for. Since elite athletic teams in individual sports are of individual importance the case study strategy would better evaluate the utility of these analyses.

This thesis attempted to evaluate and demonstrate the effectiveness of providing Hb and Hct information to coaches of elite teams. If this was found to be acceptable and useful then a contribution to enhancing the preparation of elite athletes will have been made.

Delimitations

(1) Two convenient swimming environments were used. Study 1 was conducted on members of the Thunderbolt Swim Team at Lakehead University, in preparation for the 1978 Canadian Winter National Championships. Nine male subjects between the ages of 16 and 20 years, ($\bar{X}$ = 18.2 yrs), were studied from 26/01/78 to 14/03/78, during hard and taper periods of training. Further post-competition testing was conducted on seven of the original subjects from 21/03/78 to 28/03/78, during a period of rest. Study 2 measured both the men's and women's 1978 Canadian Commonwealth Games Swimming Teams during training camp at Lakehead University.

Eighteen male subjects between the ages of 14 and 23 years, ($\bar{X}$ = 18.7 yrs), and 19 female subjects between the ages of 16 and 24 years, ($\bar{X}$ = 17.4 yrs), were studied from 13/07/78 to 27/07/78.

(2) Dependent variables were limited to micro methods for determining Hb concentrations and Hct ratios. Drabkin's cyanmethemoglobin method which has a 1.2% range of error was used to determine Hb concentration. Wintrobe's micro method which has a 2% range of error was used to determine hematocrit levels.

(3) Diurnal variation was avoided by testing the subjects at the same time of the day at each session.

(4) The training content of the Thunderbolt swimmers' programs was bound by decisions and opportunities that are normally associated with Mr. Don Talbot's coaching program.

(5) All subjects in this study were Caucasians.

(6) Since the literature reported extensively on Hb concentration and exercise, but seldom on Hct levels, this study emphasized and discussed only Hb features. Data concerning Hct was presented for interest purposes and served as an initial analysis of that factor.

Limitations

(1) The subjects in study 1 were coach designated.

(2) The subjects in study 1 were convenient male samples therefore restricting generalization.

(3) The subjects of study 2 were the total memberships of both the men's and women's 1978 Canadian Commonwealth Games Swimming Teams.

(4) Any changes to be noted had to be readily visible.

(5) The exploratory nature of this study is accepted as being sufficient to indicate directions for future, more detailed studies.

Definitions

Hemoglobin (Hb) is the iron-containing protein of the red blood cell that combines with oxygen and carries it to the tissues.

Hematocrit (Hct) is the percent volume of whole blood that is occupied by red blood cells.

Elite swimmers are those swimmers who are nationally and/or internationally ranked.

Tapering is defined as the final stage of preparing for an event, it involves the changing of training stressors (varying the quality and/or quantity of work load) after a period of hard training. Study 1 was limited to the athletes experiencing a taper program as directed by Mr. Don Talbot, one of the world's foremost swimming coaches, in his team's preparations for the 1978 Canadian Winter National Championships.

Hard training consisted of eleven training sessions of swimming per week averaging 11,000 to 13,000 meters per day. The concentration in each session was on hard work. Weight and supplementary training was also included.

Maintenance training consisted of ten training sessions per week averaging 8,000 to 10,000 meters per day. If a swimmer showed "undue" amounts of fatigue, rest was prescribed to allow recovery to take place. The difference between this form of training and tapering is that the

emphasis is on quality work in as great an amount as the swimmer can sustain.

Sports anemia is a decrease in Hb concentration caused by a protein deficiency which is due to an increased protein requirement in physical training as muscle hypertrophy begins (Yoshimura, 1970).

Hypoproteinemia is a deficiency of protein in the blood.

Normochronic - normocytic anemias are anemias in which on the average, the red cells are not altered in size, shape or color (Normocytic Anemia), and the mean corpuscular hemoglobin concentration (MCHC) is also normal (Normochronic Anemia) (Wintrobe, 1974).

Erythropoiesis is the formation of erythrocytes.

Mean Hb Value for the Canadian Population is the Hb value which represents the sex and mean age groups of the subjects in studies 1 and 2 (Nutrition Canada 1975).

Chapter 2

REVIEW OF LITERATURE

Since the purpose of this study was to demonstrate and evaluate Hb and Hct tests as support services for the preparation of elite swimmers for serious competition, the review of literature is divided into two sections: the relationships of Hb and Hct values to performance, and possible causes, cures and preventions of Hb and Hct abnormalities.

The Relationship of Hb and Hct Values to Performance

Karvonen and Kunnas (1952) showed through clinical observation that in athletic training camps the appearance of symptoms of staleness or overtraining was regularly associated with a marked fall in Hb concentration. These observations were supported by Carlile (1960, 1975) who recorded decreases of up to 20% from normal levels when swimmers were in a state of physical strain due to very hard training. Sutton (1971) related similar observations made by the Australian swimming coach Don Talbot, who found a decrease of 2 or more gm Hb/100 ml whole blood (gm% Hb) in swimmers who exhibited decreased performance during training.

The observations of these researchers proposes a positive relationship between Hb concentrations and performance. If the relationship is causal, then the reinstatement of Hb levels should facilitate at least partially recovered performance capacities.

This then serves as a potential screening device for establishing the performance capabilities of athletes.

Kjellberg, Rudhe, and Sjostrand (1949) stated that the amount of Hb and blood volume varies with the degree of physical training. Nour-Eldin (1973) proposed that this was due to the accelerated destruction of red cells brought on by excessive exercise, which may in turn serve as a stimulus to erythropoiesis. This interpretation is supported by Berry, Beveridge, and Bransby (1949), Bevegard, Holmgen, and Johnson (1963), and Stewart, Steel, and Toyne (1972) that athletes should be expected to have Hb values that are at least average and possibly higher than average.

Observations made by Stewart, Clarkson, and Steel (1970) showed that thoroughbred horses which won races in metropolitan tracks in Melbourne, Australia had significantly higher Hb and Hct values than thoroughbred horses studied in a more general population survey. This would seem to indicate that there is a positive relationship between hemological values and superior performance. There was also a significant relationship between both Hb and Hct values and the distances of the races won. The minimum Hb and Hct values obtained from winners of races longer than one mile were significantly higher than those winners of shorter races, showing a positive relationship between these hematological values and endurance. Several studies (Åstrand & Rodohl, 1977; DeWijn, DeJongste & Mosterd, 1971; Gardner, Edgerton & Barnard, 1975) have clearly shown that subnormal Hb concentrations inhibited performance particularly in aerobic events.

A low Hb concentration may be a limiting factor for aerobic capacity because of a reduction in the medium for oxygen transportation. Ekblom, Goldbarg, and Gullbring (1972) showed that changes in $\dot{V}O_2$ maximum correlated well with Hb concentrations and that with a decrease in Hb concentrations there was a decrease in maximal work time. The ability of the circulatory system to deliver oxygen and thus, the capacity for aerobic work, increases as the Hct ratio increases towards a certain value and declines when the Hct ratio goes beyond this value (Crowell & Smith, 1967; Guyton, 1966; Larson, 1974).

Åstrand and Saltin (1964) stated that physical work capacity depended to a large extent on the adequacy of the oxygen transport system. A decrement in this function could seriously impair one's ability for maximum work. Anderson and Barkve (1970) reported that this impairment was due to an excessively increased load on the cardio-respiratory functions. They felt that the higher ventilation equivalents (ventilations /O_2 uptake) were related to the lower levels of Hb. They also reported higher cardiac output in response to exercise and a reduced buffering capacity of the blood when Hb levels were low.

Cullumbine (1949) found that moderate exercise could be sustained for a longer time before it produced exhaustion when there was a greater Hb concentration. These results were supported by Edgerton, Bryant, and Gillespie (1972) when in 12 out of 13 occasions in four separate experiments the capacity of rats to perform an exhaustive endurance run test on a motor driven treadmill was directly related to

their Hb concentrations and Hct percentages. Anemic rats on each occasion ran for a significantly shorter time than their normal counterparts. Upon repletion of normal iron levels in the anemic animals the difference in endurance performance between the groups was eliminated. These findings, combined with higher peak exercise and recovery heart rates as well as higher resting and post-exercise lactate levels present in anemic subjects (Anderson & Barkve, 1970), leaves little question that physical work capacity is detrimentally affected by reductions in Hb and Hct levels.

Stewart et al. (1972) published a report on Hb concentrations and Hct ratios of most 1968 Australian Olympic Athletes. The athletes were tested three times before the 1968 Olympic Games. First, in Australia during the month of July, second, 14 days after arrival in Mexico (September 24 and October 1), and third, between October 4 and 9. The Olympic Games commenced on October 13 and ended on October 26, 1968. They divided the athletes into two categories:

(1) Category A included events which require greater endurance, such as, athletic track events of at least 800 meters, cycling, swimming, rowing, canoeing, pentathlon, boxing, hockey, and basketball.

(2) Category B included events which required less endurance, such as, athletic field events and track events of 400 meters or less, weight-lifting, equestrial events, diving, fencing, and wrestling.

One need only be concerned with Category A since Hb concentration and Hct percentage do not seem to have any effect on performance of lesser endurance or anaerobic events (Stewart et al., 1972). They then

made a demarcation by choosing the mean Hb and Hct levels in athletes in Category A at the third examination. Hemoglobin and Hct values at or above the mean were said to be optimal and those values below the mean, suboptimal. On this basis it was found that suboptimal Hb and Hct values were associated with less satisfactory performances in athletes in individual endurance events. For example, five of the 14 female swimmers had Hb and Hct levels below the mean values (Hb = 14.6 gm/100 ml and Hct = 45%). Of these, four were eliminated in the first heats of their events, and one reached the finals of the 200 meter freestyle in which she finished seventh. By comparison, of the nine female swimmers whose results were above the mean, only two were eliminated in the first heats. This suggested that Hb levels were predictive of a general assessment of competition performances.

In another survey comparing Hb levels of Olympic athletes Clement, Asmundson, and Medhurst (1977) found Canadian Olympic athletes to have significantly lower Hb values than the 1975 Canadian general population, and the 1968 Australian and Dutch Olympic teams. One might speculate that if the Hb level of the Canadian Olympic Team had been at least equal to that of the Canadian general population their maximal oxygen uptake would have been increased. This raises the spectre of possibly being able to have affected the general level of performance of that team by increasing their Hb levels prior to competition.

Although these performance observations are isolated and few, they do suggest that a subdivision of the normal range into optimal

and suboptimal levels may be a useful concept in the hematological investigation of athletes in preparation for performance.

Possible Causes, Cures and Preventions of Hb and Hct Abnormalities

An increased destruction of erythrocytes during strenuous muscular exercise has been reported since the beginning of this century. Studies to determine its mechanism were first made by Broun (1922) who postulated that a decrease in erythrocytes, and consequently in Hb, after prolonged exercise in dogs was due to a reduction of resistance in the erythrocytes' membrane. This was caused by the wear and tear of increased circulation through the capillaries. Davis (1937) concluded that the decrease in the resistance in the erythrocyte membrane was due to the high body temperature brought on by heavy muscular work. Rice and Steinhaus (1931) showed that treadmill running produced an increased acidity level in the blood of dogs. They postulated that this might be the determining factor in erythrocyte destruction during hard physical exercise.

During the 1950's and 60's a group of Japanese researchers tried to determine the causes/cures/prevention of reduced Hb and Hct during hard physical work. Their results, although not conclusive, give a better understanding of the phenomena.

Yamaji (1954) found that a significant anemia and hypoproteinemia appeared temporarily during training, and returned to normal during rest periods. Yamaji further found that the nitrogen balance became positive during physical exercise, therefore, suggesting an increase

in the protein requirement in physical training as muscle hypertrophy begins, causing a protein deficiency. Yamaji theorized that the anemia and hypoproteinemia could be avoided if dietary protein intake was increased to meet the elevated needs.

Yoshimura (1970) defined this kind of anemia as "sports anemia", and concluded that dietary protein of 2 gm/kg body wt/day, is required to prevent an athlete in training from developing sports anemia. In 1965 Yoshimura found an Hb decrease of 10% after one week of training in rugby players.

Yamada (1958) found a decrease in the osmotic resistance of erythrocytes in athletes in training. The decrease in Hb which was exhibited returned to normal after two weeks rest, and the erythrocyte resistance was restored. Hiramatsu (1960a), in experiments with dogs and humans, also found that the increased destruction of erythrocytes was due to decreases in osmotic and mechanical resistances in the initial stage of physical training. Hiramatsu further demonstrated that sports anemia is normochronic and normocytic.

Hiramatsu (1960b) showed that erythrocyte hemi-iron may be utilized to synthesize muscle hemin more directly than from serum iron. The utilization may be promoted by the destruction of erythrocytes during physical training. This was further supported by Yoshimura (1970) who demonstrated an increase in myoglobin in a two week exercise program on rats as compared to their resting controls. Yoshimura concluded that the Hb in erythrocytes is utilized to produce muscle protein and new erythrocytes. As this regeneration is accelerated in

muscular exercise accompanying an increased destruction of erythrocytes, it may be regarded as one of the adaptive reactions which promotes hypertrophy of muscles and regeneration of new and strong erythrocytes.

Yoshimura (1970) cited Ohtsuka (1966) who demonstrated a close correlation between sports anemia and the difficulty of the work required. Ohtsuka also supported data by Usami (1957) which suggested an accelerated secretion of adrenal hormones during strenuous muscular exercise may be responsible for the destruction of erythrocytes. In experiments with rats that received daily intramuscular injections of 0.1 mg adrenalin, increased fragility of erythrocytes occurred after about 10 days.

Although many researchers have reported a decrease in erythrocytes due to training others have reported no change. DeLanne, Barnes, and Brouha (1960) did not find erythrocyte destruction when subjects performed a submaximal work load to a maximal exertion. Oscai, Williams, and Hertig (1968) found an increase in total blood volume (TBV) after prolonged training, however, their findings showed the elevation in TBV was reflected by an increase in plasma volume, and was not accompanied by a rise in erythrocyte volume. Rasch, Hamby, and Burns (1969) also showed no change in Hb or Hct values between pre and post-training. They did, however, find significantly lower Hb and Hct values after three days of training. They concluded that under more stressful conditions where nutrition may be only borderline, the results may be different.

The cures and prevention of the decrease in the hematological

values are nearly as many as the suggested causes. The most widely reported are protein supplementation, iron replacement, and rest.

Advocates of protein supplements (Hiramatsu, 1960a, 1960b; Yamaji, 1954; Yoshimura, 1965, 1968, 1970) argue that the anemia is always concomitant with hypoproteinemia and thus, is closely related to protein deficiency which is caused by adaptive changes in training. They report that taking 2 gm/kg/day of dietary protein (containing more than 25% animal protein) will prevent sports anemia and hypoproteinemia. It is further suggested that the anemia may not be prevented by taking 2 gm/kg/day of the low quality protein in rice, while it may be prevented by taking 1.2 gm/kg/day of high quality protein with an animal content of 57% or more.

Nutrition Canada (1975) reported that in the general population 15.4% of the males and 21.2% of females had suboptimal serum iron values. Edgerton et al. (1972) showed that iron deficient anemia was detrimental to performance, however, no specific iron supplement or dosage was recommended to remedy this problem during training. DeWijn et al. (1971) also showed an iron deficiency anemia in athletes. However, upon an analysis of 7-day dietary food records, they found adequate iron content. The percentage of calories provided by fat in the diets averaged 42.5%, suggesting that excessive fat and other natural dietary antagonistic factors may inhibit iron absorption. This diet could lead to suboptimal Hb and iron depletion without anemia and would have an inhibitory effect on optimal athletic performance. This hypothesis was supported by Weswig and Winkler (1974)

who found no significant increase in Hb or serum iron when iron supplements were given to swimmers undergoing training.

The most consistent cure seems to be rest. Karvonen and Kunnas (1952), Yamada (1958), Yamaji (1954), and Yoshimura (1965, 1968, 1970) all found that the hematological factors returned to normal after rest. Carlile (1960) reported that the adding of "blood forming" food substances to the diet such as iron and liver extract made no apparent difference. Only decreasing the training load, was a successful remedy. Stewart et al. (1972) supported these findings with the 1968 Australian Olympic team, when they reported that many athletes with suboptimal Hb levels had a daily protein intake above 2 gm/kg/day. With regards to iron intake, all athletes studied exceeded the suggested allowances for Australians. They concluded that in general, the iron and protein intakes were not major factors in producing suboptimal Hb levels. It was suggested that an increase in Hb levels may have been the inverse of the training effect. During training taper-off the depressed Hb levels rose to more optimal levels.

Although there are varying theories as to the causes/cures/preventions of decreased Hb and Hct values brought on by hard physical work, it would appear that the identification of suboptimal hematological parameters in the last weeks of training could be useful in the preparation of athletes for top level performance.

Chapter 3

METHODOLOGY

Hemoglobin concentration was determined by the cyanmethemoglobin method and hematocrit percentage with micro hematocrit technique. Blood samples were obtained from the subjects' fingers. The subjects stood while awaiting testing and were seated during blood sampling (Karvonh & Saarela, 1976).

Cyanmethemoglobin Method

The basis for a cyanmethemoglobin method is to dilute 0.02 ml of blood in a 5 ml solution containing potassium cyanide and potassium ferricyanide (Drabkin, 1948). Ferricyanide then converts hemoglobin iron from a ferrous to a ferric state to form methemoglobin in an alkaline solution. Methemoglobin then combines with potassium cyanide to produce the stable pigment cyanmethemoglobin. The absorbance of the solution was then measured in a Baush and Lomb spectronic 20 colourimeter[1] at a wavelength of 540 mu and compared to a standard curve[2] to find gm% Hb of whole blood. The average of two determinations was recorded (Dacie & Lewis, 1970).

---

1. Appendix A.

2. Appendix A.

Micro Hematocrit Method

The hematocrit percentage was determined by employing the micro-capillary tube technique described by Wintrobe (1974). Two samples were centrifuged at 11,500 rpm for 5 min and read for percent red cell volume by means of a spiral tub reader[3]. The average of these two volumes was recorded. No correction was made for trapped plasma.

Error

The error of the methods for a single determination of Hb concentration and Hct percentages were calculated from duplicate measurements performed within 2 hours on 10 individuals not participating in this study. The difference between the two measures were averaged for the 10 subjects. The average differences on this test-retest evaluation were .2 gm% Hb and .18% Hct. These figures were deemed by this writer to be the size of error of measurement obtained using the procedure and facilities that were available.

Decision Criteria

As an arbitrary measure of determining notable differences in Hb values a difference of .25 gm% was considered to be of sufficient excess to the error value of 1.2 gm% Hb to report decisions. This measure was chosen by this writer for decision making purposes.

---

3. Appendix A.

Other readers might wish to adopt alternative criteria. To determine if changes in Hb values occurred and were noteworthy the following criteria were employed for decision making purposes.

1. If an Hb value exceeded another value by .25 gm% or more then the value was deemed to have increased.

2. If an Hb value was less than another value by .25 gm% or more, then the value was deemed to have decreased.

3. Values which lay between these two extremes were considered not to have changed sufficiently to warrant attention.

For comparative purposes, contrasts were made to the mean Canadian population values for both sexes. Females ages 10 to 19, $\overline{X}$ Hb = 13.6; males ages 10 to 19, $\overline{X}$ Hb = 14.6 (Nutrition Canada 1975). If a single observation equalled or exceeded the population mean it was deemed to be above average. If it was below the mean it was deemed below average. These criteria allow for decisions to be made to indicate whether values changed from below to above average, remained stable, or changed from above to below average.

Study 1

Subjects

The subjects of this study were selected members of the Thunderbolt Swim Team from Thunder Bay in preparation for the 1978 Canadian Winter National Championships. Nine male subjects between the ages of 16 and 20 years, ($\overline{X}$ = 18.2 yrs) were tested.

Environment and Testing Schedule

The testing took place at Lakehead University from 26/01/78 to 14/03/78, during hard and taper periods of training. The last testing took place three days before competition. Further post-competition testing was conducted on seven subjects from 21/03/78 to 28/03/78, during a period of rest. Each subject was tested twice a week on Tuesdays and Thursdays. Blood letting took place between 2:45 pm and 3:15 pm and analyses were made immediately thereafter.

Study 2

Subjects

The subjects of this study were the total memberships of both the Men's (Group M) and Women's (Group W) 1978 Canadian Commonwealth Games Swimming Teams. Eighteen male subjects between the ages of 16 and 24 years, ($\bar{X}$ = 18.7 yrs), and nineteen female subjects between the ages of 14 and 23 years, ($\bar{X}$ = 17.4 yrs), were tested.

Environment and Testing Schedule

Testing took place at Lakehead University during the Commonwealth Games training camp from 13/07/78 to 27/07/78. The last testing took place 6 days before competition. Subjects had experienced 6 days of hard, fatiguing competition and travel causing a two hour time change.

Each subject was tested five times on a staggered schedule, Group M was tested on Friday, Tuesday, Friday, Tuesday, and Thursday

consecutively; while Group W was tested on Thursday, Monday, Thursday, Monday, and Wednesday. Blood letting took place between 3:00 pm and 5:00 pm on these days and analyses were made immediately thereafter.

Chapter 4

RESULTS

Study 1

The physical characteristics and raw data of the subjects in this study are presented in Appendix B, Table A.

During the course of this study illness and hard work or a combination of both seemed to have a profound influence on the hematological parameters under investigation. These observations were exemplified by individual figures (see Appendix B, Figures A-I) which illustrate the responses of Hb and Hct values to hard training, illness, taper and rest.

The mean values presented in Figures 1 and 2 (actual values in Table B, Appendix B) illustrated weekly variations in Hb values occurring on Tuesdays and Thursdays during heavy training. Just prior to the taper period and thereafter the weekly cycle ceased and values steadily increased.

The mean Hb concentration decreased up to .75 gm% and the mean Hct percentage decreased up to 1.25% after hard training was introduced. At the inception of tapering both Hb and Hct values began to increase. The last test before competition showed Hb and Hct values to be .28 gm% and 1.12% higher than initial values. For the seven subjects that remained with the study during a rest period after competition, Hb and Hct levels increased over the initial values .84 gm% and 1.64% respectively (see Table 1).

Table 1

Differences Between Initial and Final Hb and Hct Values

Subject	Hb Values gm%			Hct %		
	Initial	Final	Difference	Initial	Final	Difference
A	15.3	15.8	+ .5	45.0	48.3	+3.5
B	15.9	15.9	0.0	47.0	47.0	0.0
C	13.8	15.2	+1.4	44.0	44.0	0.0
D	15.3	16.0	+0.7	45.0	47.5	+2.5
E	13.4	15.8	+2.4	42.0	45.5	+3.5
F	15.8	16.5	+0.7	47.0	47.5	+0.5
I	15.8	16.0	+0.2	46.0	47.5	+1.5
Average	15.04	15.88	+ .84	45.14	46.78	+1.64

NOTE: Subjects G and H did not participate in the study during the rest period.

Table 2

A Comparison of the Hemoglobin Values on the First and Thirteenth Test Days for the Group (n=9), When Each Value is Compared to the Mean Value for the Canadian Populations (MVCP)

First Test Day	Thirteenth Test Day	Subjects n=9
Above MVCP	Above MVCP	7
Above MVCP	Below MVCP	0
Below MVCP	Above MVCP	2
Below MVCP	Below MVCP	0

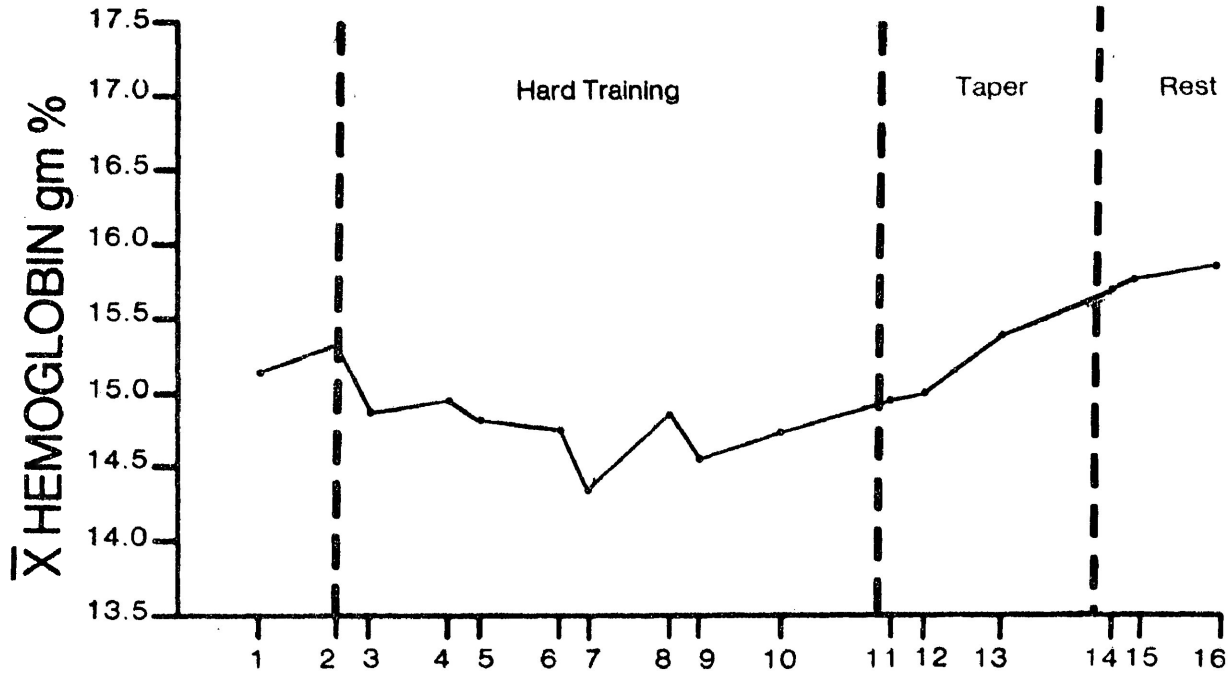


Figure 1. Mean Hb values for Study 1.

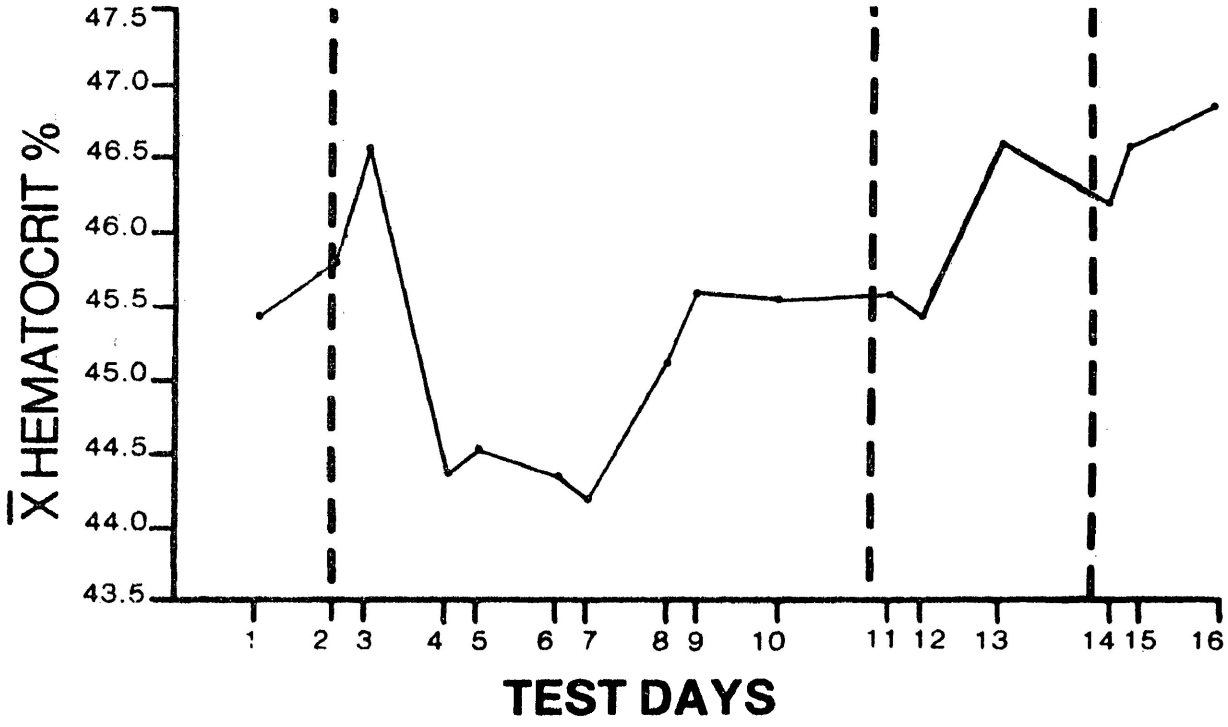


Figure 2. Mean Hct values for Study 1.

Hemoglobin concentrations for test days 1 and 13 were compared to the mean value of the Canadian population and are shown in Table 2. Seven subjects began the study with Hb values above the mean and all nine subjects were above the mean on the last test day before competition.

Since the importance of this hematological testing as a support service in the preparation of elite swimmers for competition lies in the individual's response rather than in the general trend, each subject was analyzed as to his specific response to hard training, illness, tapering and rest.

Subject A, suffered from three bouts of illness over the course of this study, the illness combined with the heavy work load lowered his Hb values .8, 1.3 and .7 gm% respectively. It appeared that the third cold, which occurred during taper, may have retarded the inverse training effect. When at rest and healthy, this subject surpassed all previous Hb values by .7 gm%.

Subject B, showed a decrease of 1.2 gm% Hb after 4 weeks of hard training. This subject exhibited a recovery response to taper but did not reach his initial Hb level at the last test day before competition. Upon returning from competition this subject's Hb concentration increased to its initial value.

Subject C, entered testing with an illness and an anemic Hb level. Iron supplements were taken and upon recovery from the illness the Hb level increased 1.4 gm%. This new high was again affected by a combination of hard training and illness as the Hb

concentration dropped 1.0 gm% before recovery from the illness. When a further decrease of .5 gm% Hb was observed the subject was placed again on iron supplementation and began tapering. This treatment provided a favourable response as the Hb value neared its previous high before competition, and continued to increase after competition.

Subject D, who entered the study with an illness, showed a steady increase in Hb concentration until the second week of hard training, when the subject exhibited a decrease of .7 gm% and a further drop of .6 gm% the following week. At this point the work load was reduced slightly, due to a competition, held between the tenth and eleventh test days, and tapering was begun one day before the eleventh test. This combination of events resulted in an increase of 1.6 gm% Hb. A brief illness between the eleventh and twelfth tests exhibited a decrease of .8 gm% Hb, which was recovered before competition. This new value was .9 gm% Hb higher than the initial value. After competition the Hb level remained relatively constant.

Subject E, entered the testing with an illness and showed a more or less steady increase in Hb concentration throughout the study. This subject showed no apparent adverse effects to heavy training. The subject did, however, exhibit a positive response to tapering and rest.

Subject F, exhibited a decrease in Hb concentration immediately after hard training was introduced. This decrease reached a maximum

drop of 1.8 gm% Hb, after three weeks of hard training. Within the following two weeks this subjects Hb value nearly reached the initial level. When tapering, and rest after competition were introduced, the initial value was reached and surpassed by .7 gm% Hb.

Subject G, showed a decrease of 2.2 gm% Hb after three weeks of hard training. This was followed by an increase until a 2 week illness caused a decrease of 1.1 gm% Hb. The recovery from the illness coincided with tapering and an increase of 1.1 gm% Hb was recorded before competition. This level was .6 gm% Hb lower than the initial value.

Subject H, exhibited a relatively constant Hb concentration until the subject became ill, at which time a decrease of .8 gm% was demonstrated, with a further decrease of .7 gm%, after recovery from the illness. This was followed by an increase in Hb concentration equalling the initial value. There was a decrease in Hb between tests 10 and 11, but once tapering was begun the Hb level regained its initial value.

Subject I, showed a decrease of 1.1 gm% Hb, seemingly due to hard training and illness. This level remained relatively constant until tapering was introduced, at which time the Hb concentration began to increase. The final test before competition showed an Hb concentration of .2 gm% below the initial value. The Hb concentration increased during the rest period after competition to .2 gm% above the initial value.

The Hct % showed similar trends to the Hb values in the majority

of cases. Slight variations may be due to the variability in either the hemoglobin hematocrit ratio of 1:3, (± 3%) (Wintrobe, 1974).

Study 2

The physical characteristics and raw data of the subjects in this study are presented in Appendix C, Table A.

The mean Hb and Hct values for groups M and W are illustrated in Fugres 3, 4, 5, and 6, and listed in Table 3. Group M exhibited a stable Hb concentration over the first four test days and an increase between test days 4 and 5 when a reduced work load was introduced. The Hct values for group M showed similar trends to the Hb values. Group W exhibited an increase in Hb concentration between test days 1 and 2, and later between the third and fifth test days which corresponded to a reduction in work load. The Hct values for group W also showed similar trends to the Hb values except for the last day. The decrease in Hct on test day 5 does not correspond with the increased Hb value for that day, and cannot be accounted for. From these results it is apparent that a reduced work load increases Hb and Hct levels.

Table 4 shows the general trend between the first and last test days and the reaction of Hb concentration to a reduced work load between test days 4 and 5. Group M showed an overall increase in Hb concentration in 50% of its members while 5.6% decreased and 44.4% remained stable. A majority of subjects, 72.2%, increased between test days 4 and 5, while 16.7% decreased and 11.1% remained stable.

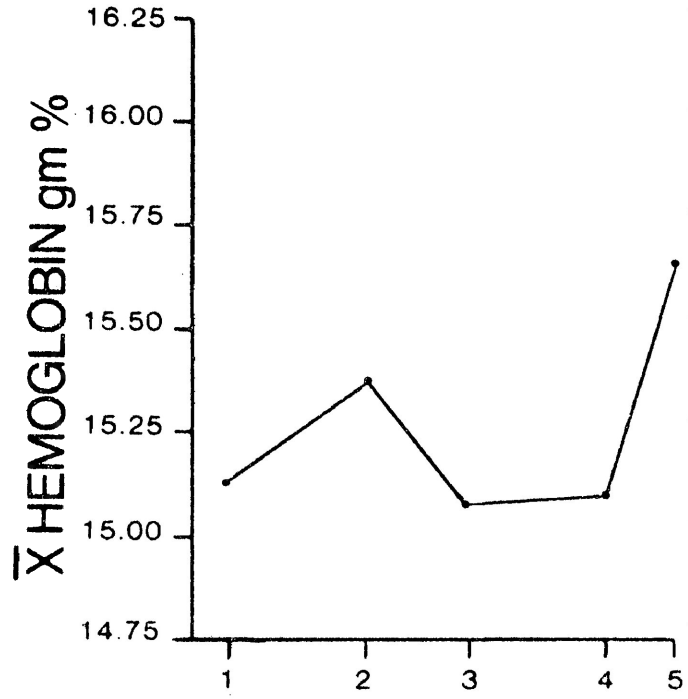


Figure 3. Mean Hb values for Group M, Study 2.

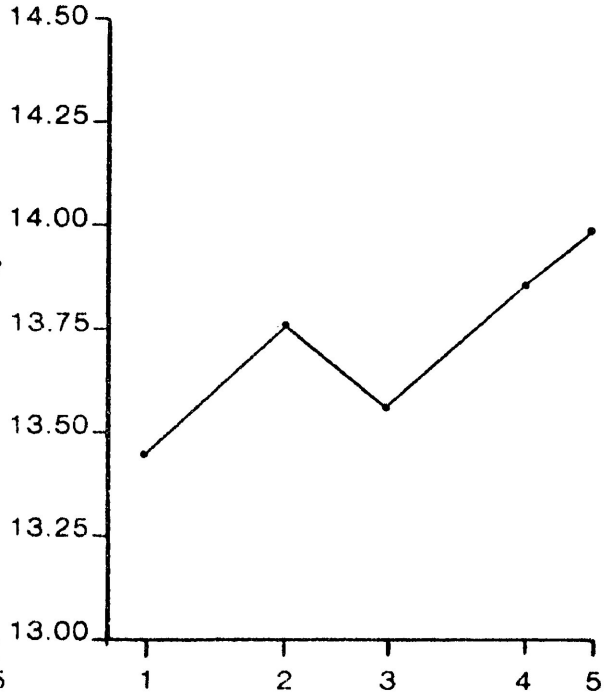
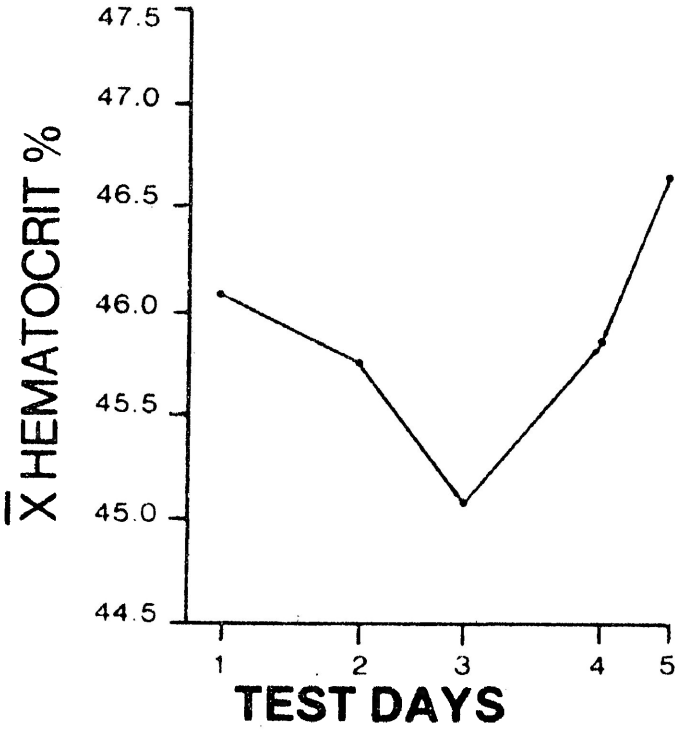
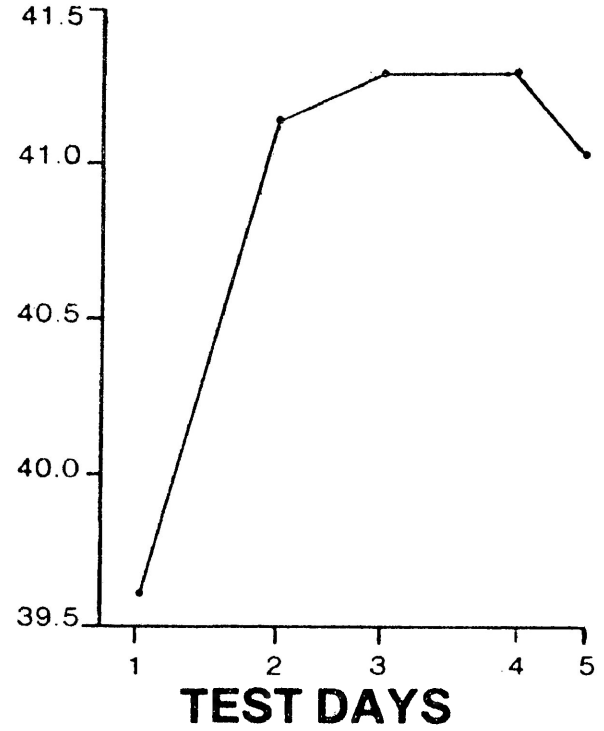


Figure 5. Mean Hb values for Group W, Study 2.



GROUP M:

Figure 4. Mean Hct values for Group M, Study 2.



GROUP W:

Figure 6. Mean Hct values for Group W, Study 2.

Table 3

Mean Hb and Hct Values for Groups M and W on Test Days 1 to 5

Measurement	Groups	Test Days				
		1	2	3	4	5
Hb	Men	15.16	15.39	15.11	15.13	15.68
	Women	13.43	13.75	13.55	13.82	13.98
Hct	Men	46.06	45.75	45.09	45.86	46.61
	Women	39.66	41.16	41.32	41.32	41.03

Group W showed an overall increase by 78.9% of its subjects while 5.3% decreased and 15.8% remained stable. Only 58% increased between test days 4 and 5 while 21% decreased and 21% remained stable.

The Hb value for the first and fifth tests of both groups M and W were compared to the mean values of the Canadian population in Table 5. Fifteen subjects from group M and 9 subjects from group W began the study above the mean, and all 18 subjects from group M and 15 subjects from group W were above the mean on the last test day before competition.

Since the importance of this hematological testing as a support service in the preparation of elite swimmers for competition lies in the individual's response rather than in the general trend, each subject was analyzed as to his or her specific response to training stress, reduced work, and coach determined supplementation (see Appendix C, Tables C & D, and Figures 1-18 for Group M and 1-19 for Group W).

Subject M1, exhibited an overall increase of .1 gm% Hb. The range was .8 gm% Hb with the highest value being recorded at the second test day. This subject did not undergo rest during the training camp.

Subject M2's final Hb value equalled the initial value. The range was .5 gm% Hb with the highest values being recorded on the second and third test days. A small but consistent decrease was recorded during both the fourth and fifth test days with reduced work load showing no apparent effect on the Hb value.

Subject M3, exhibited an overall increase of 1.7 gm% Hb with

Table 4

A Comparison of Overall Hemoglobin Concentration Changes Between Test Days 1 and 5, and General Trend Reaction to Rest Between Test Days 4 and 5.

Test Days 1 and 5				Test Days 4 and 5		
Groups	Increase >.25 gm%	Decrease >.25 gm%	Stable $\leq \pm$.25gm%	Increase >.25 gm%	Decrease >.25 gm%	Stable $\leq \pm$.25 gm%
M	9	1	8	13	3	2
W	15	1	3	11	4	4

Table 5

A Comparision of the Hemoglobin Values on the First and Fifth Test Days for Group M (n=18) and Group W (n=19) When Each Value is Compared to the Mean Value for the Canadian Population (MVCP)

First Test Day	Fifth Test Day	Group M n=18	Group W n=19
Above MVCP	Above MVCP	15	9
Above MVCP	Below MVCP	0	-
Below MVCP	Above MVCP	3	6
Below MVCP	Below MVCP	0	4

the highest value being recorded on the fifth test day. This subject showed a positive response in the Hb concentration during reduced work.

Subject M4, exhibited an overall increase of .3 gm% Hb. The range of values was .6 gm% Hb with the highest value occurring on the fourth test day. Although this subject illustrated a continual Hb increase between tests 1 to 4 a decrease of .5 gm% occurred between tests 4 and 5.

Subject M5, exhibited an overall decrease of .1 gm% Hb. The range was .6 gm% Hb with the highest value being recorded on the second test day. A constant decrease in Hb concentration occurred between test days 2 and 5 with reduced work showing no apparent effect on the Hb concentration.

Subject M6, exhibited an overall increase of .1 gm% Hb. The range was 1.3 gm% Hb with the highest value being recorded on the fifth day. Although a constant decrease was recorded between test days 1 and 4 a strong positive response occurred during reduced work and iron supplementation between test days 4 and 5.

Subject M7, exhibited an overall increase of .3 gm% Hb. The range was 1.4 gm% Hb with the highest value being recorded on the fifth test day. Reduced work and iron supplementation appeared to produce a positive response on the Hb concentration.

Subject M8, exhibited an overall increase of .3 gm% Hb. The range was .7 gm% Hb with the highest value being recorded on the second test day. Reduced work seemed to produce a positive response

on the Hb concentration.

Subject M9, exhibited an overall decrease of .1 gm% Hb. The range was .5 gm% Hb with the highest value occurring on the first test day. Although a decrease in Hb concentration was recorded between test days 1 and 3, a reduction in work seemed to produce a positive response.

Subject M10, exhibited an overall increase of .8 gm% Hb. The range was 1.3 gm% Hb with the highest value recorded on the fifth test day. Reduced work seemed to produce a positive response on the Hb concentration.

Subject M11's final Hb value equalled the initial value. The range was .2 gm% Hb with the highest value being recorded on the third and fourth test days. Reduced work did not seem to have any effect on the Hb concentration of this subject.

Subject M12, exhibited an overall decrease of .1 gm% Hb. The range was .3 gm% Hb with the highest value recorded on the third test day. Reduced work did not seem to have any effect on the Hb concentration of this subject.

Subject M13, exhibited an overall decrease of .3 gm% Hb. The range was 1.0 gm% Hb with the highest value being recorded on the second test day. This subject became ill with a diagnosed allergy after the second test day, and was treated with antihistamines, reduced work and iron supplements. By the fifth test day this subject had nearly recovered from the allergy and exhibited an increased Hb concentration of .6 gm% Hb over the fourth test day.

Subject M14, exhibited an overall increase of 1.1 gm% Hb. The range was 1.1 gm% Hb with the highest value being recorded on the fifth test day. A reduction in work seemed to produce a positive response on the Hb concentration of this subject.

Subject M15, exhibited an overall increase of .2 gm% Hb. The range was .5 gm% Hb with the highest value being recorded on the fifth test day. Reduced work seemed to have a positive effect on the Hb concentration of this subject.

Subject M16, exhibited an overall increase of 2.0 gm% Hb. The range was 2.0 gm% Hb with the highest value being recorded on the fifth test day. Work reduction and iron supplementation seemed to have a strong positive effect on this subject's Hb concentration.

Subject M17, exhibited an overall increase of .6 gm% Hb. The range was 2.2 gm% Hb with the highest value being recorded on the fifth test day. Reduced work seemed to have a strong positive effect on this subject's Hb concentration.

Subject M18, exhibited an overall increase of 2.6 gm% Hb. The range was 2.6 gm% Hb with the highest value being recorded on the fifth test day. A reduction in work seemed to have a positive effect on this subject's Hb concentration.

Subject W1, exhibited an overall increase of 1.1 gm% Hb. The range was 1.2 gm% Hb with the highest value being recorded on the fifth test day. A reduction in work seemed to have a positive effect on the Hb concentration.

Subject W2, exhibited an overall increase of .7 gm% Hb. The range was .8 gm% Hb with the highest value being recorded on the fifth test day. Reduced work and iron supplements seemed to have a positive effect on the Hb concentration of this subject.

Subject W3, exhibited an overall increase of .1 gm% Hb. The range was .8 gm% Hb with the highest value being recorded on the third test day. A constant decrease in the Hb concentration occurred between test days 3 and 5 with no apparent positive response in Hb due to work load reduction or iron supplementation.

Subject W4, exhibited an overall increase of .4 gm% Hb. The range was .7 gm% Hb with the highest value being recorded on the fourth test day. An early reduction in work load and iron supplementation seemed to have a positive effect on the Hb concentration between test days 2 and 4. The reduction in Hb concentration between test days 4 and 5 cannot be accounted for.

Subject W5, exhibited an overall increase of .8 gm% Hb. The range was .8 gm% Hb with the highest value being recorded on the fifth test day. A work load reduction seemed to produce a positive response on the Hb concentration.

Subject W6, exhibited an overall increase of .2 gm% Hb. The range was .6 gm% Hb with the highest value being recorded on the fifth test day. Reduced work seemed to produce a positive response on the Hb concentration.

Subject W7, exhibited an overall increase of .6 gm% Hb. The

range was .6 gm% Hb with the highest value being recorded on the fifth test day. Reduced work and iron supplementation seemed to produce a positive response on the Hb concentration.

Subject W8, exhibited an overall decrease of .3 gm% Hb. The range was .7 gm% Hb with the highest value being recorded on the first test day. A work load reduction seemed to have a slightly positive effect on the Hb concentration of this subject.

Subject W9, exhibited an overall increase of .9 gm% Hb. The range was .9 gm% Hb with the highest value being recorded on the fifth test day. Reduced work seemed to have a positive effect on the Hb concentration of this subject.

Subject W10, exhibited an overall decrease of .7 gm% Hb. The range was 1.1 gm% Hb with the highest value being recorded on the fourth test day. A work load reduction did not seem to have a positive effect on the Hb concentration of this subject.

Subject W11, exhibited an overall increase of .3 gm% Hb. The range was .7 gm% Hb with the highest value being recorded on the fifth test day. A reduction in work load seemed to have a positive effect on the Hb concentration of this subject.

Subject W12, exhibited an overall increase of .3 gm% Hb. The range was 1.4 gm% Hb with the highest value being recorded on the fourth test day. This value, which was by far the highest value recorded for group W, was followed by a drop of 1.1 gm% Hb on the fifth test day.

Subject W13, exhibited an overall increase of .5 gm% Hb. The range was 1.7 gm% Hb with the highest value being recorded on the fifth test day. Reduced work and iron supplementation seemed to have a positive effect on the Hb concentration of this subject.

Subject W14, exhibited an overall increase of 1.9 gm% Hb. The range was 2.2 gm% Hb with the highest value being recorded on the fifth test day. Reduced work and iron supplementation seemed to have a positive effect on the Hb concentration of this subject.

Subject W15, exhibited an overall increase of .7 gm% Hb. The range was 1.1 gm% Hb with the highest value being recorded on the fifth test day. A work load reduction and iron supplementation seemed to have a positive effect on the Hb concentration of this subject.

Subject W16, exhibited an overall increase of .4 gm% Hb. The range was 1.2 gm% Hb with the highest value being recorded on the second test day. Reduced work did not seem to have any effect on this subject's Hb concentration.

Subject W17, exhibited an overall increase of .5 gm% Hb. The range was 1.2 gm% Hb with the highest value being recorded on the second test day. This subject did not show a change in Hb concentration during the reduced work load period.

Subject W18, exhibited an overall decrease of .2 gm% Hb. The range was 1.4 gm% Hb with the highest value being recorded on the fourth test day. This subject did not show a positive response in

the Hb concentration during a reduction in work load.

Subject W19, exhibited an overall increase of .7 gm% Hb. The range was 1.2 gm% Hb with the highest value being recorded on the second test day. Reduced work and iron supplementation seemed to have a positive effect on the Hb concentration of this subject.

The Hct% response patterns for both groups M and W supported the Hb trends. Slight variations may have been due to the variability in the hemoglobin hematocrit ratio of 1:3 ($\pm$ 3%) (Wintrobe 1974).

Chapter 5

DISCUSSION

Study 1

Illness and hard training seemed to have a detrimental effect on Hb and Hct values of the subjects in this study. DeWijn et al (1971) stated that mild anemia may be caused by infection. Subject A exhibited three reductions in Hb values that coincided with reported illness. Other subjects also showed Hb reductions associated with illness. Many researchers (Karvonen & Kunnas, 1952; Hiramatsu, 1960a, 1960b; Yamada, 1958; Yamaji, 1954; Yoshimura, 1965, 1968, 1970) found decreases in Hb and Hct levels due to hard training. The data for each individual in this study supported this finding without exception.

An interesting observation showed a weekly variation in Hb values, with higher mean values being recorded on Tuesdays than Thursdays (see Figure 1). This supported the findings of Karvonen and Kunnas (1952) who showed decreases in Hb concentration which occurred in one day of heavy muscular work. They further observed that Hb concentration recovered after a full day of rest. The weekly variation in Hb concentration observed in this study may have been the result of a day and a half of rest occurring on Saturday (half day) and Sunday (full day). This opportunity for recovery would facilitate higher Hb readings at the start of the week. These observations are exemplified by subjects C, F and H (see Appendix B, Figures C, F, H) who showed these elevations on Tuesday test days. From these

observations, it seems reasonable that Hb and Hct values increased during the weekend due to one and one half days rest and decreased during weekly training due to an accumulation of training fatigue. Since a progressive decrease is evident it is doubtful that the weekly rest period offered sufficient time for Hb and Hct values to completely regain their initial levels. The variation in this response may have been due to differing recuperative capacities of the individuals under study since some subjects did not display the cyclic trend. This stresses the need for individual evaluations and personalized training programs being created for each member of elite swimming teams.

The Hb values for the first and thirteenth test days were compared to the Canadian mean on both days. Little concern for these individuals' blood properties is warranted. Two subjects commenced below the mean and ended above, indicating adequate or correct training. Seven subjects commenced and ended above the mean, once again indicating adequate or correct training.

With the reduction of work load during taper, initial Hb and Hct values were equalled or surpassed by only five of the nine subjects. In view of the fact that no testing was conducted during competition, it was possible that the Hb level increased before and during competition. Support for this interpretation was suggested in the first post-competition Hb values recorded for the seven subjects who remained with the study. Each equalled or surpassed their Hb values recorded on the thirteenth test day. Subsequent testing showed further

increases in six of seven subjects with subjects C, D and E exhibiting an overall increase of over 1 gm% Hb. All of the subjects exhibited values above the Canadian population mean.

This post-competition increase suggests that blood properties of the swimmers were not optimal when they went into competition. Changes in training experience during the taper period may be necessary to optimize this capacity.

Study 2

This study began after the subjects had experienced six days of hard, fatiguing Commonwealth Games Trials competition and travel. Some subjects may have been more tired than others due to the scheduling and amount of the pre-testing competition events.

The mean values (Figures 3, 4, 5, 6, Table 3) indicated an initial increase in both Hb and Hct for group W between test days 1 and 2, while group M remained stable until the reduced work period of test day 5. This initial increase in group W may have been due to the staggered testing schedule in which group M was examined one day after group W, therefore allowing an extra day of recovery.

With a reduction in work load at the end of the training camp, 14 of 18 subjects in group M and 17 of 19 subjects in group W equalled or surpassed their initial Hb test values. This agreed with the findings of study 1 and those of other authors (Carlile, 1960; Stewart et al, 1972; Sutton, 1971) that a reduction in work load increases the

Hb levels of elite swimmers. Three swimmers, W7, M16 and M18 had increases of over 1 gm% Hb between the initial and final test days.

The Hb values for the first and fifth tests of both groups M and W were compared to the mean value of the Canadian population (Nutrition Canada, 1975). Group M, showed fifteen subjects equal or above that value on both days, and three subjects initially below but ending above. Group W showed nine subjects equal to or above the mean population value on both days, six subjects initially below and ending above, and four subjects beginning and ending below the population mean. The subjects which started and ended above the mean value show no cause for worry. Those subjects that started out below and ended above the mean indicate that correct training was provided. Those subjects who started and ended below the mean indicated either incorrect training or the influence of an extraneous variable, since actions which were not successful were attempted by the coaching and support staff to remedy this situation. Because of the importance attached to international swimming teams, it may be necessary to attach support staff or consultation services which have the expertise to diagnose and rectify hematological problems as evidenced here.

The differences exhibited between groups M and W strongly suggest two different training effects. This was not surprising since two different staffs were employed, one for each group. What they demonstrated was that blood characteristics do react quickly and

sensitively to variations in training. Because of this sensitivity it is recommended that greater emphasis be placed on conditioning athletes' blood for competition than is generally followed.

Cautionary Notes

This study was purely descriptive. The investigator had no control over the experiences of the athletes (work load, rest, diet, iron supplementation, etc.) thus, explanations are, at best, speculative. Further, the blood characteristics were limited to the two factors described. Although causality has been suggested in what was observed it has been done in a cautionary vein recognizing that only relationships have been observed. The strength for offering causal interpretation lies in the fact that what was observed supported the findings of other independent researchers.

This writer employed self determined arbitrary criteria for decision making purposes. The data are open to different interpretations if other criteria are used.

The reporting of hemoglobin values was maintained as described in the thesis limitations. The hematocrit values serve as a comparative basis for further research.

Chapter 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary

Since hemoglobin and hematocrit are important for optimal physical performance, this thesis was designed to demonstrate and evaluate such tests as support services in the preparation of elite swimmers for competition. Study 1 evaluated Hb and Hct values for members of the Thunderbolt Swim Team of Lakehead University, in preparation for the 1978 Canadian Winter Nationals. Study 2 monitored Hb and Hct levels of the 1978 Canadian Commonwealth Games Swimming Teams during a training camp experience.

Study 1

Nine male subjects between the ages of 17 and 19 years, ($\bar{X}$ = 18.4 yrs) were tested for Hb concentration and Hct % during hard and taper periods of training. Hemoglobin concentration was determined by the cyanmethemoglobin method and hematocrit percentage with the micro hematocrit technique. Blood samples were obtained from the subjects' fingers. Testing took place at Lakehead University on Tuesdays and Thursdays for a period of two months.

Decreases in Hb and Hct levels were recorded in some subjects during hard training and during illness. Increases were exhibited in all subjects during tapering and post-competition rest. A weekly

variation was observed in mean Hb values, with Tuesday recordings exhibiting higher values than Thursday. Two subjects began the testing with Hb values below the mean value of the Canadian population, however none of the subjects were below this value on the last test day before competition. All seven subjects which remained with the study during post-competition rest, exhibited an Hb values above the mean of the Canadian population.

The coach involved in this study used the Hb and Hct evaluations as aids in determining taper programs and administering iron supplementation.

Study 2

Eighteen male subjects (group M), between the ages of 16 and 24 years ($\overline{X}$ = 18.7 yrs), and 19 female subjects (group W), between the ages of 14 and 23 years ($\overline{X}$ = 17.4 yrs), were tested for Hb concentrations and Hct % during maintenance training in a Games Training camp situation. Hemoglobin concentrations and hematocrit percentages were determined in the same manner as in study 1. The testing took place at Lakehead University on a staggered schedule over a three week period. Sub-optimal Hb and Hct values were diagnosed and treated with reduced work loads, and iron supplementation.

Three subjects from group M and 10 subjects from group W began the study with Hb values below the mean value of the Canadian population. None of the subjects from group M and only four subjects from group W remained below the population mean on the final examinations.

The coaches involved with this study used the Hb and Hct evaluations as aids in preparing the athletes for competition.

Conclusions

The results of these two studies indicated that:

1) Hemoglobin concentrations and hematocrit percentages decrease due to hard training and illness.

2) Hemoglobin concentrations and hematocrit percentages increase during taper, reduction in work loads, and rest.

3) Repetitive evaluations of Hb and Hct values on entire teams of elite athletes are both practical and useful.

4) Such testing was accepted by both coaches and swimmers.

5) Serious competition and travel may be detrimental to Hb and Hct levels.

6) All elite swimmers do not react in the same way to similar training stresses. Therefore, individualized programs must be developed if each swimmer is to receive an optimal training effect.

Recommendations

1. These observations should be extended under less variable circumstances than were possible in this study.

2. If causal factors are to be defined, the researcher must have experimental control over work load, diet, and supplementation.

Further hematological parameters including iron and protein content, size, shape and colour of erythrocytes, total Hb volume, and plasma volume, must be considered.

3. Due to the practical implications of this study in aiding in the preparation of elite swimmers for competition, similar screening examinations should not wait for scientific verification and explanation, rather they should be continued and re-evaluated as new information becomes available.

REFERENCES

Anderson, H.T., & Barkve, H. Iron deficiency and muscular work performance. Scandinavian Journal of Clinical and Laboratory Investigation, 1970, 114, 7-41.

Åstrand, P.-O., & Salton, B. Plasma and red cell volume after prolonged, severe exercise. Journal of Applied Physiology, 1964, 19, 829-832.

Astrand, P.-O., & Rodohl, K. Textbook of work physiology, (2nd ed.). New York: McGraw-Hill, 1977.

Berry, W.T.C., Beveridge, J.B., & Bransby, E.R. The diet, hemoglobin values and blood pressures of Olympic athletes. British Medical Journal, 1949, 1, 300-304.

Bevegard, S., Holmgen, A., & Johnson, P. Circulatory studies in well trained athletes at rest and during heavy exercise, with special reference to stroke volume and influence of body position. Acta Physiologica Scandinavia, 1963, 57, 43-50.

Broun, G.O. Blood destruction during exercise. Journal of Experimental Medicine, 1922, 36, 461-500.

Carlile, F. Training and overtraining. Proceedings of the Australian National Swimming Coaches Forum at Sydney, 1960. (Summary)

Carlile, F. The swimmer in stress. Proceedings of the National Coaches Seminar Australian Sports Council at Melbourne, 1975, 34-57.

Clement, D.B., Asmundson, R.C., & Medhurst, B. Hemoglobin values: comparative survey of the 1976 Canadian Olympic Team. Canadian Medical Association Journal, 1977, 177, 614-616.

Crowell, J.W., & Smith, E.E. Determinant of the optimal hematocrit. Journal of Applied Physiology, 1967, 22, 501-504.

Cullumbine, H. Hemoglobin Concentration on Physical Fitness. Journal of Applied Physiology, 1949, 2, 274-277.

Dacie, J.V., & Lewis, S.M. Practical Hematology (4th ed.) London: Churchill, 1970.

Davis, J.E. Changes in erythrocyte fragility due to physical exercise and variation of the body temperature. The Journal of Laboratory and Clinical Medicine, 1937, 5, 786-790.

DeLanne, R., Barnes,J.R., & Brouha, L. Hematological changes during muscular activity and recovery. Journal of Applied Physiology, 1960, 15, 31-36.

DeWijn, J.F., DeJongste, J.L., & Mosterd, W. Hemoglobin, packed cell volume, serum iron and iron binding capacity of selected athletes during training. Nutrition and Metabolism, 1971, 13, 129-139.

Drabkin, D.L. Standardization of Hemoglobin measurement. American Journal of Medical Sciences, 1948, 215, 110-111.

Edgerton, V.R., Bryant, S.L., & Gillespie, C.A. Iron deficiency anemia and physical performance and activity of rats. Journal of Nutrition, 1972, 102, 381-400.

Ekblom, B., Goldbarg, A.N., & Gullbring, B. Response to exercise after blood loss and reinfusion. Journal of Applied Physiology, 1972, 33, 175-180.

Gardner, G.W., Edgerton, V.R., & Barnard, J.R. Cardio-respiratory, hematological and physical performance responses of anemic subjects to iron treatment. American Journal of Clinical Nutrition, 1975, 28, 982-988.

Guyton, A.C. Textbook of Medical Physiology. Philadelphia: Saunders, 1966.

Hiramatsu, S. Studies on the cause of erythrocyte destruction in muscular exercise. ACTA Hematology Japan, 1960a, 23, 843-851.

Hiramatsu, S. Metabolism of hemin iron in muscular exercise and sports-anemia. ACTA Hematology Japan, 1960b, 23, 852-861.

Karvonen, M.J., & Kunnas, M. Erythrocyte and hemoglobin changes during protracted heavy muscular work. Annales of Medical Experimental Biological Fennial, 1952, 30, 180-185.

Karvonh, J., & Saarela, J. Hemoglobin changes and decomposition of erythrocytes during 25 hours following a heavy exercise run. Journal of Sports Medicine, 1976, 16, 171-16.

Kjellberg, S.R., Rudhe, U., & Sjostrand, T. Increase of the amount of hemoglobin and blood volume in connection with physical training. ACTA Physiology Scandinavia, 1949, 19, 146-151.

Larson, L.A., (Ed.). Fitness, Health and Work Capacity. New York: Macmillan, 1974.

Nour-Eldin, F. Revision of hematology with examination exercises. London: Butterworth, 1973.

Nutrition Canada. British Columbia Survey. Ottawa: Health and Welfare Canada, 1975.

Oscai, L.B., Williams, B.T., & Hertig, B.A. Effect of exercise on blood volume. Journal of Applied Physiology, 1968, 24, 622-624.

Ohtsuka, A. (The factor affects the occurrence of sports anemia during the exercise.) Scientific Year Book of the University of Doshisha, 1966, 81-107. (Yoshimura, H. Anemia during physical training. Nutrition Reviews, 1970, 28, 251-253.

Rasch, P.J., Hamby, J.W., & Burns, H.J.J. Protein dietary supplementation and physical performance. Medicine and Science in Sports, 1969, 1, 195-199.

Rice, H.A., & Steinhaus, A.H. Acide-base changes in Serum of exercised dogs. American Journal of Physiology, 1931, 96, 529-532.

Stewart, G.A., Clarkson, G.T., & Steel, J.D. Hematology of the racehorse and factors affecting interpretation of the blood count. American Associates of Equine Practitioners, 1970, 16, 17-35.

Stewart, G.A., Steel, J.E., & Toyne, A.H. Observations on the hematology and the iron and protein intake of Australian Olympic athletes. Medical Journal of Australia, 1972, 2, 1339-1343.

Sutton, J. Pathology in the Limitation of performance. Australian Journal of Sports Medicine, 1971, 4 (2), 6-14.

Usami, S. Destruction of erythrocytes as a stress reaction of strenuous muscular exercise. Journal of Physiology Society Japan, 1957, 19.

Weswig, P.H., & Winkler, W. Iron supplementation and hematological data of competitive swimmers. Journal of Sports Medicine, 1974, 14, 112-119.

Wintrobe, M.M. Clinical Hematology, (7th ed.). Philadelphia: Lea & Febiger, 1974.

Yamada, T. Study on the properties of red blood corpuscle during the exercise. Japanese Journal of Physical Fitness, 1958, 7, 231-241.

Yamaji, R. Protein metabolism of subjects engaged in training for sports. Journal of the Physiology Society of Japan, 1954, 13, 476-483.

Yoshimura, H. Adult protein requirement. Federation of American Societies for Experimental Biology, 1961, 20, 103-110.

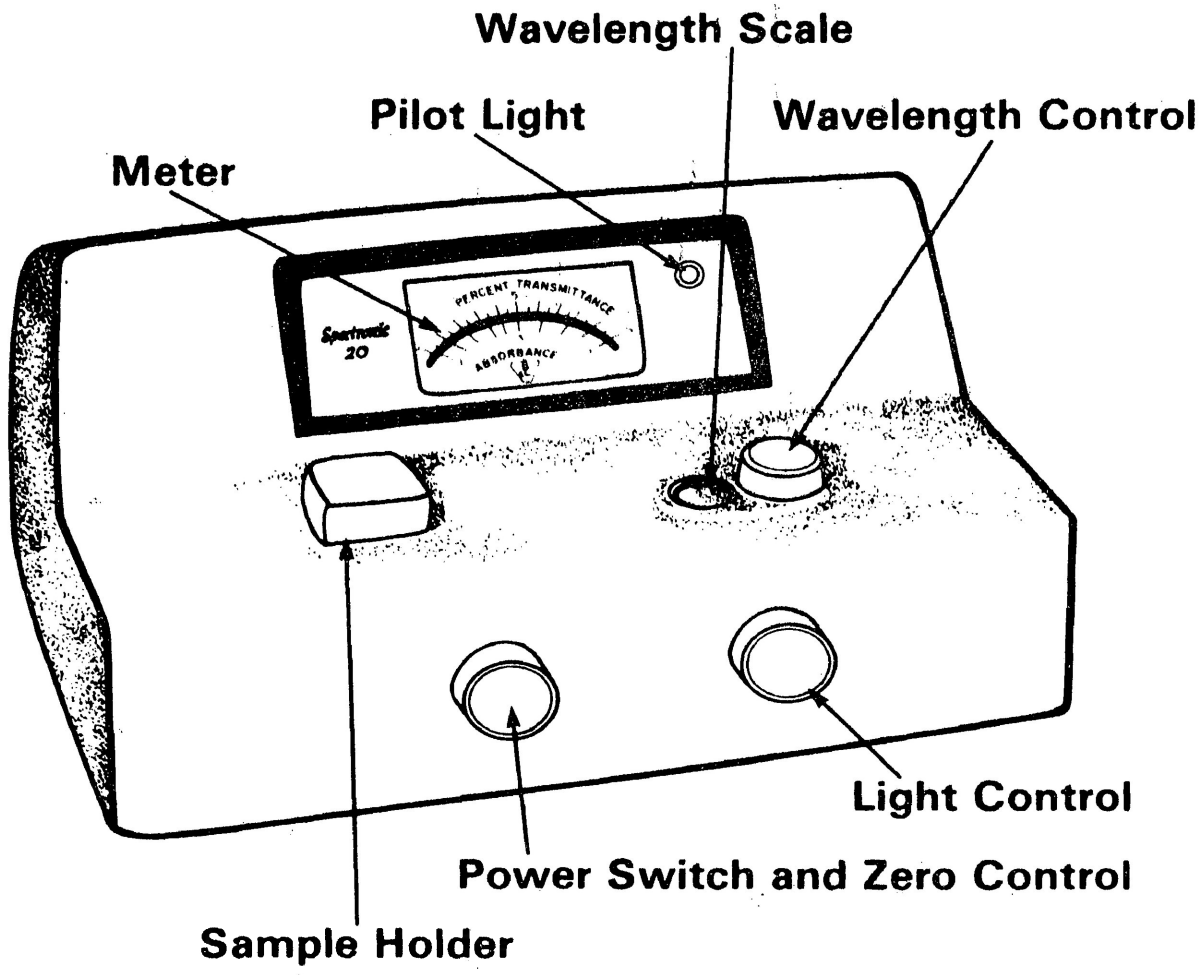
Yoshimura, H. Studies on protein metabolism in hard muscular work in relation to its nutritional requirements. Arctic Aeromedical Laboratory, Fort Wainwright, Alaska, 1965.

Yoshimura, H. Studies on erythrocyte destruction due to strenuous muscular exercise which causes "Sports-Anemia" and analysis of causes of "March Hematuria." United States army research and development: Far East Report No. J-279 A-1, 1968.

Yoshimura, H. Anemia during physical training. Nutrition Reviews, 1970, 28, 251-253.

APPENDIX A

HEMATOLOGICAL TESTING METHODS



BAUSH AND LOMB SPECTRONIC 20 COLORIMETER

PROCEDURE:

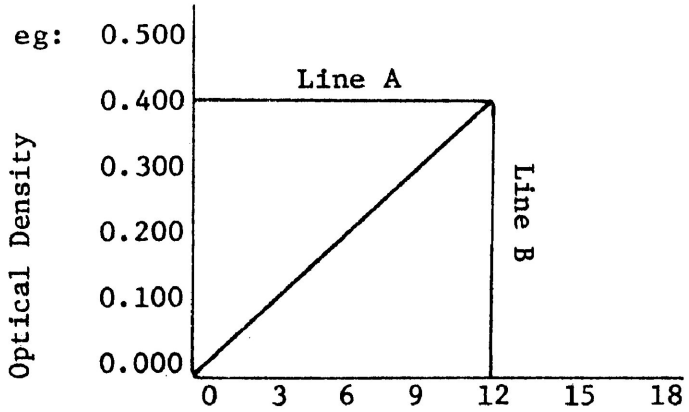
1. The instrument was allowed to warm up for one hour.
2. The wavelength was set to 540 m μ.
3. The meter needle was adjusted to 0% transmittance by using the zero control.
4. The bank (Drabkin's Reagent) was placed in the light path in the curvett holder.
5. The meter needle was adjusted to 100% transmittance and absorbance.
6. The blank was removed and replaced with an unknown (5 ml of Drabkin's Reagent and 0.02 ml of whole blood).
7. The optical density value was recorded for the unknown.
8. The Hb concentration was found by comparing the optical density value of the unknown to a standard curve.

Drabkin's Reagent - was conveniently prepared by means of "Acudyl" Diluent Pellets obtained from Ortho-Diagnostic.

Setting up of the Standard Curve

An ampul of cyanmethemoglobin standard was brought to room temperature and the optical density of the solution was measured, against a blank of Drabkin's reagent. Readings of optical density were also obtained with the standard solution diluted with the reagent in the following volumes:

gm% Hemoglobin	15%	12%	9%	6%	3%	0%
ml of Standard	5 ml	4 ml	3 ml	2 ml	1 ml	0 ml
ml of Reagent	0 ml	1 ml	2 ml	3 ml	4 ml	5 ml
Optical Density	0.500	0.400	0.300	0.200	0.100	0.000



The use of the Standard Curve to Determine Hb Concentration

1. The finger was cleaned with 70% alcohol.

2. The finger was punctured with a sterile lancet, the first drop of blood was wiped off to allow a second drop to accumulate.

3. The end of the capillary tube was placed in the drop. The tube was held in a horizontal position to allow the blood to enter the tube until it reached the black line (0.2 ml mark). The finger was not squeezed or "milked" for blood.

4. The optical density of the 0.02 ml whole blood diluted in 5 ml of Acudyl Diluent was determined. (eg. Optical density reading of 0.400).

5. From the optical density reading of 0.400 a straight line was drawn parallel to the horizontal axis, until it intersected the standard curve (Line A).

6. From this intersection a line was drawn parallel to the vertical axis, down to the horizontal axis (Line B).

7. Hemoglobin value of the unknown whole blood was 12.0 gm%.

NORMAL VALUES

	Means ± S.D.	
Men	14.6 ± 1.8	(males ages 10-19)
Women	13.6 ± .9	(females ages 10-19)

(Nutrition Canada, 1975)

NOTE: For more accurate readings use well-matched curvettes. This may be accomplished by finding the optical density of the cyanmethemoglobin standard in all curvettes, and eliminating the curvettes which vary from the mode.

Hematocrit Determination

The hematocrit is the percent volume of whole blood that is occupied by red blood cells. It was determined by centrifuging the blood in special "hematocrit" capillary tubes (capillary tubes containing dried heprin). The percent of whole blood made up of cells was determined by the height of the red cells in the tube, compared to the height of the total column of blood.

Procedure:

1. Since the finger had already been punctured for the Hb determination, a heparinized capillary tube was touched to the drop of blood. The tube was held in a horizontal position and the blood allowed to enter the tube until it was 1/2 to 3/4 full.

2. One end of the tube was sealed by pushing it into a tablet of sealing compound, and rotating it to form a plug.

3. The capillary tube was placed in the micro-hematocrit centrifuge with the sealed end to the outside, and centrifuged for 5 minutes.

4. The Hct percentage was read by rotating the carrying tray relative to the scale plate in the centrifuge.

NORMAL VALUES

Men	40-54%	(over age 12)
Women	35-47%	(over age 12)
		(Dacie & Lewis, 1970)

NOTE: The normal ratio for Hct: Hb is 3:1, $\pm$ 3%.

APPENDIX B

RAW DATA AND INDIVIDUAL FIGURES OF SUBJECTS IN STUDY 1

TABLE A

PHYSICAL CHARACTERISTICS STUDY 1

SUBJECTS	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)
A	20	179.3	82.6
B	18	178.0	08.4
C	18	178.2	77.3
D	19	173.9	75.0
E	16	173.4	77.5
F	19	178.5	75.4
G	18	178.0	86.4
H	18	177.4	75.2
I	18	161.7	72.7
MEAN	18.2	175.4	76.7
RANGE	16–20	178.5–161.7	86.4–75.0

TABLE B

RAW DATA: INDIVIDUAL HEMOGLOBIN AND HEMATOCRIT VALUES FOR SUBJECTS IN STUDY 1

Subjects	Tests	TEST DAYS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A	Hbgm%	15.3	15.2	14.5	14.6	14.6	14.7	14.8	15.3	14.0	14.5	15.1	14.4	15.0	15.3	15.8	15.8
	Hct%	45.0	46.0	47.0	47.0	45.0	44.5	44.0	46.0	43.0	43.0	47.0	44.5	48.0	47.0	47.5	48.5
B	Hbgm%	15.9	15.9	15.5	15.2	15.0	14.8	15.1	14.8	14.7	15.2	15.2	15.0	15.3	15.6	15.8	15.9
	Hct%	47.0	45.0	47.0	45.0	45.0	44.0	44.5	44.0	46.0	45.5	47.0	46.5	46.0	46.0	46.5	47.0
C	Hbgm%	13.8	14.7	14.7	15.2	14.5	14.8		14.2	14.7	13.7	14.7	14.8	14.9	15.0	15.0	15.2
	Hct%	44.0	46.0	44.0	43.5	43.0	43.5		43.0	46.0	45.0	44.5	45.5	43.5	43.5	43.5	44.0
D	Hbgm%	15.3	15.2	15.5	15.6	15.7	15.8	15.1	15.6	14.5	15.3	16.1	15.3	16.2	16.2	16.0	16.0
	Hct%	45.0	47.0	48.0	45.0	45.5	45.5	45.0	48.0	46.0	46.0	48.5	46.0	50.0	48.0	47.5	47.5
E	Hbgm%	13.4	13.6	13.9	14.0	14.0	13.8	13.4	14.4	13.7	14.0	14.4	14.4	15.3	15.8	15.9	15.8
	Hct%	42.0	43.0	46.0	43.5	42.5	42.5	42.0	45.0	45.0	43.0	43.5	43.0	44.0	44.0	45.8	45.5
F	Hbgm%	15.8	15.9	15.7	15.1	15.3	14.9	14.0	15.1	15.0	15.6	15.6	15.8	15.8	16.1	16.2	16.5
	Hct%	47.0	46.0	48.0	43.0	44.0	44.5	44.0	46.0	46.0	47.5	47.5	47.0	47.0	49.0	48.0	47.5
G	Hbgm%	15.6	15.4	13.6	14.2	14.0	13.8	13.4	14.6	14.7	13.6	13.9	14.8	15.0			
	Hct%	48.0	43.5	45.0	43.0	43.5	42.5	43.0	45.0	46.0	42.0	41.5	45.0	46.0			
H	Hbgm%	15.3	15.5	15.3	15.5	14.7	14.8	14.0	14.4	14.3	15.3	14.7	14.9	15.3			
	Hct%	45.0	46.5	46.0	44.0	46.0	46.0	45.0	44.0	46.0	47.0	43.5	45.5	46.5			
I	Hbgm%	15.8	16.1	15.3	15.4	15.2	15.2	15.0	14.8	15.2	14.9	15.1	15.6	15.6	15.8	15.8	16.0
	Hct%	46.0	49.0	48.0	45.0	46.0	46.0	46.0	45.0	46.0	46.0	47.0	47.0	48.0	46.0	47.0	47.5
mean	Hbgm%	15.10	15.28	14.88	14.98	14.78	14.73	14.35	14.80	14.52	14.68	14.97	15.00	15.38	15.69	15.79	15.89
	Hct%	45.44	45.78	46.56	44.33	44.50	44.30	44.19	45.11	45.55	45.00	45.50	45.44	46.56	46.21	46.54	46.78

INDIVIDUAL FIGURES

FOR

SUBJECTS IN STUDY 1

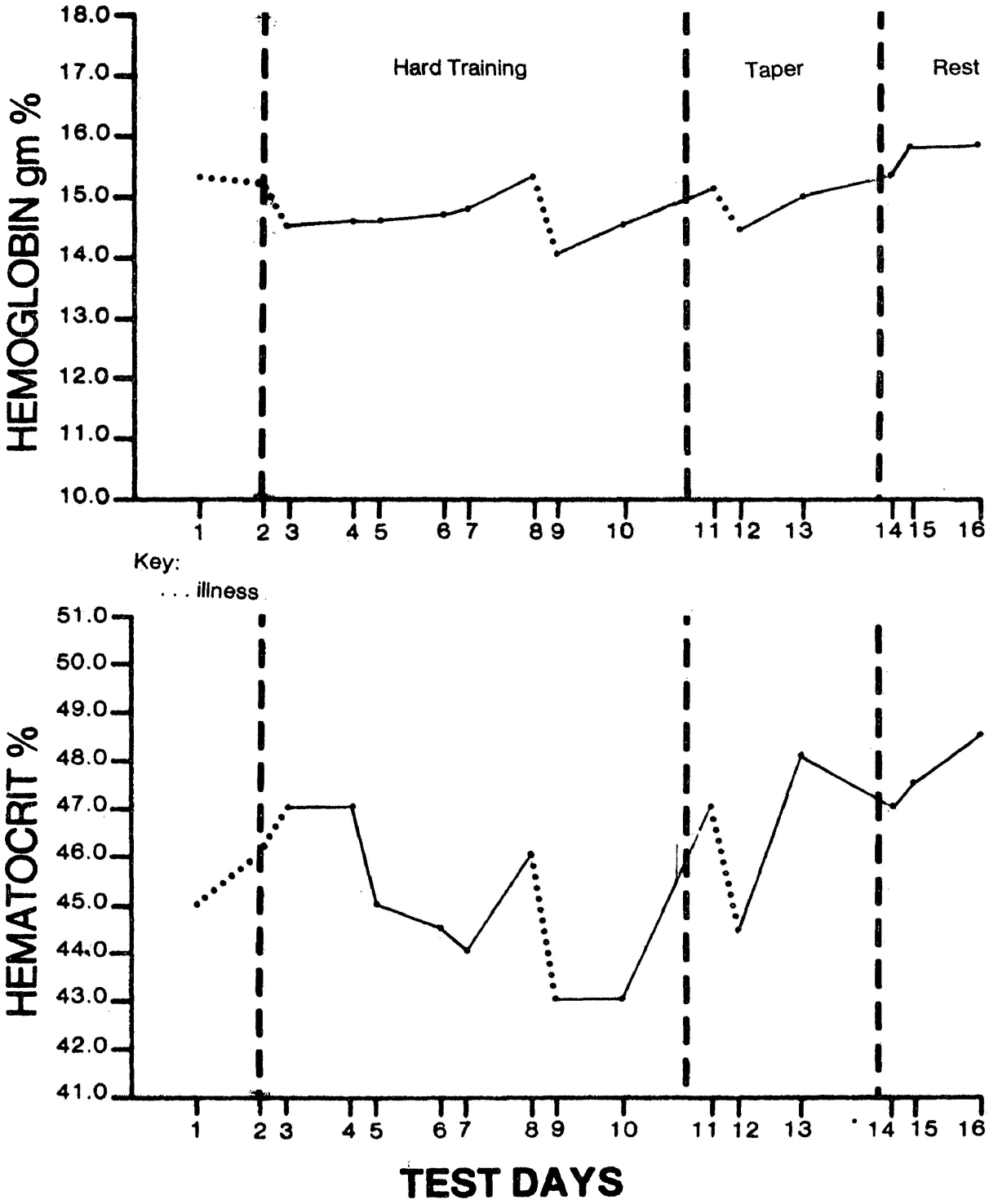


Figure 1. Hb and Hct values for subject A.

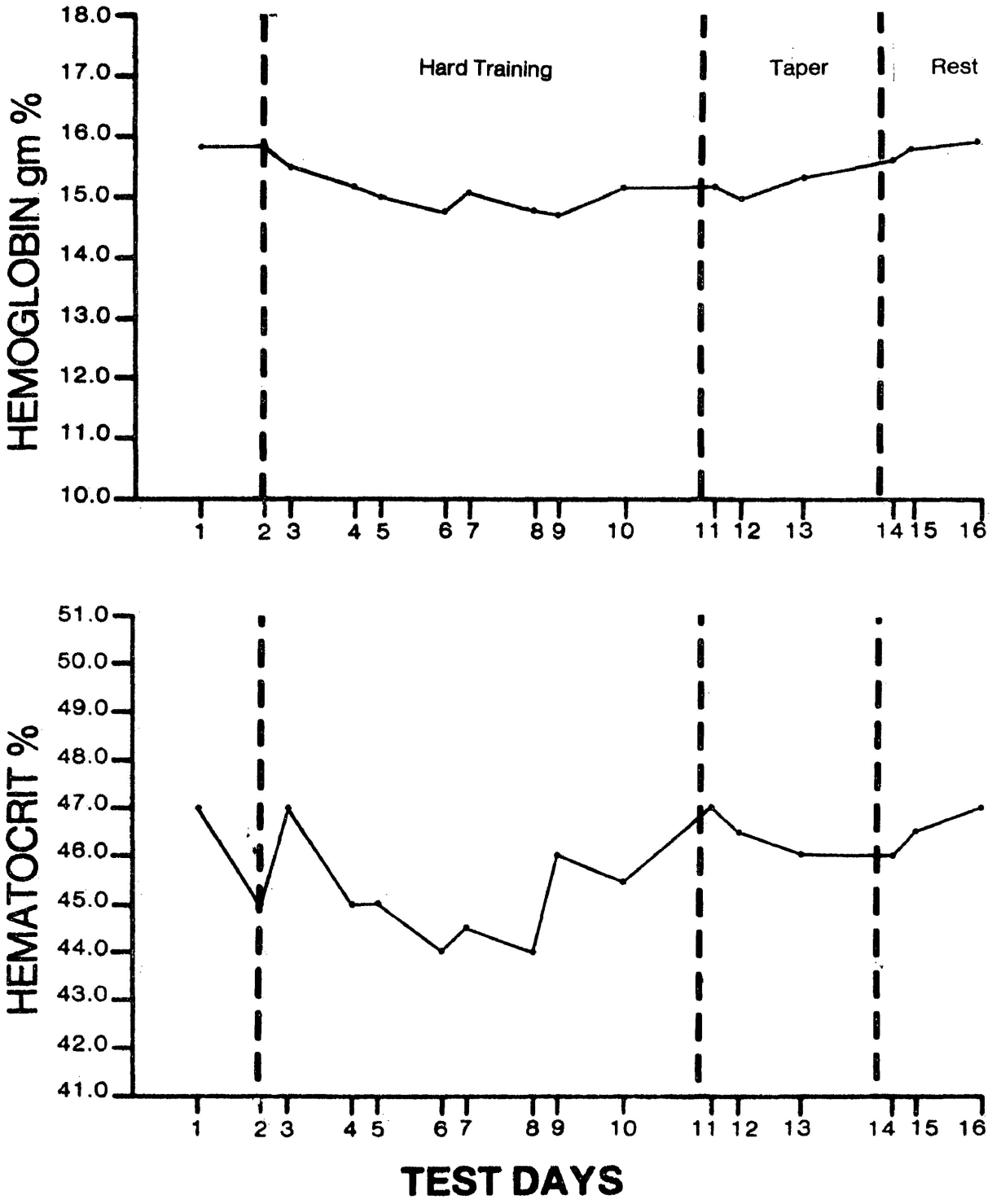


Figure 2. Hb and Hct values for subject B.

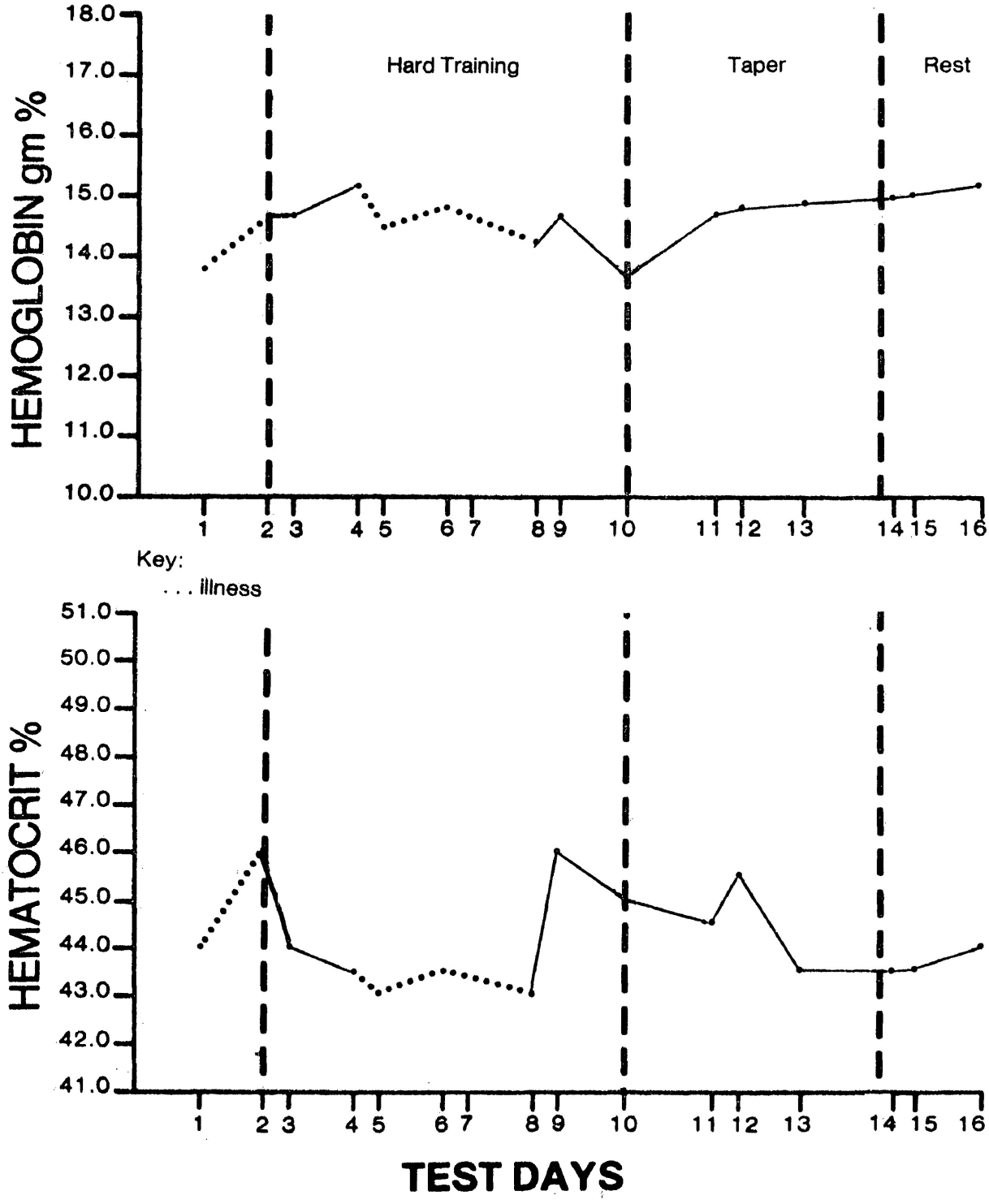


Figure 3. Hb and Hct values for subject C.

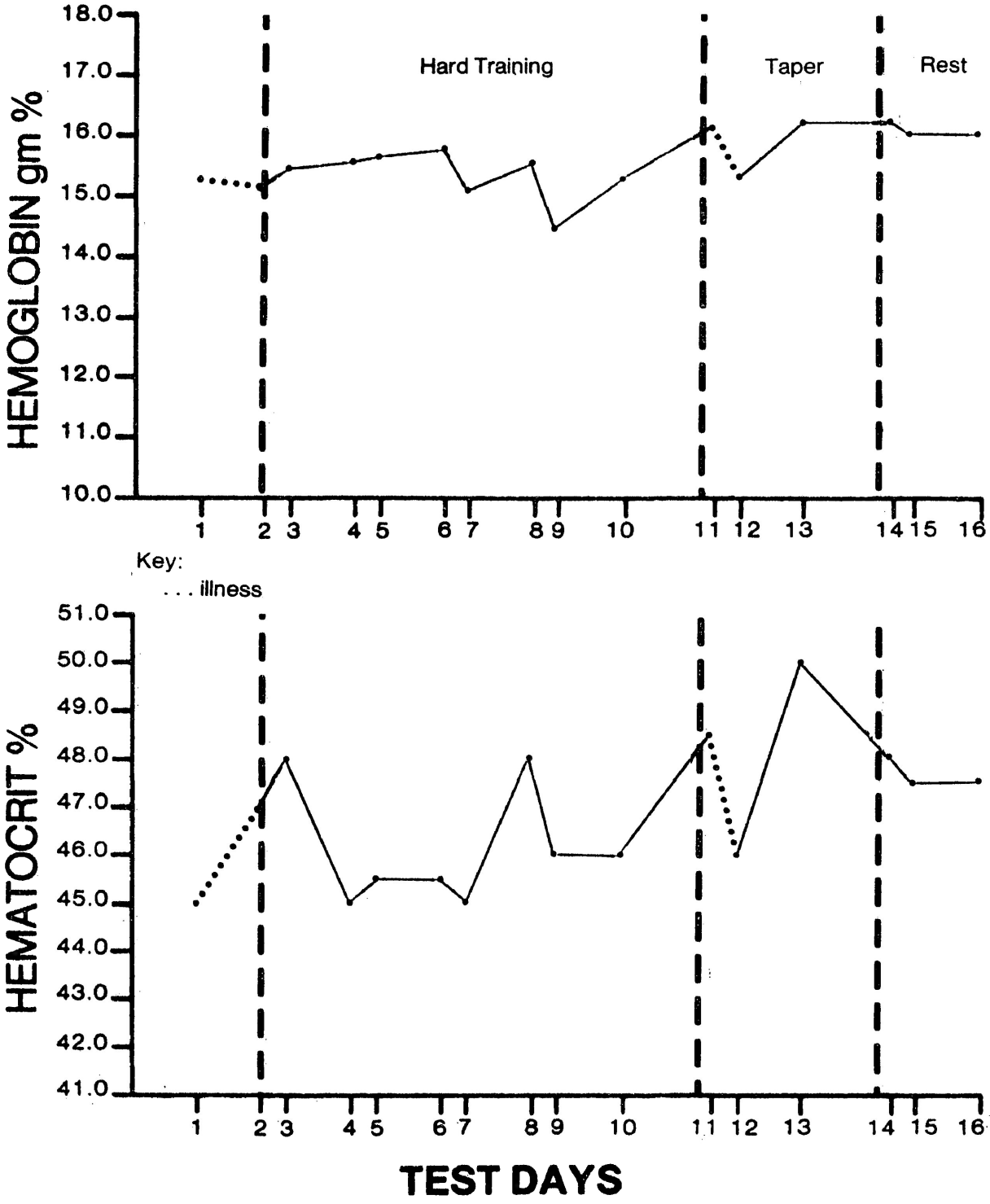


Figure 4. Hb and Hct values for subject D.

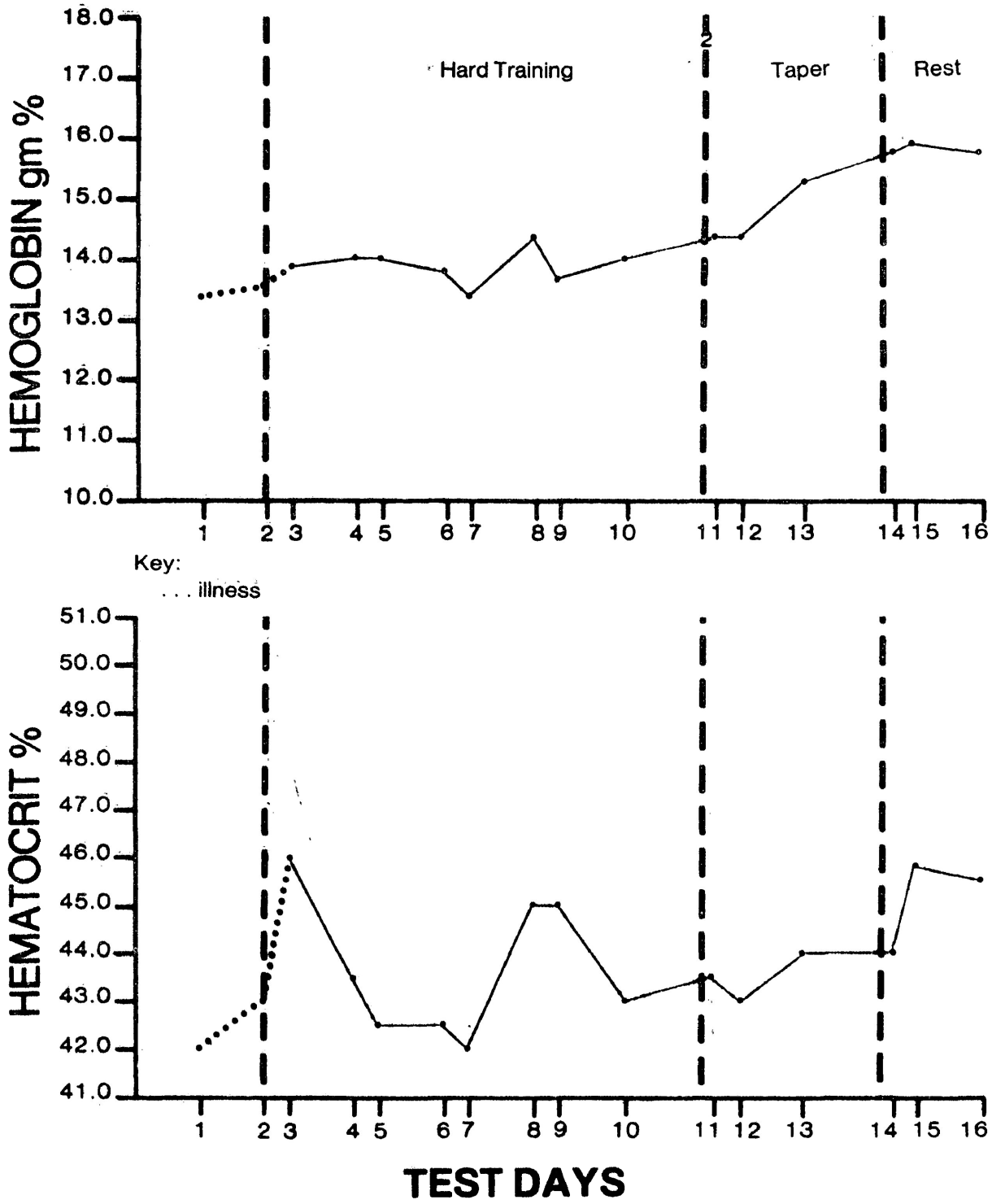


Figure 5. Hb and Hct values for subject E.

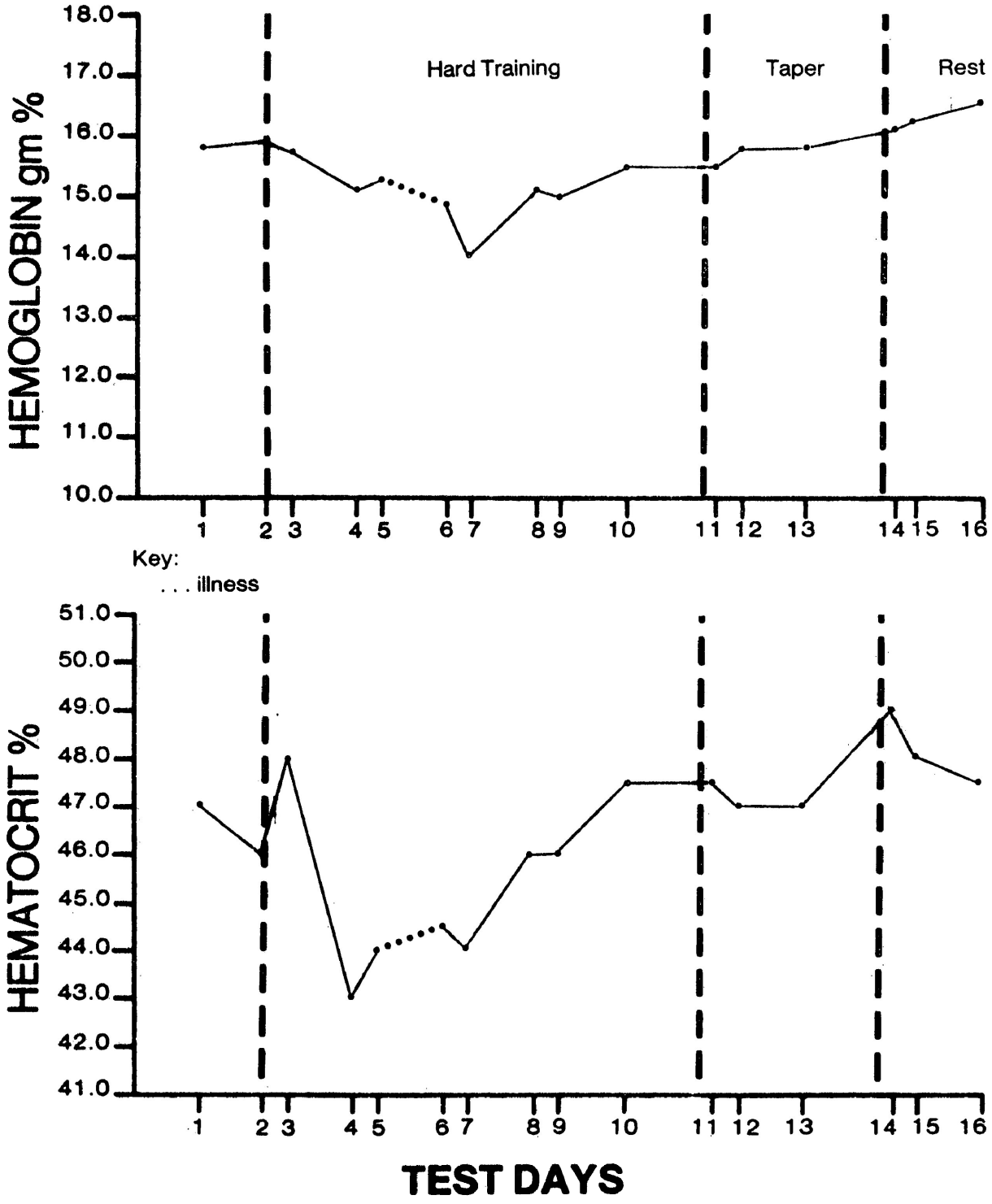


Figure 6. Hb and Hct values for subject F.

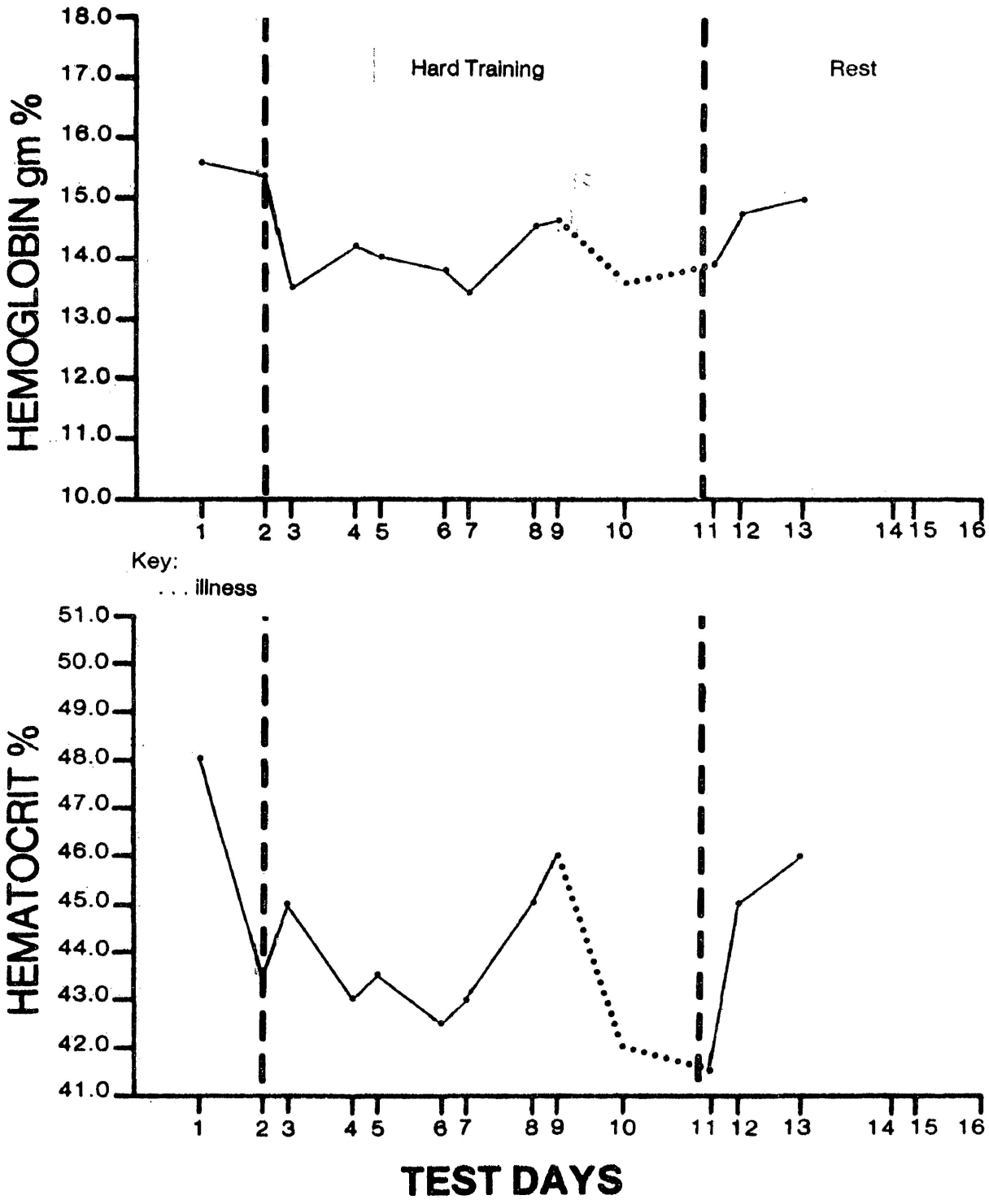


Figure 7. Hb and Hct values for subject G.

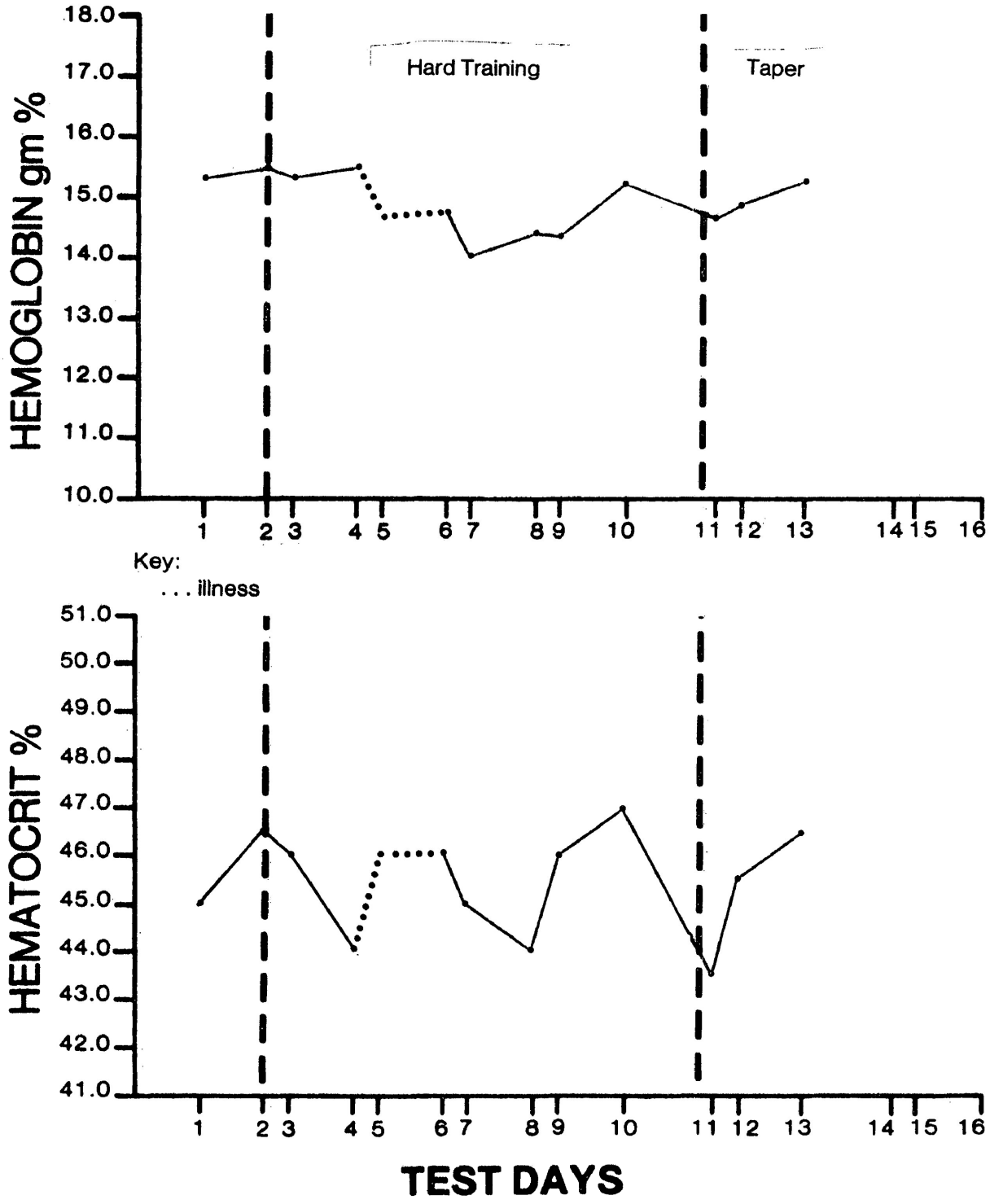


Figure 8. Hb and Hct values for subject H.

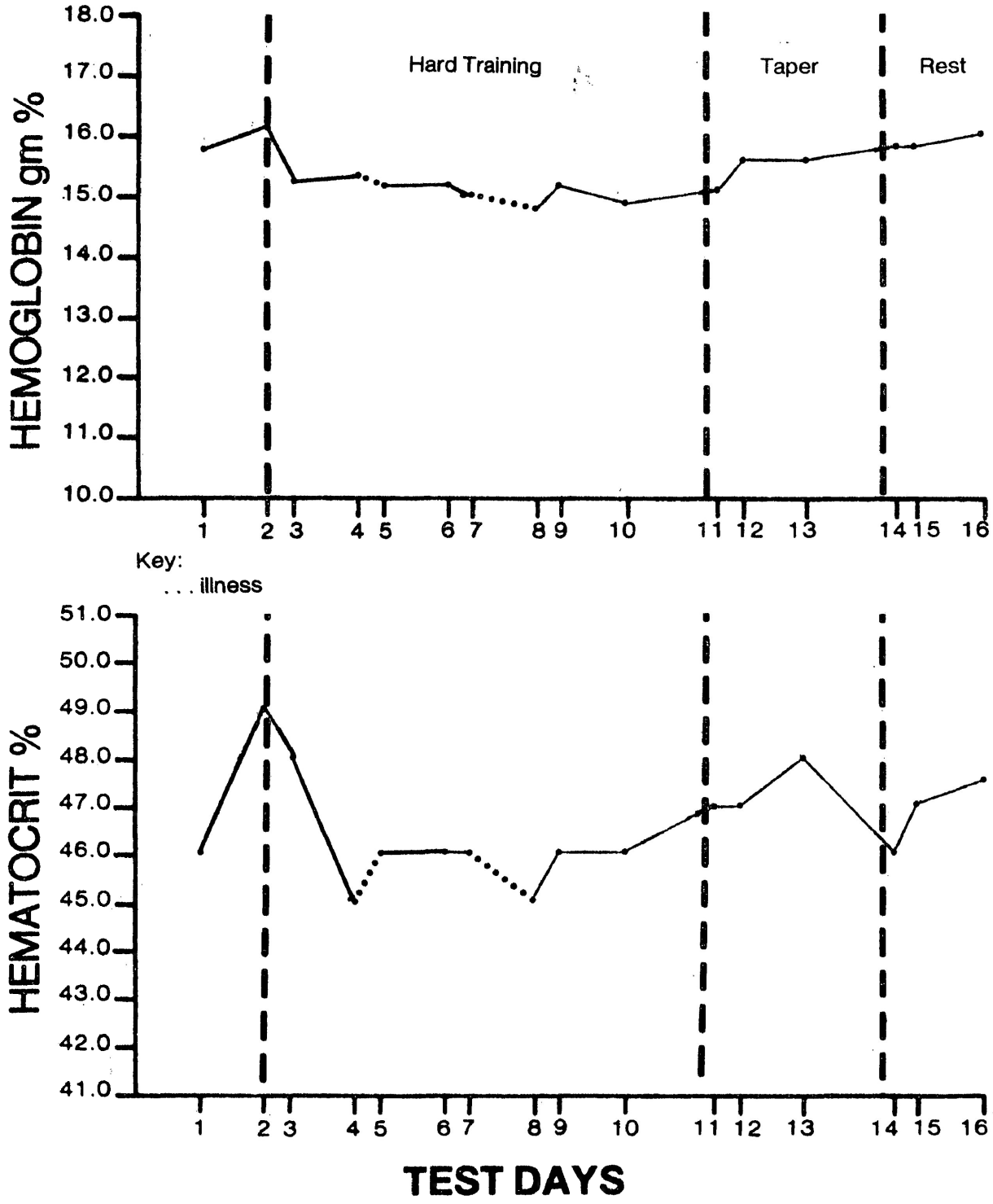


Figure 9. Hb and Hct values for subject I.

APPENDIX C

RAW DATA AND INDIVIDUAL FIGURES OF SUBJECTS IN STUDY 2

TABLE A

PHYSICAL CHARACTERISTICS OF GROUP M

SUBJECTS	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)
M1	16	190.5	81.1
M2	18	181.0	68.9
M3	18	175.0	77.3
M4	19	180.5	80.7
M5	17	185.0	73.0
M6	17	183.5	80.7
M7	18	173.0	61.0
M8	24	180.0	77.4
M9	21	175.0	71.6
M10	19	178.0	68.2
M11	19	185.5	74.3
M12	20	177.5	75.6
M13	19	178.5	77.7
M14	16	180.5	77.8
M15	18	195.0	89.6
M16	22	185.0	77.0
M17	17	185.0	77.2
M18	18	184.0	79.7
MEAN	18.7	181.8	76.0
RANGE	16–24	173.0–195.0	89.6–61.0

PHYSICAL CHARACTERISTICS OF GROUP W

SUBJECTS	AGE (yr)	HEIGHT (cm)	WEIGHT (kg)
W1	17	165.0	52.8
W2	21	184.0	72.0
W3	19	166.5	58.7
W4	16	167.5	56.6
W5	14	167.0	56.2
W6	15	165.0	58.0
W7	16	168.0	71.5
W8	18	161.5	61.5
W9	18	172.0	54.8
W10	17	163.0	54.8
W11	15	167.0	56.5
W12	15	162.5	55.0
W13	18	164.0	56.9
W14	15	170.0	55.1
W15	19	174.0	63.4
W16	16	166.0	53.8
W17	20	170.0	66.1
W18	19	157.5	53.9
W19	23	162.0	52.1
MEAN	17.4	167.0	58.4
RANGE	14–23	157.5–184.0	72.0–52.1

TABLE C

RAW DATA: INDIVIDUAL Hbgm%, Hct%, AND Wt(kg) VALUES FOR GROUP M

Subjects	Test	TEST DAYS 1	2	3	4	5	Subjects	Test	TEST DAYS 1	2	3	4	5
M1	Hbgm%	14.9	15.2	14.4	14.3	15.0	M10	Hbgm%	15.1	15.3	14.6	15.0	15.9
	Hct%	45.0	45.8	42.5	46.5	45.3		Hct%	44.0	44.8	43.3	44.0	46.0
	Wt(kg)	81.5	80.8	81.2	81.3	80.9		Wt(kg)	68.5	68.1	67.3	68.5	68.6
M2	Hbgm%	14.7	15.2	15.2	15.0	14.7	M11	Hbgm%	16.1	16.2	16.3	16.3	16.1
	Hct%	43.0	44.5	44.0	44.5	44.8		Hct%	48.0	47.0	46.0	47.8	46.8
	Wt(kg)	69.5	68.5	68.3	68.9	69.3		Wt(kg)	75.3	74.6	73.8	74.0	73.6
M3	Hbgm%	15.0	15.1	16.0	16.0	16.7	M12	Hbgm%	16.3	16.2	16.4	16.1	16.2
	Hct%	45.5	44.0	45.5	48.8	48.5		Hct%	47.5	46.8	47.0	44.3	45.8
	Wt(kg)	78.2	77.6	76.8	77.2	76.7		Wt(kg)	76.0	75.5	75.1	76.0	75.3
M4	Hbgm%	14.4	14.7	15.0	15.2	14.7	M13	Hbgm%	15.2	15.1	14.2	14.3	14.9
	Hct%	46.0		43.5	44.8	45.8		Hct%	45.0		42.5	43.5	44.8
	Wt(kg)	81.5	80.6	80.0	80.7	80.7		Wt(kg)	79.0	77.6	77.4	76.8	77.9
M5	Hbgm%	14.7	15.2	14.6	14.7	14.6	M14	Hbgm%	15.1	15.8	15.8	15.8	16.2
	Hct%	46.5	43.8	44.5	44.3	44.5		Hct%	49.5	49.5	49.5	49.5	50.5
	Wt(kg)	72.8	73.0	73.1	73.5	72.9		Wt(kg)	77.2	77.6	77.5	78.1	78.4
M6	Hbgm%	14.9	14.5	14.0	13.7	15.0	M15	Hbgm%	15.0	14.7	14.9	15.0	15.2
	Hct%	44.0	43.5	44.3	45.8	45.8		Hct%	46.5	45.0	45.0	47.0	47.0
	Wt(kg)	80.6	80.7	80.5	81.0	80.5		Wt(kg)	88.9	90.0	89.6	89.7	
M7	Hbgm%	15.5	15.5	14.4	14.5	15.8	M16	Hbgm%	14.1	15.4	14.7	14.8	16.1
	Hct%	47.0	47.0	43.5	44.5	47.8		Hct%	46.0	45.3	48.0	45.0	47.3
	Wt(kg)	61.9	60.6	61.0	61.5			Wt(kg)	76.9	76.5	77.4	77.2	
M8	Hbgm%	16.1	16.5	15.7	15.7	16.4	M17	Hbgm%	15.8	14.7	14.2	14.3	16.4
	Hct%	48.0	49.0	47.5	47.3	48.5		Hct%	44.5	45.0	43.0	43.5	44.3
	Wt(kg)	77.0	77.4	77.5	77.8			Wt(kg)	78.7	76.5	77.0	76.5	
M9	Hbgm%	15.5	15.2	15.0	15.1	15.4	M18	Hbgm%	14.4	16.5	16.6	16.5	17.0
	Hct%	45.5	44.0	43.5	47.0	45.5		Hct%	47.5	47.0	48.5	47.3	50.0
	Wt(kg)	72.1	71.4	71.5	71.8	71.4		Wt(kg)	80.6	79.3	79.5	79.7	79.5

RAW DATA: INDIVIDUAL Hbgm%, Hct% AND Wt(kg) VALUES FOR GROUP W

Subjects	Test	TEST DAYS 1	2	3	4	5	Subjects	Test	TEST DAYS 1	2	3	4	5
W1	Hbgm%	13.3	14.1	13.2	14.1	14.2	W11	Hbgm%	13.9	13.6	13.5	13.6	14.2
	Hct%	41.0	43.3	43.3	40.3	42.5		Hct%	40.0	40.0	42.5	41.3	41.3
	Wt(kg)	53.4	53.1	52.1	52.7			Wt(kg)	56.6	56.4	56.3	56.7	56.7
W2	Hbgm%	12.5	12.4	12.6	12.8	13.2	W12	Hbgm%	14.8	14.9	15.3	16.2	15.1
	Hct%	39.0	39.3	37.5	40.0	39.5		Hct%	41.5	44.0	46.0	48.5	44.8
	Wt(kg)	71.4	72.5	71.9	73.2	71.2		Wt(kg)	55.4	55.2	54.5	54.9	
W3	Hbgm%	12.3	13.0	13.1	12.7	12.4	W13	Hbgm%	14.2	14.0	14.2	13.1	14.8
	Hct%	36.0	39.5	39.3	38.8	38.0		Hct%	40.5	40.0	41.0	40.3	42.5
	Wt(kg)	58.6	59.1	58.1	58.9			Wt(kg)	57.1	57.4	56.6	56.8	
W4	Hbgm%	13.0	12.7	13.5	13.8	13.4	W14	Hbgm%	12.6	11.7	12.4	13.0	13.9
	Hct%	39.0	38.5	40.8	41.3	41.0		Hct%	38.5	37.5	39.0	41.0	39.8
	Wt(kg)	56.9	56.7	56.3	56.6			Wt(kg)	55.3	55.5	55.0	54.7	
W5	Hbgm%	13.9	14.6	14.2	14.0	14.7	W15	Hbgm%	13.0	13.6	13.5	12.6	13.7
	Hct%	42.0	42.3	42.5	42.5	41.8		Hct%	40.0	41.8	42.5	39.8	42.0
	Wt(kg)	56.1	55.8	55.9	56.7	56.4		Wt(kg)	63.5	63.9	62.8	63.3	
W6	Hbgm%	13.7	13.3	13.5	13.5	13.9	W16	Hbgm%	13.4	14.6	13.8	13.8	13.8
	Hct%	39.0	40.0	41.0	40.5	40.0		Hct%	39.0	44.0	42.3	41.8	40.8
	Wt(kg)	56.9	56.7	56.2	56.7	56.4		Wt(kg)	54.0	53.8	53.5	53.9	
W7	Hbgm%	12.6	13.3	13.1	14.0	14.2	W17	Hbgm%	13.4	14.6	13.8	14.0	13.9
	Hct%	37.0	39.8	39.5	40.8	40.5		Hct%	39.0	43.0	40.0	37.8	40.0
	Wt(kg)	58.6	58.0	58.0	57.5			Wt(kg)	66.4	65.5	66.2	66.6	65.9
W8	Hbgm%	14.5	13.8	14.4	14.1	14.2	W18	Hbgm%	13.9	14.1	14.0	15.1	13.7
	Hct%	39.0	39.0	39.5	41.0	39.3		Hct%	40.5	42.8	40.5	43.8	40.3
	Wt(kg)	71.5	71.6	71.3				Wt(kg)	54.1	54.1	54.3	53.6	53.7
W9	Hbgm%	13.7	14.5	14.1	14.1	14.6	W19	Hbgm%	12.5	13.6	12.4	13.0	13.2
	Hct%	40.0	41.8	39.8	41.0	40.5		Hct%	40.0	42.5	39.0	40.8	42.0
	Wt(kg)	61.2	62.6		61.1	61.1		Wt(kg)	51.9	52.4	52.3	52.1	52.1
W10	Hbgm%	13.9	14.9	12.9	15.0	14.6							
	Hct%	42.5	43.0	43.3	43.8	43.0							
	Wt(kg)	55.0	55.1	54.7	54.7	54.3							

INDIVIDUAL FIGURES

FOR

SUBJECTS IN STUDY 2

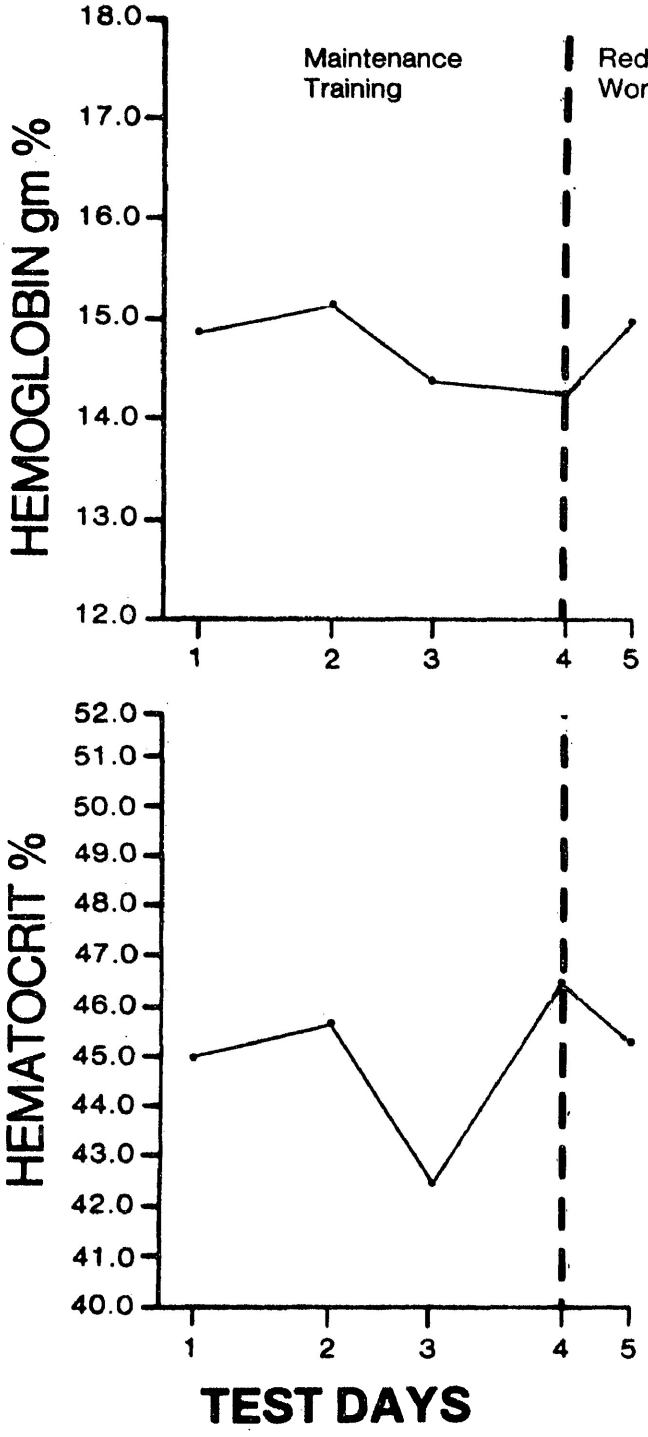


Figure 1. Hb and Hct values for subject M1.

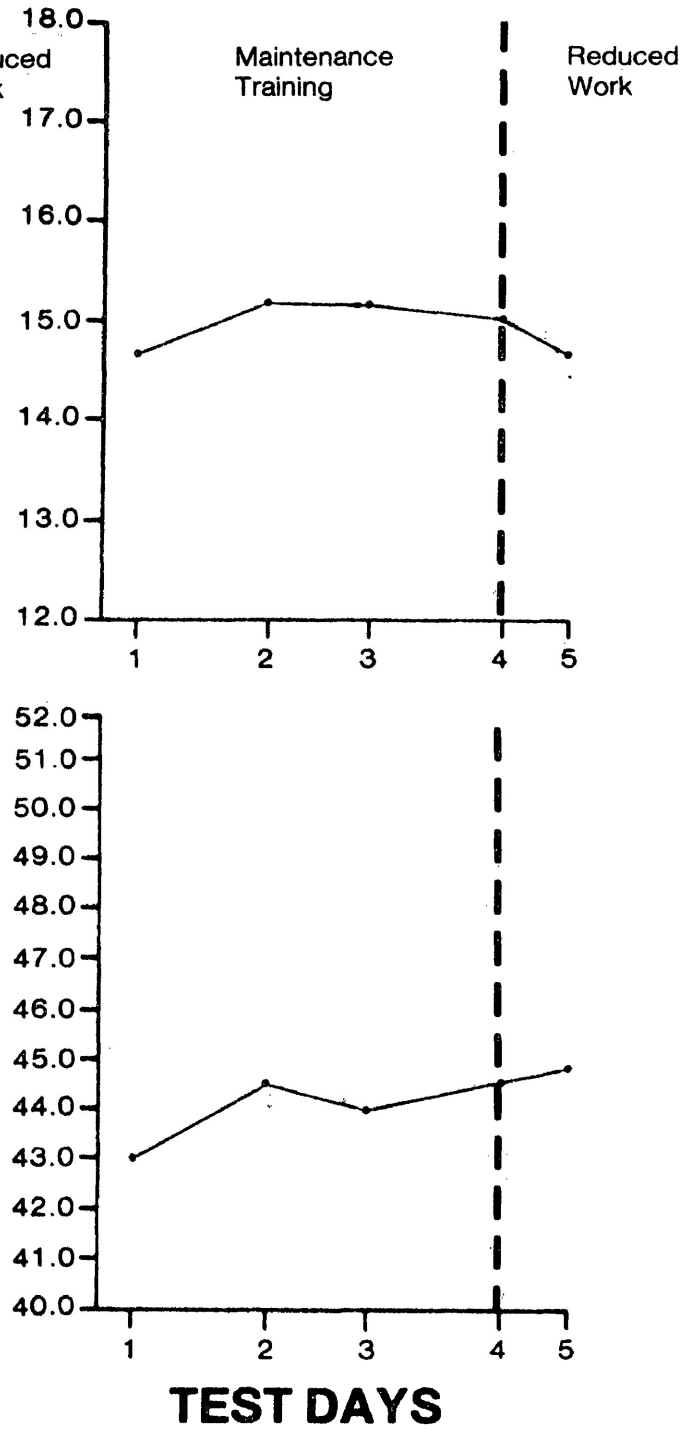


Figure 2. Hb and Hct values for subject M2.

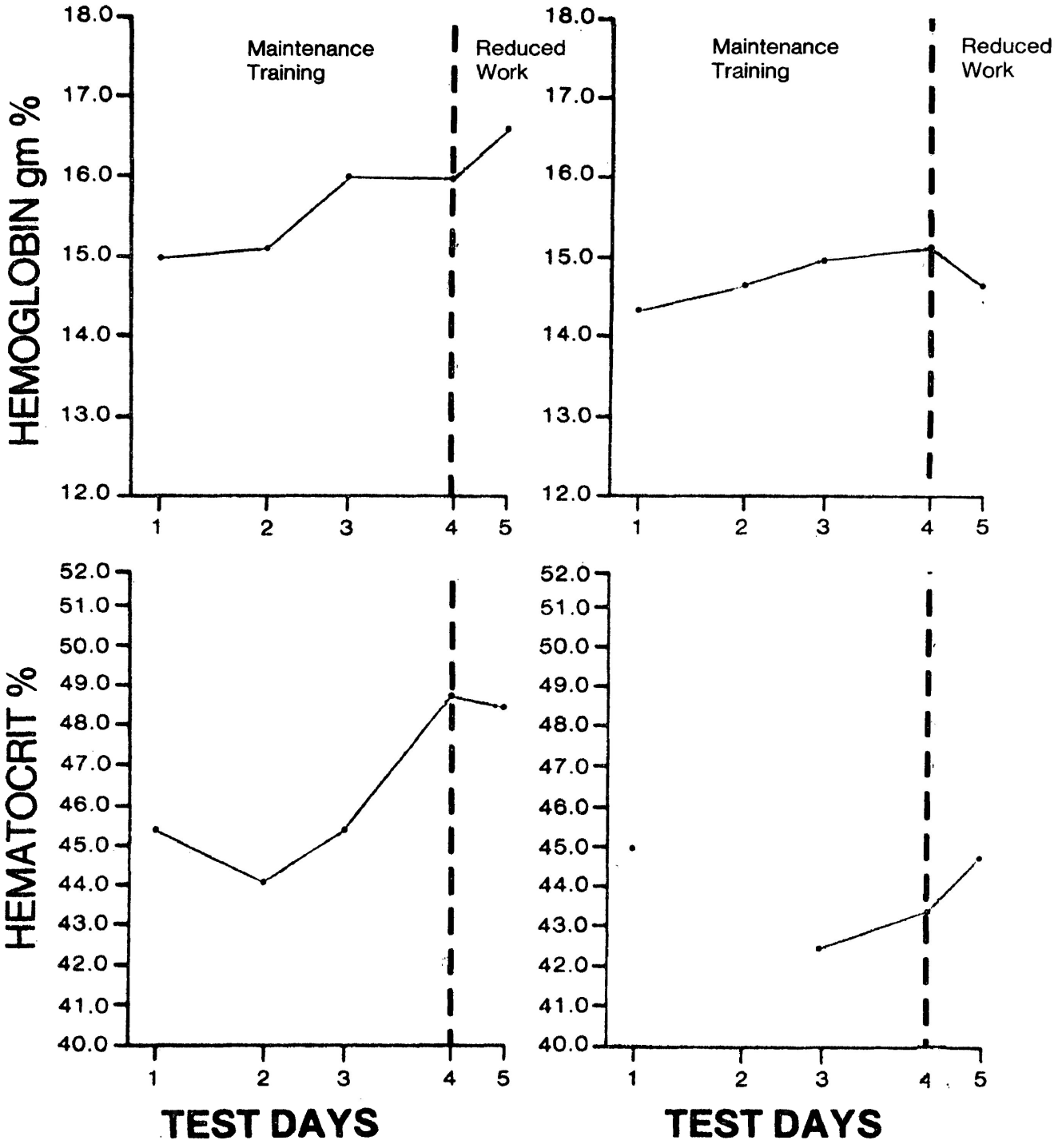


Figure 3. Hb and Hct values for subject M3.

Figure 4. Hb and Hct values for subject M4.

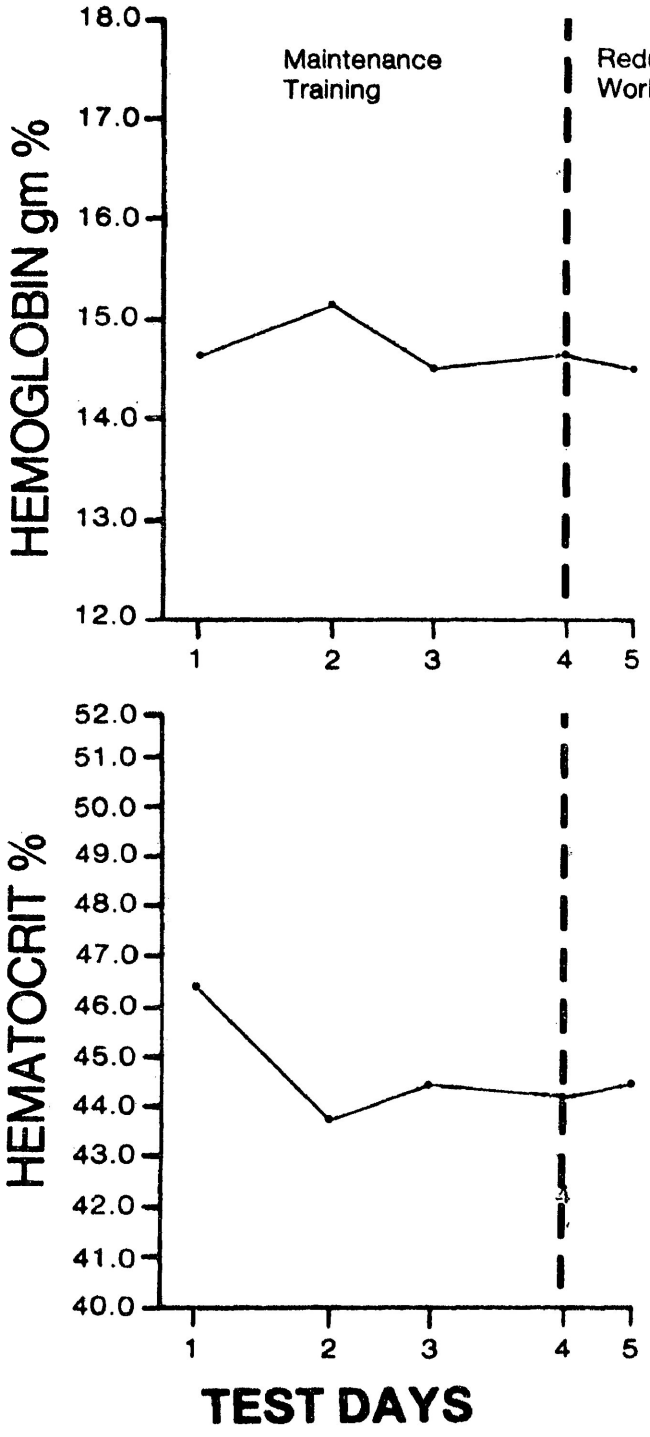


Figure 5. Hb and Hct values for subject M5.

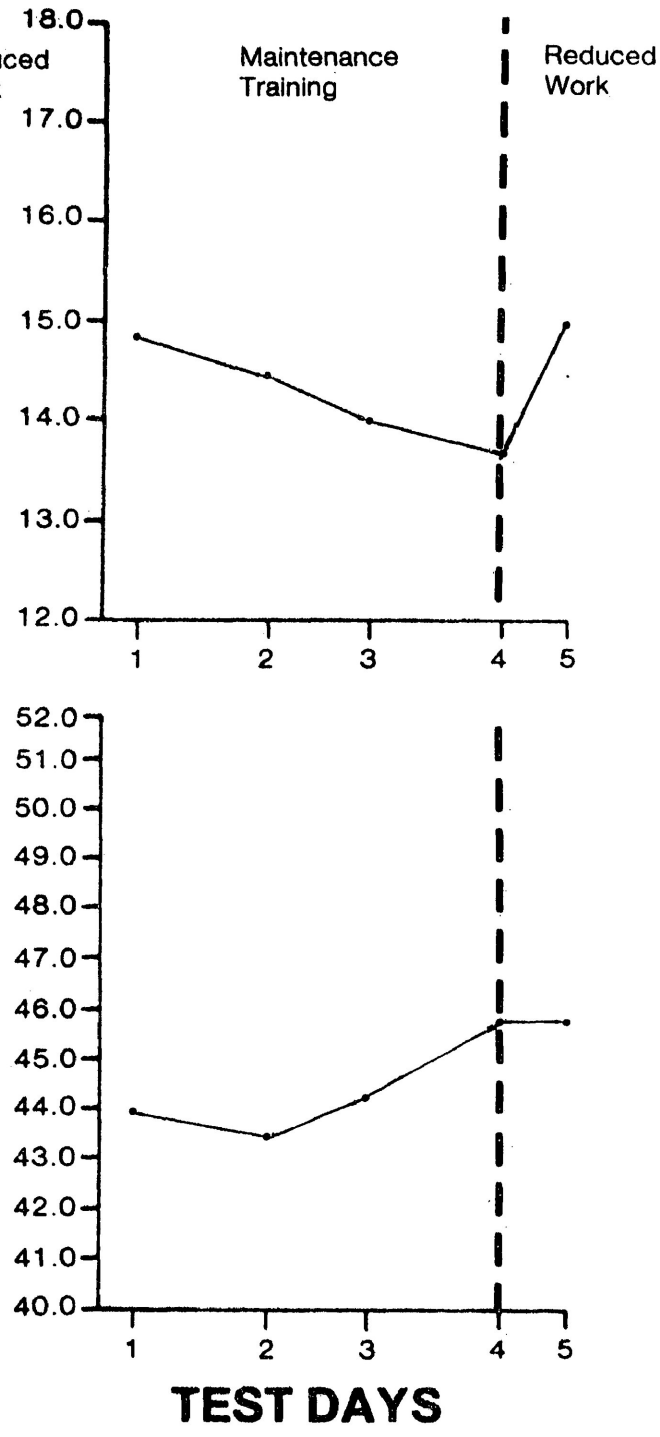


Figure 6. Hb and Hct values for subject M6.

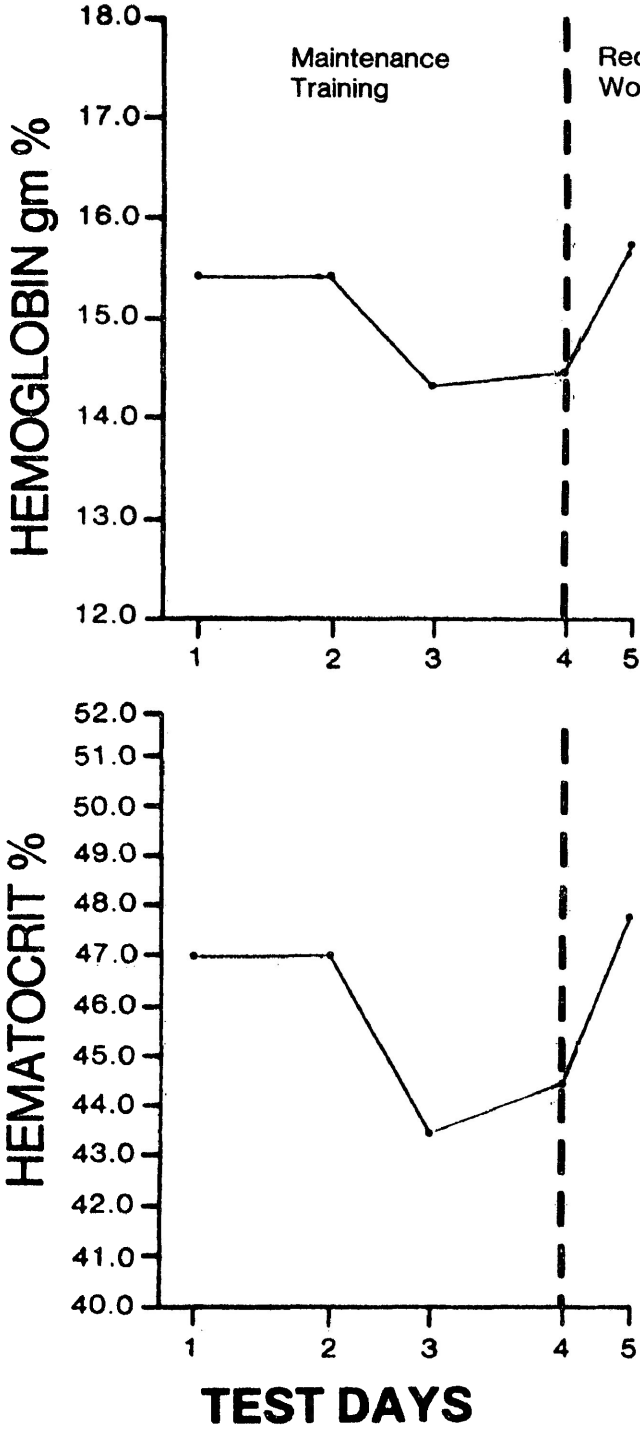


Figure 7. Hb and Hct values for subject M7.

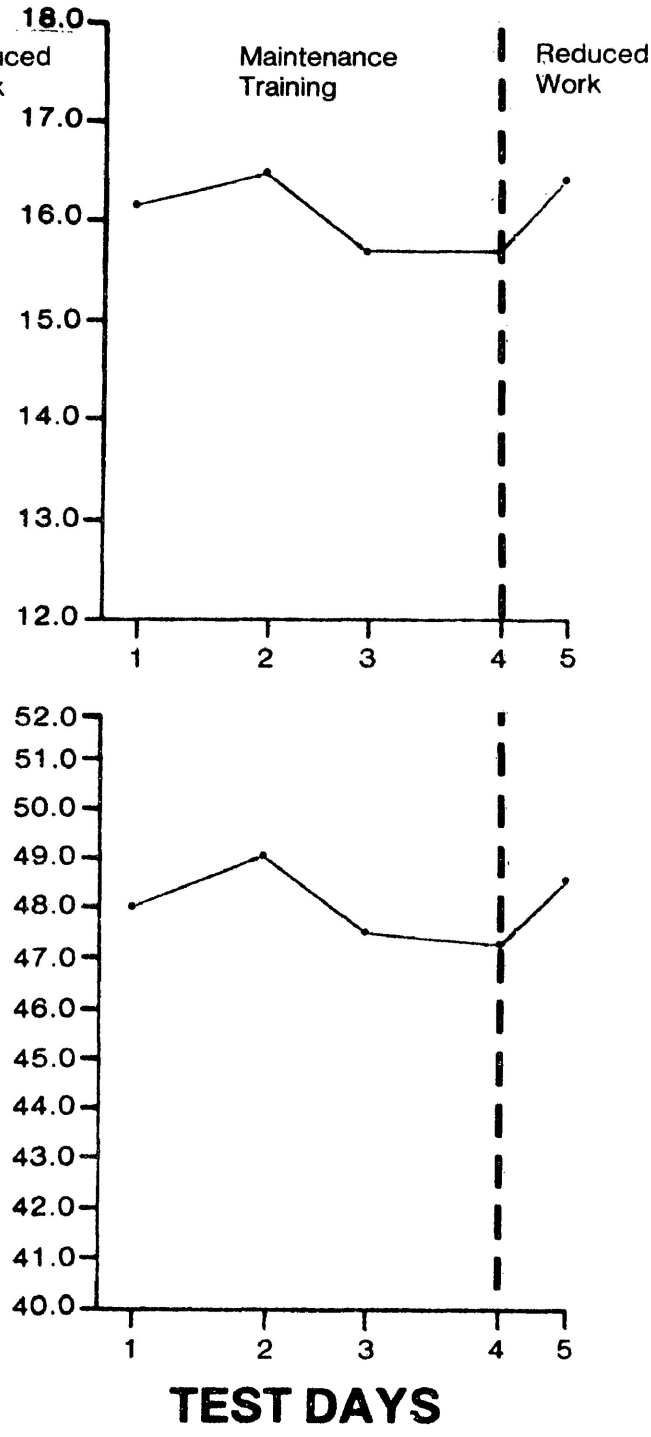


Figure 8. Hb and Hct values for subject M8.

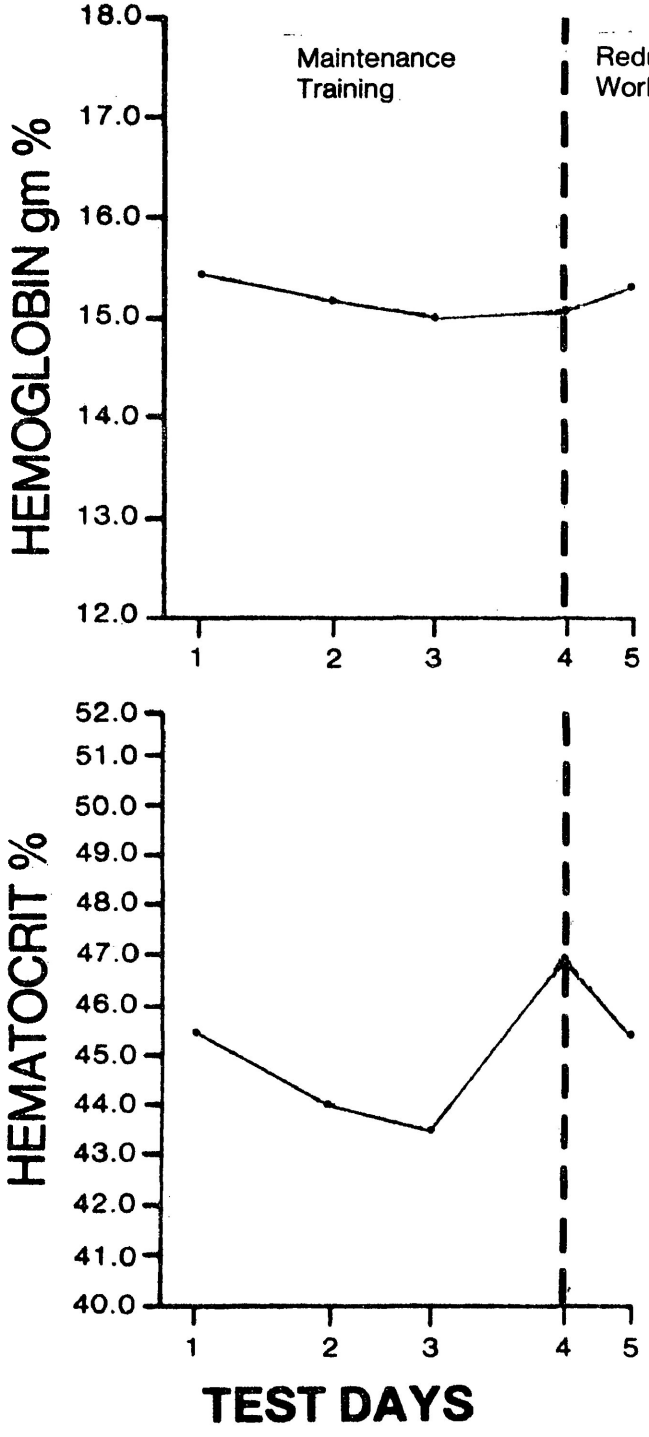


Figure 9. Hb and Hct values for subject M9.

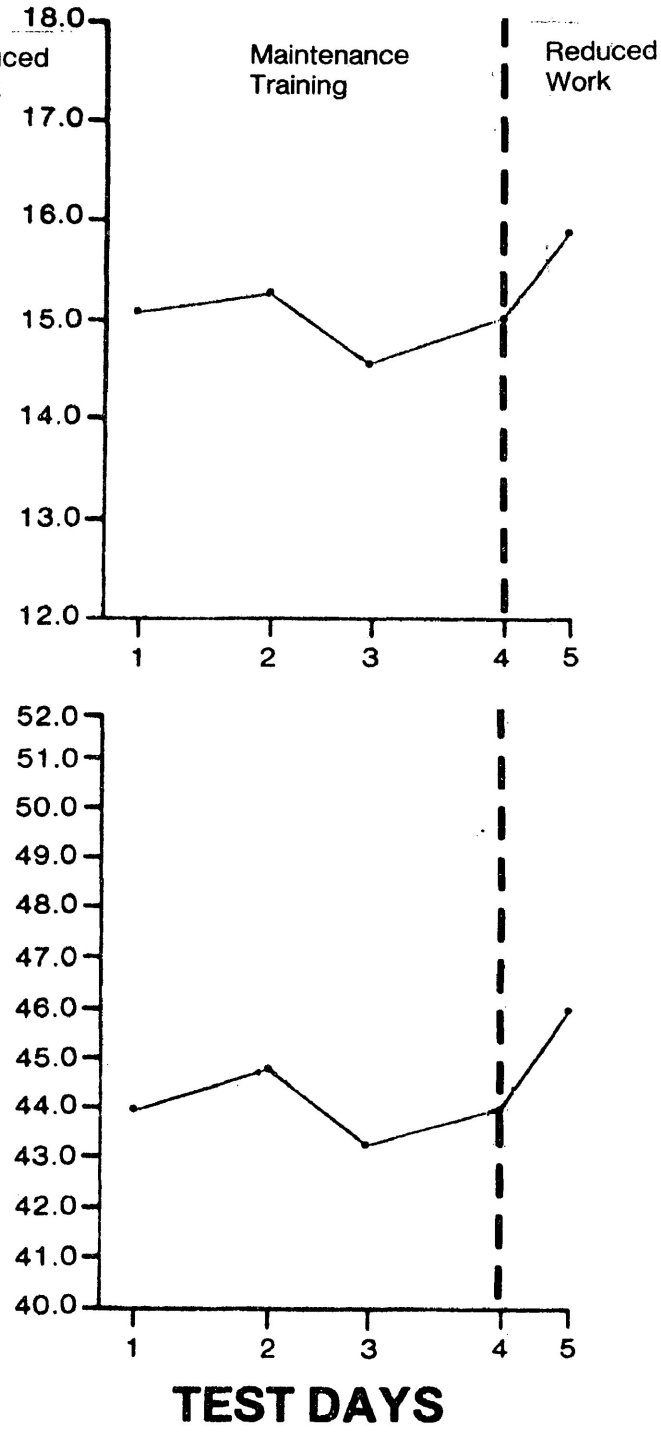


Figure 10. Hb and Hct values for subject M10.

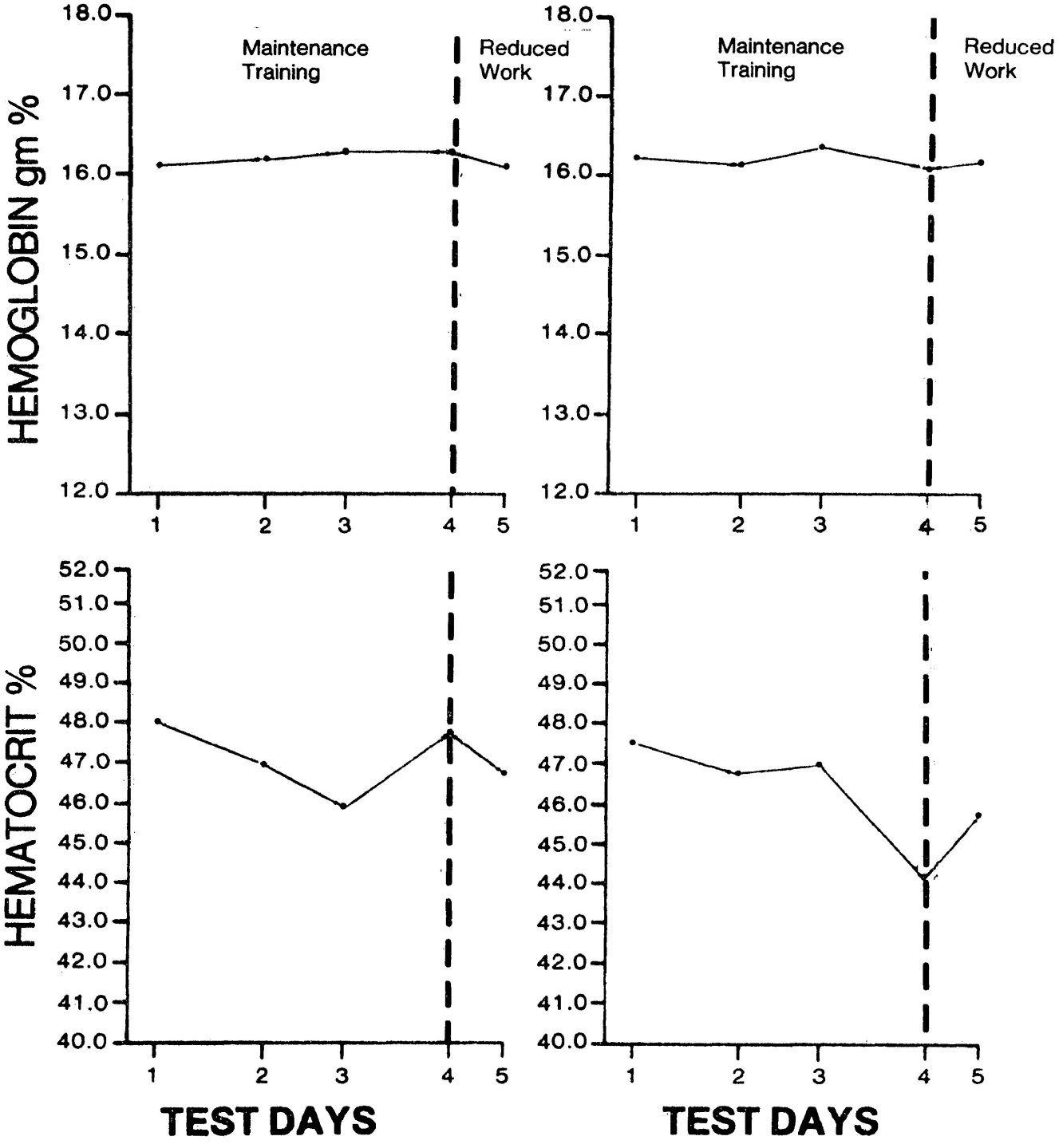


Figure 11. Hb and Hct values for subject M11.

Figure 12. Hb and Hct values for subject M12.

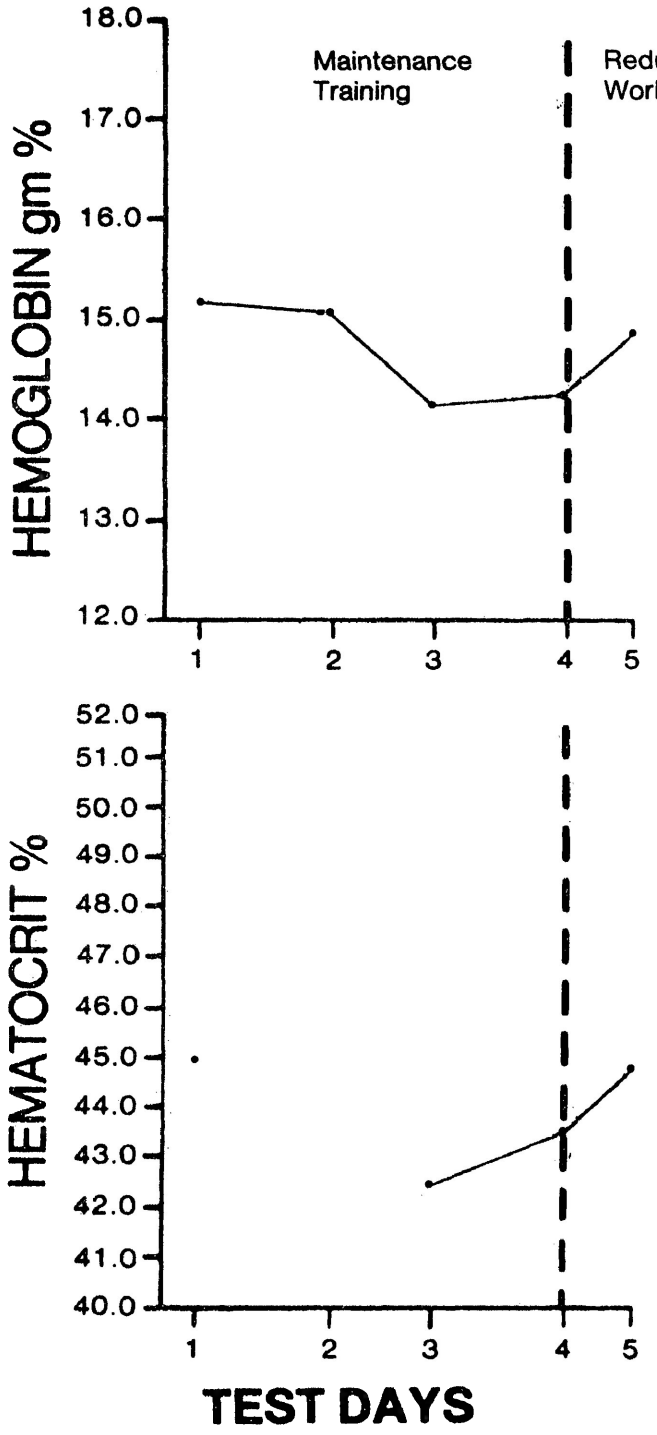


Figure 13. Hb and Hct values for subject M13.

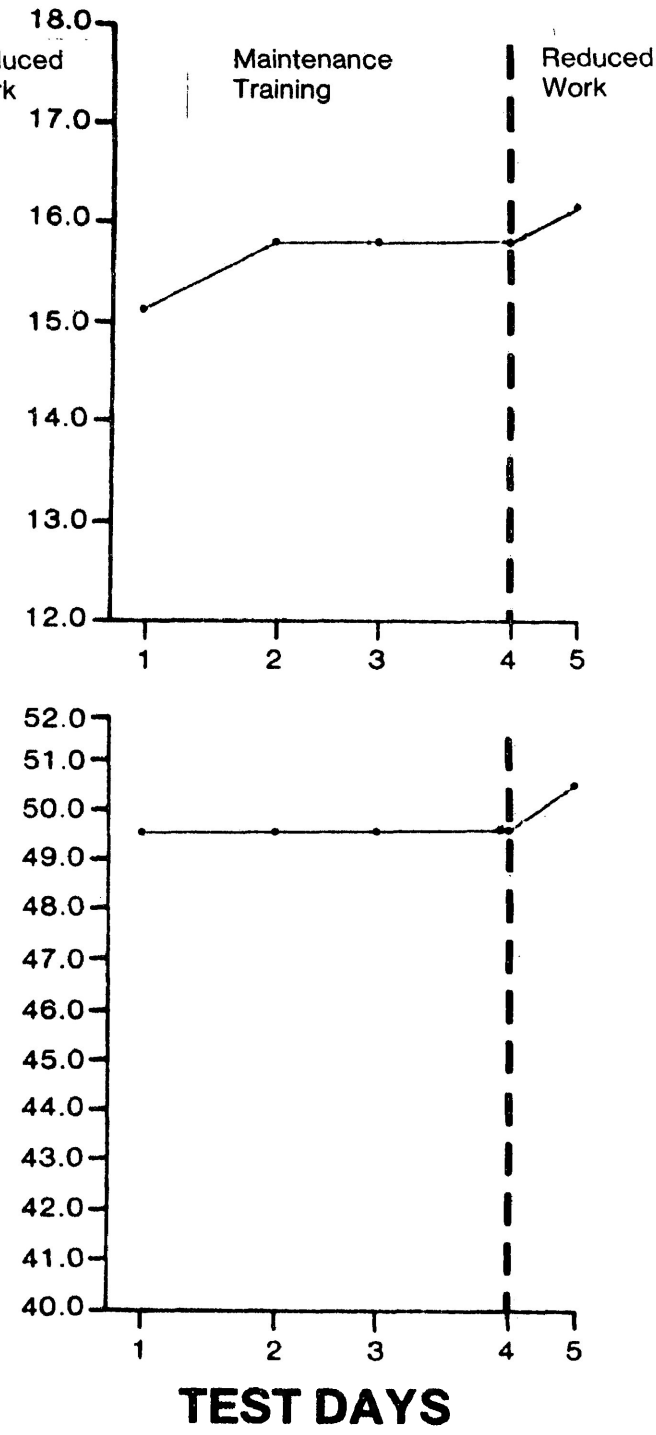


Figure 14. Hb and Hct values for subject M14.

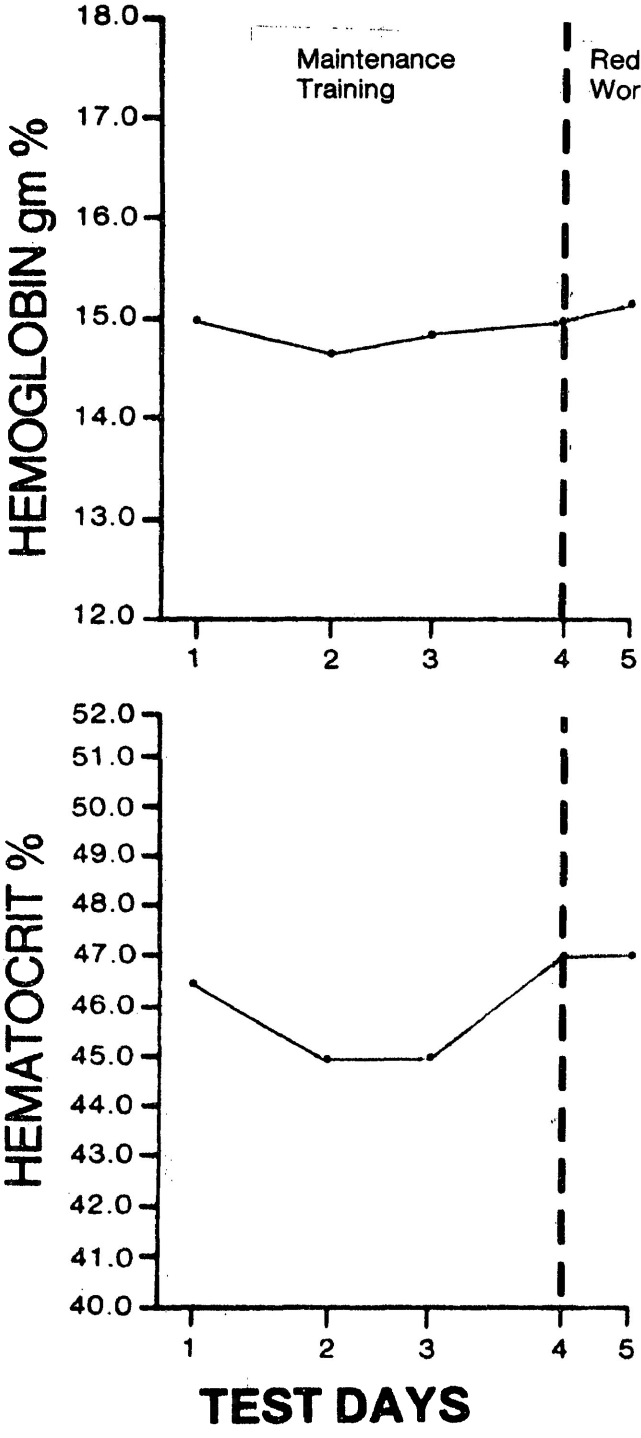


Figure 15. Hb and Hct values for subject M15.

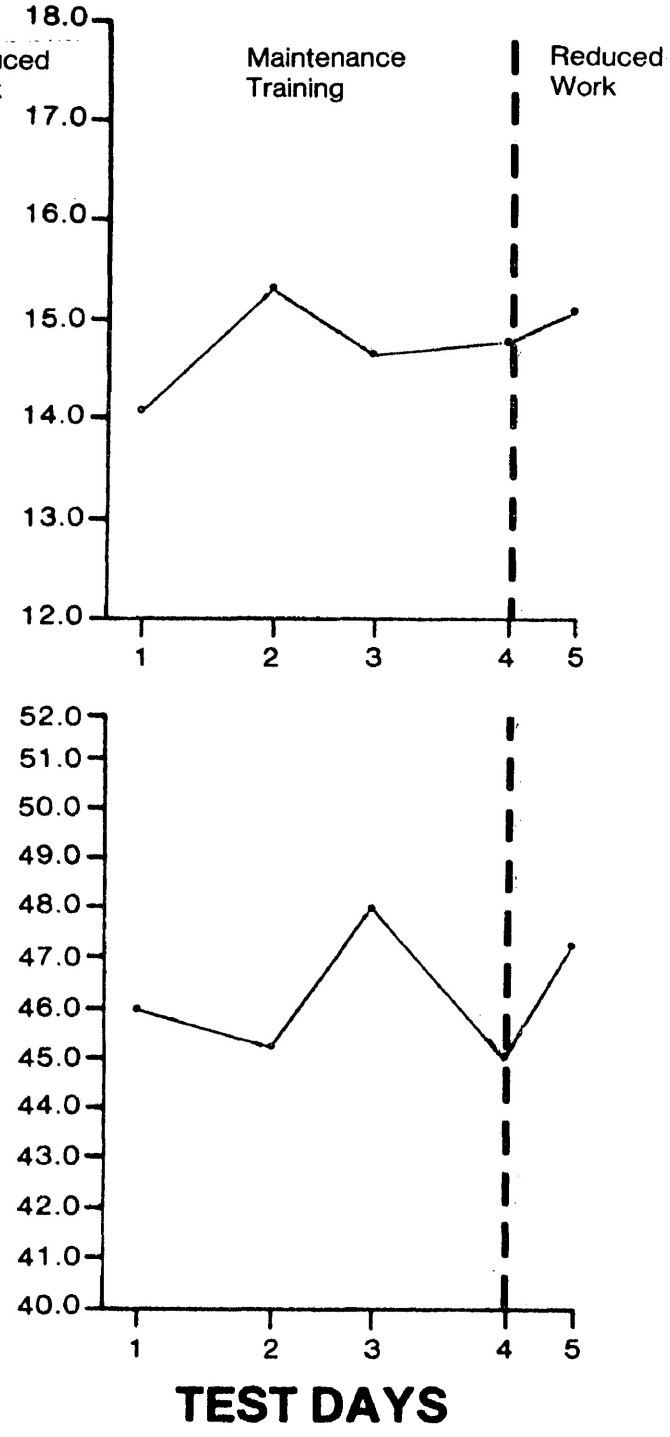


Figure 16. Hb and Hct values for subject M16.

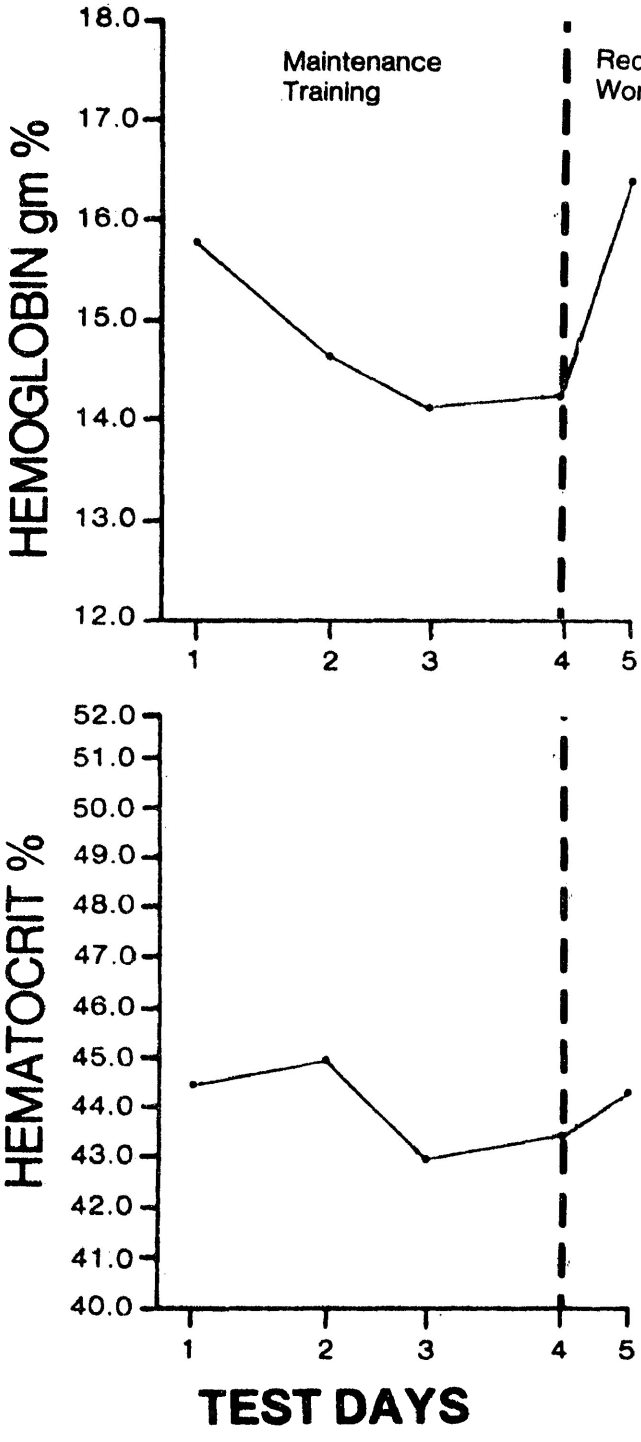


Figure 17. Hb and Hct values for subject M17.

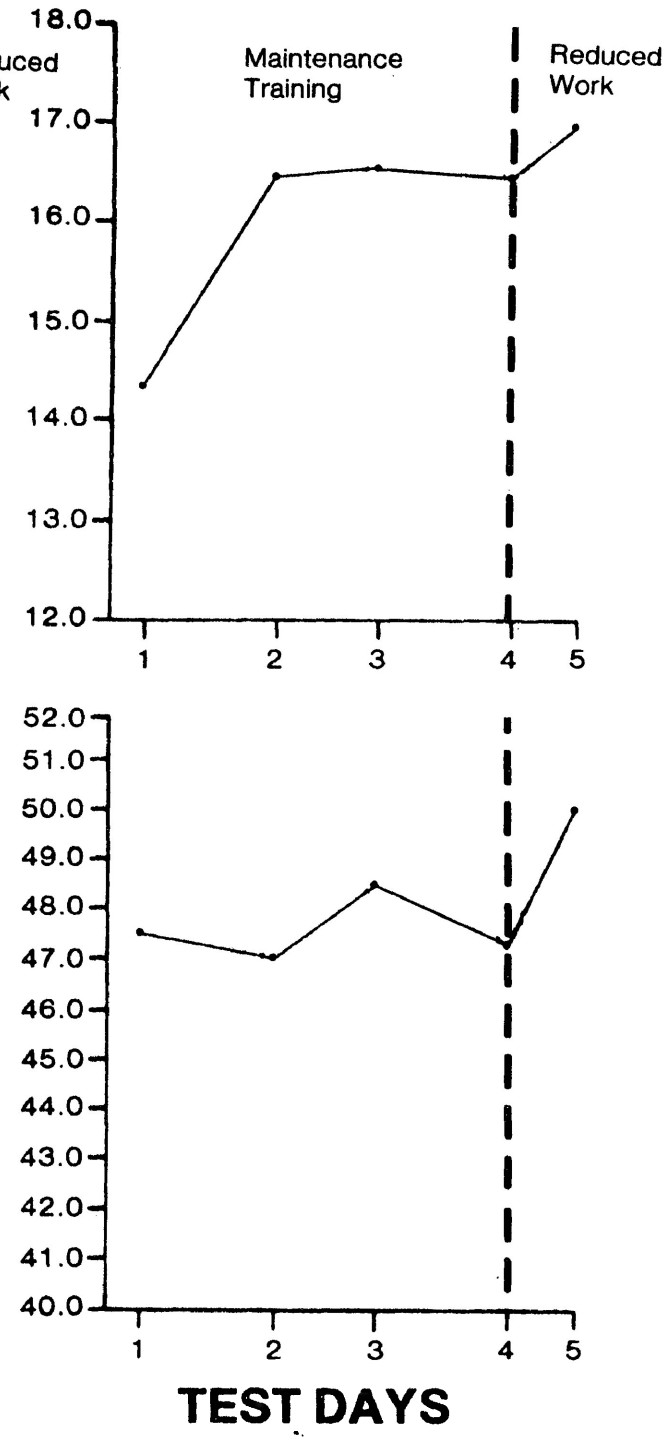


Figure 18. Hb and Hct values for subject M18.

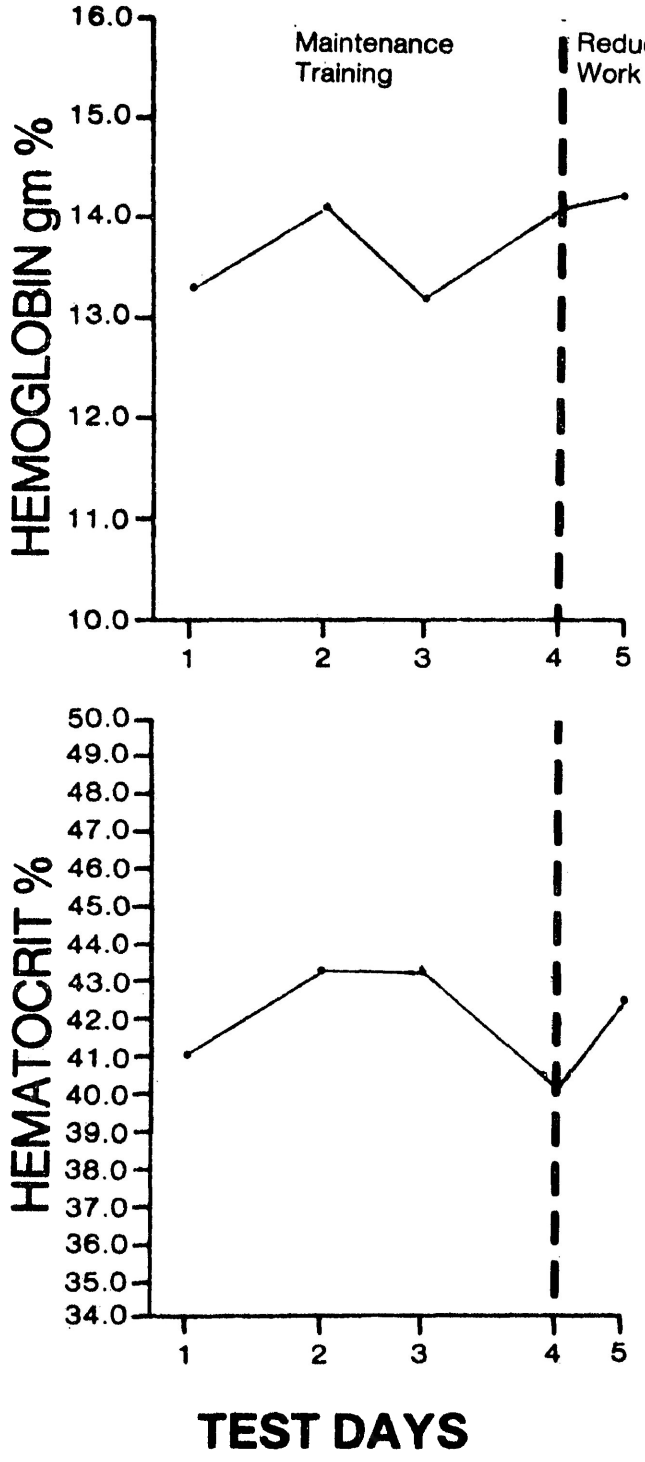


Figure 1. Hb and Hct values for Subject W1.

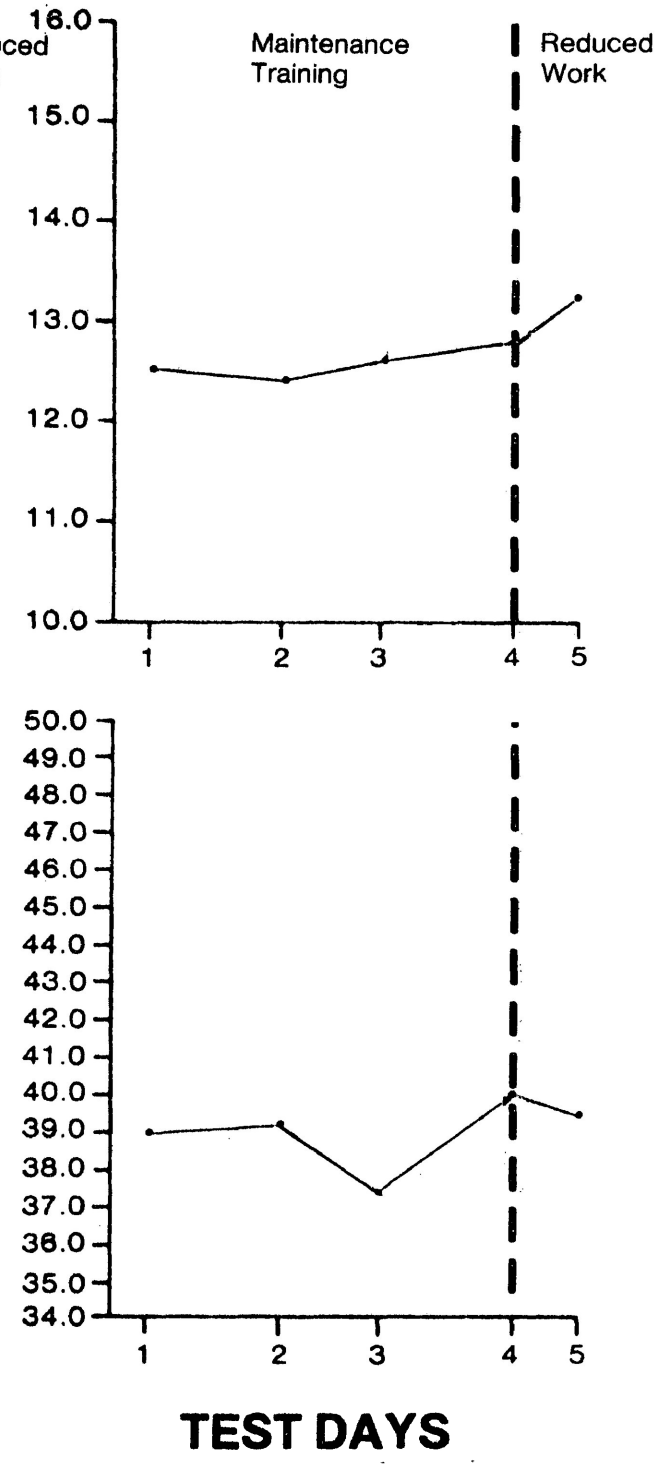


Figure 2. Hb and Hct values for Subject W2.

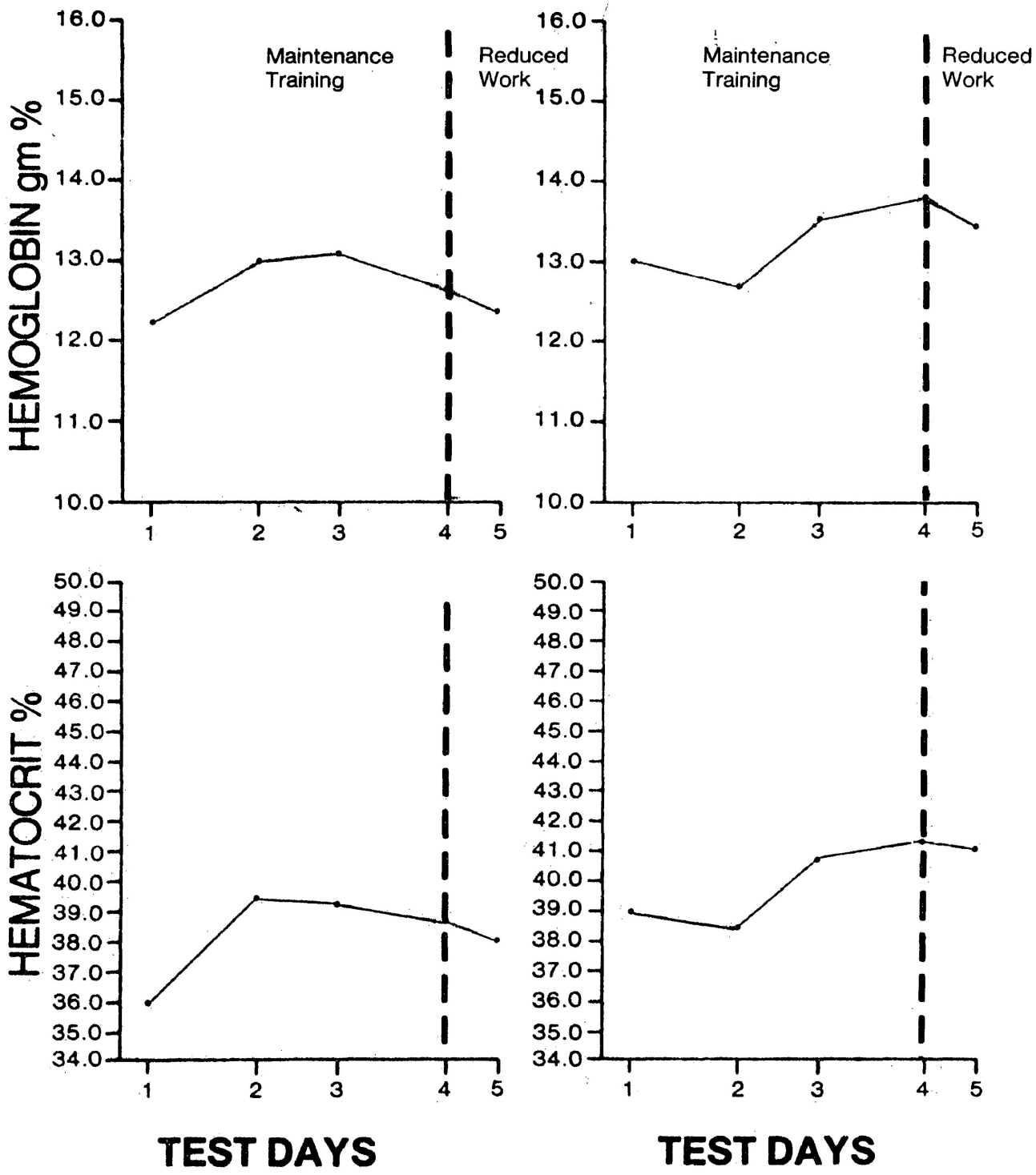


Figure 3. Hb and Hct values for Subject W3.

Figure 4. Hb and Hct values for Subject W4.

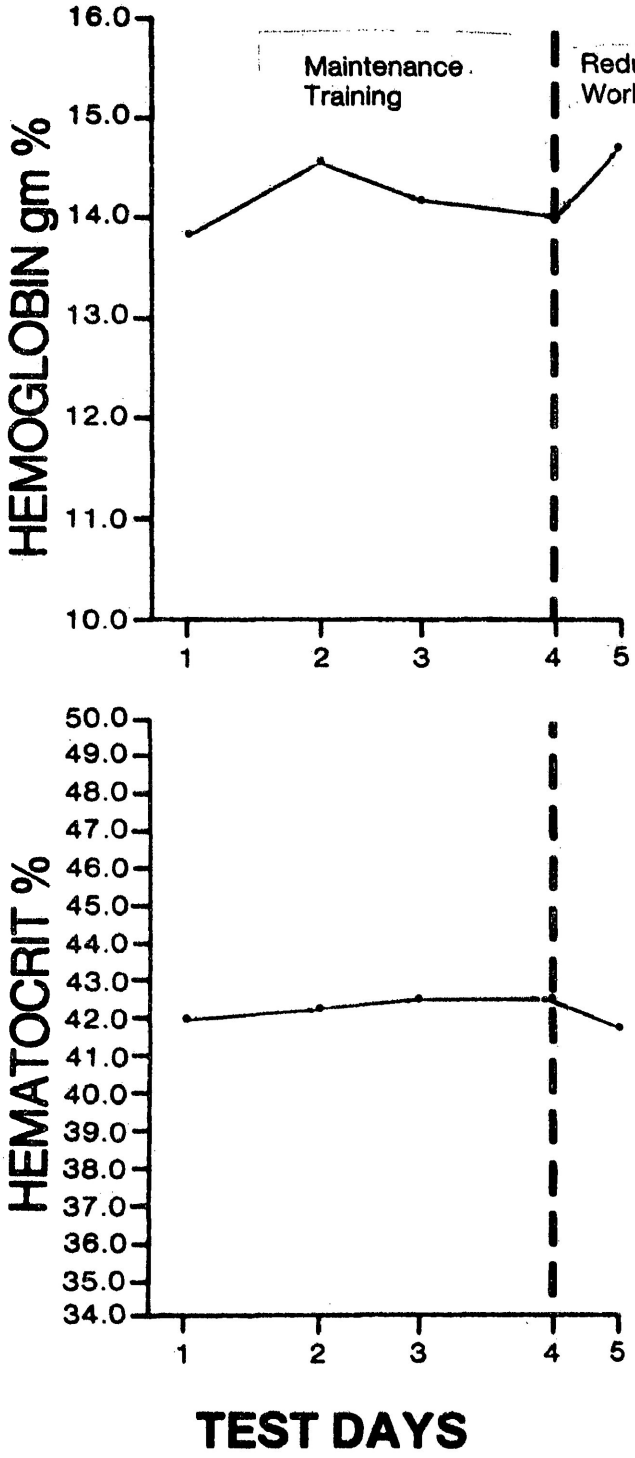


Figure 5. Hb and Hct values for for subject W5.

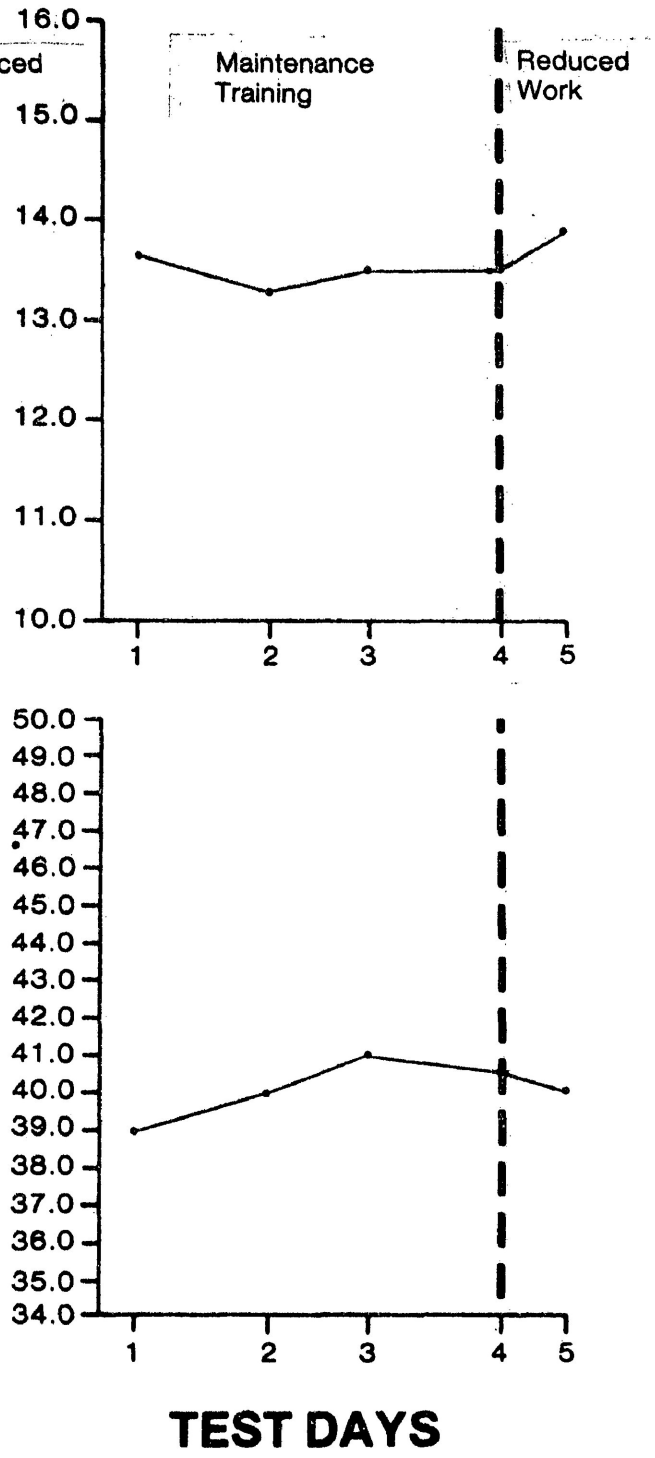


Figure 6. Hb and Hct values for Subject W6.

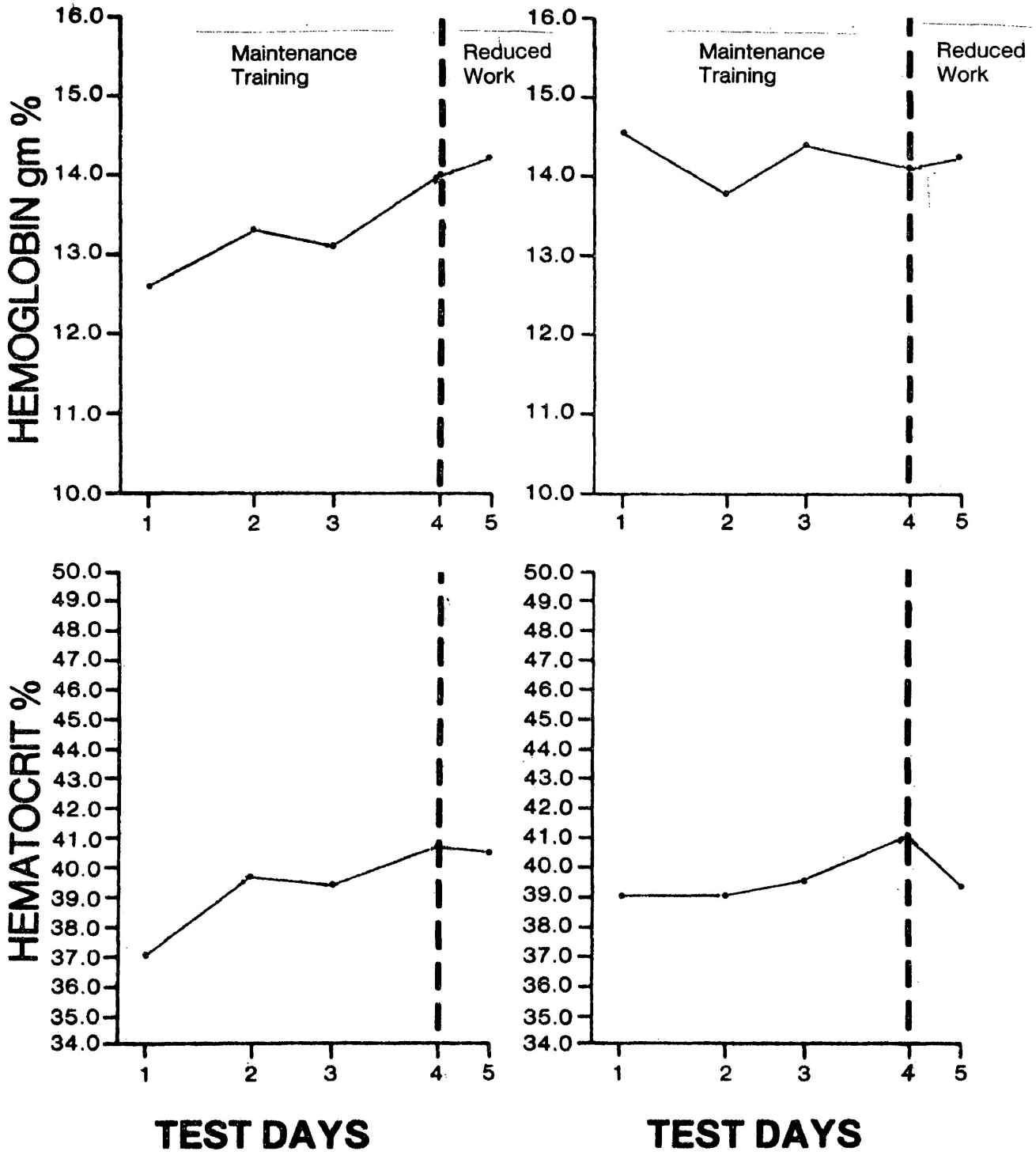


Figure 7. Hb and Hct values for Subject W7.

Figure 8. Hb and Hct values for Subject W8.

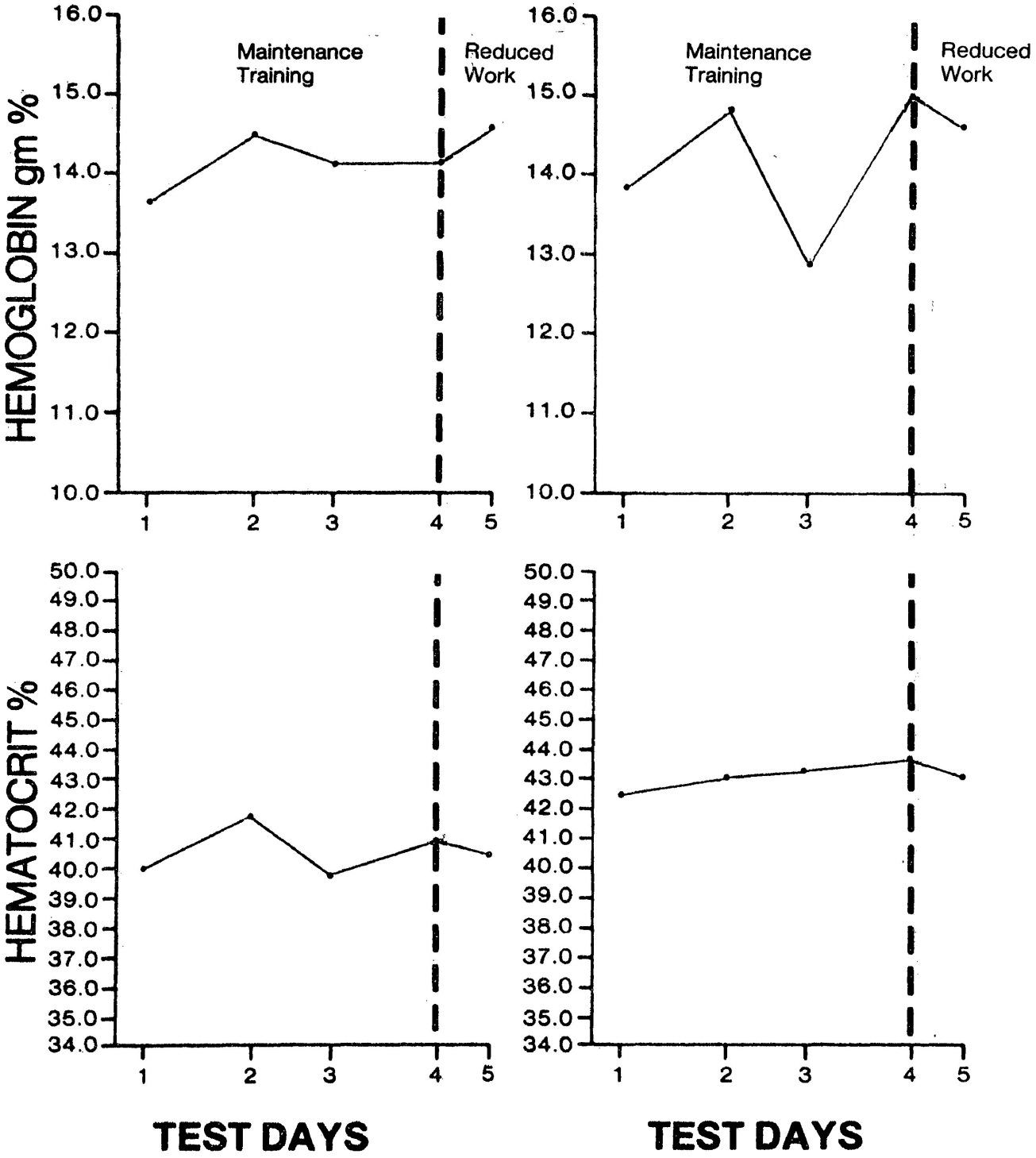
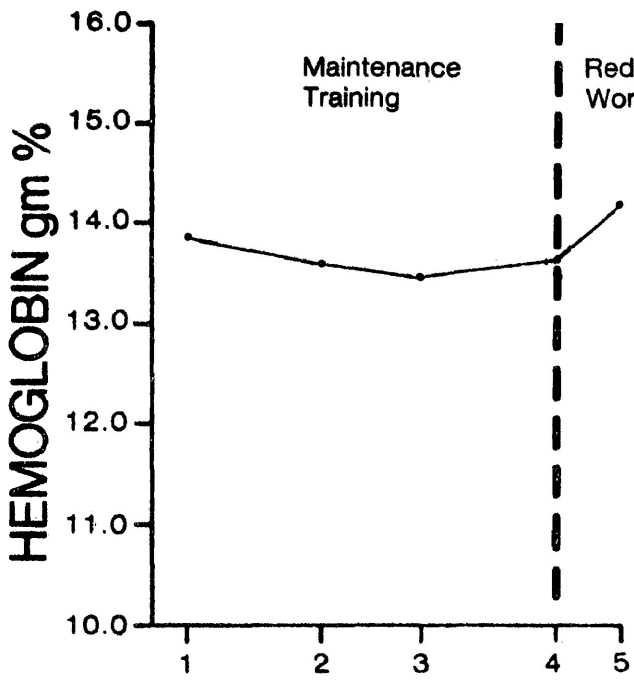


Figure 9. Hb and Hct values for Subject W9.

Figure 10. Hb and Hct values for Subject W10.



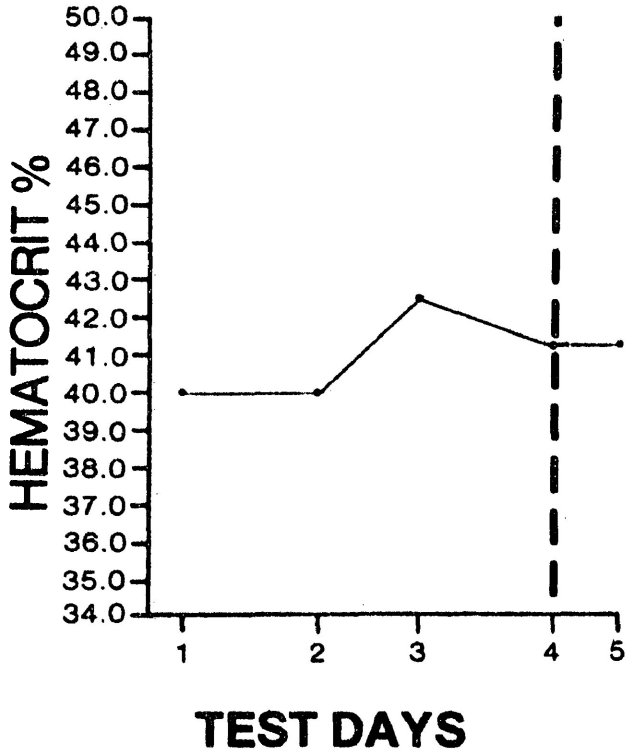
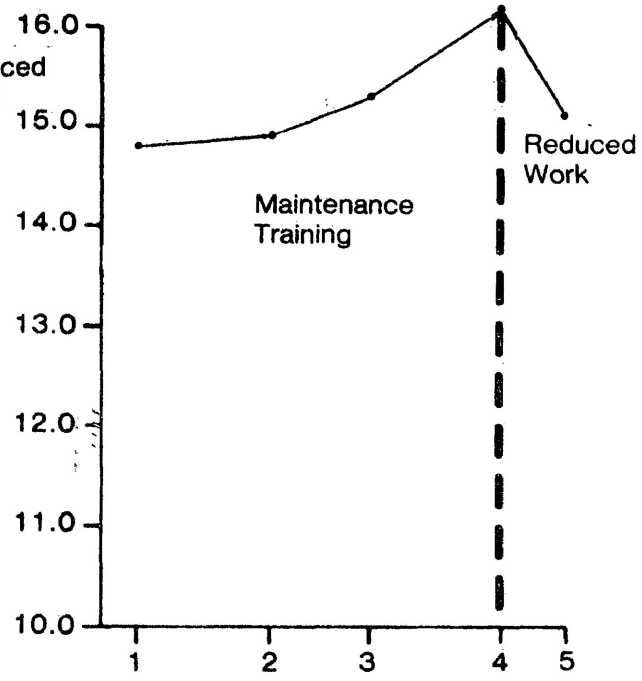


Figure 11. Hb and Hct values for Subject W11.



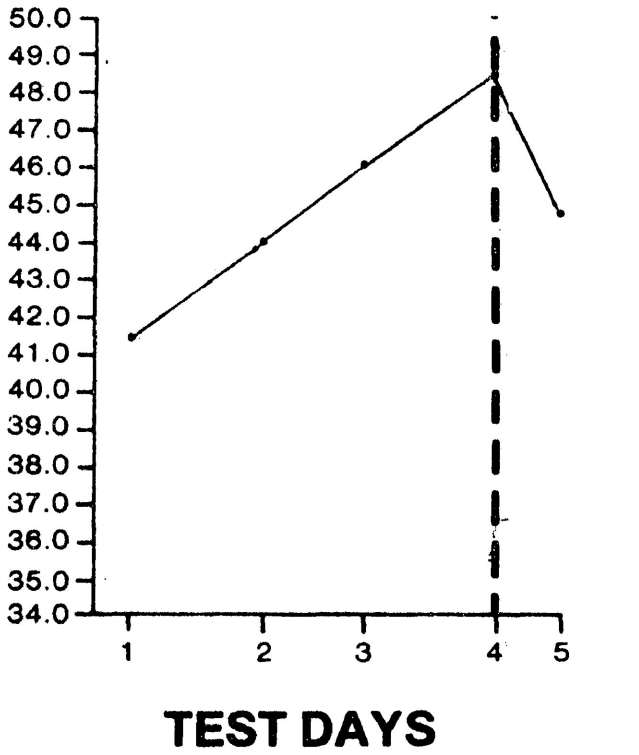


Figure 12. Hb and Hct values for Subject W12.

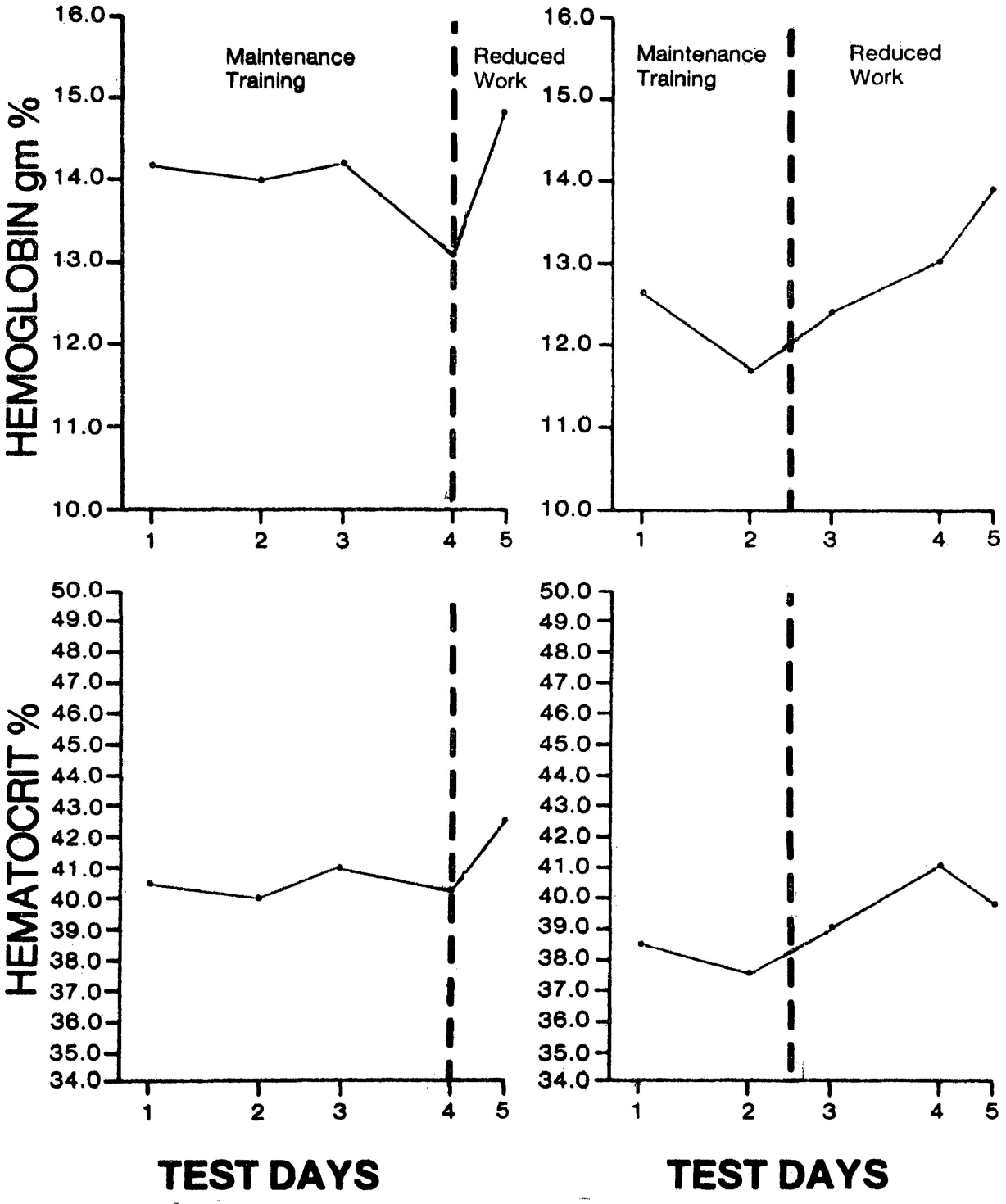


Figure 13. Hb and Hct values for Subject W13.

Figure 14. Hb and Hct values for Subject W14.

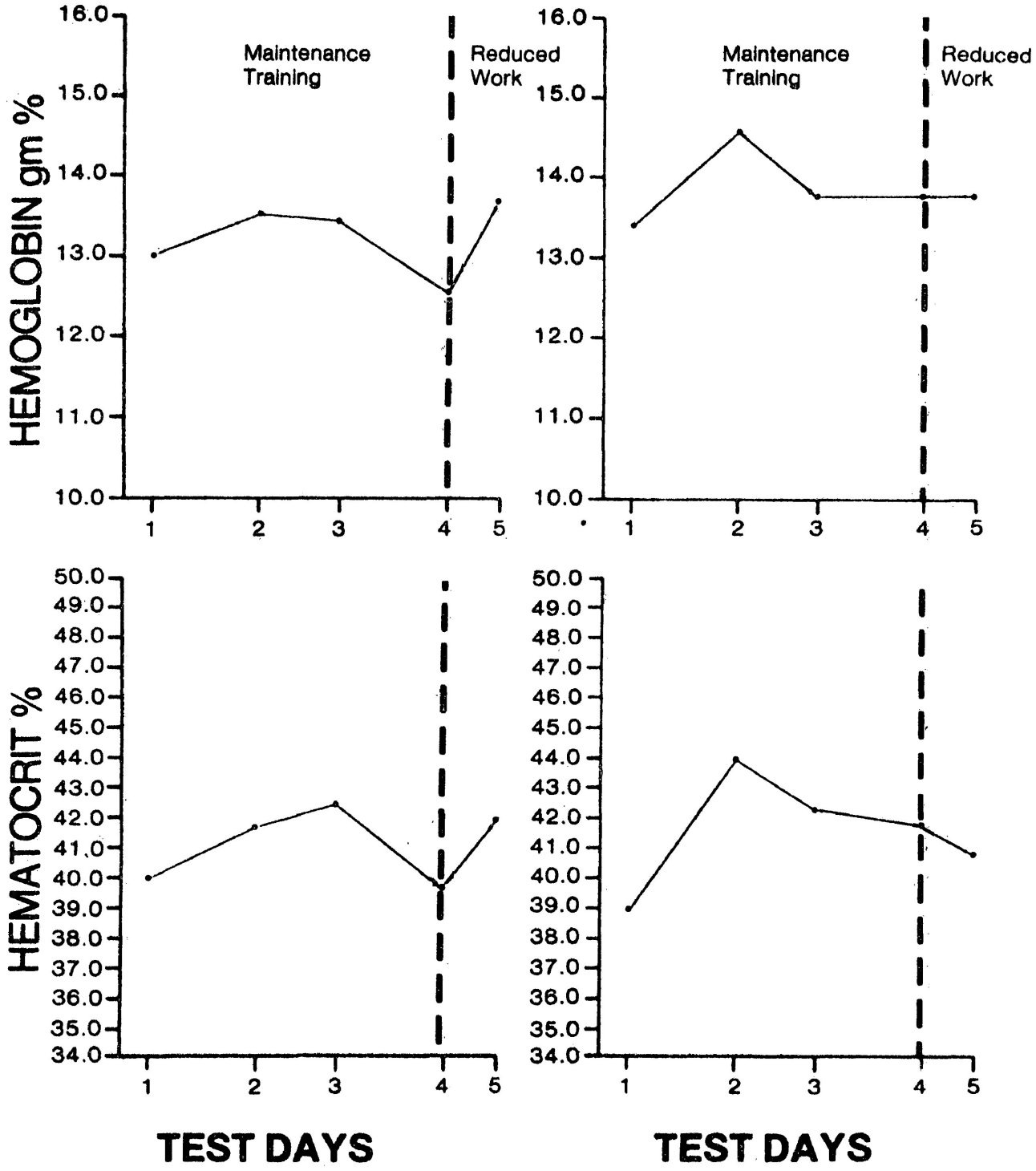


Figure 15. Hb and Hct values for Subject W15.

Figure 16. Hb and Hct values for Subject W16.

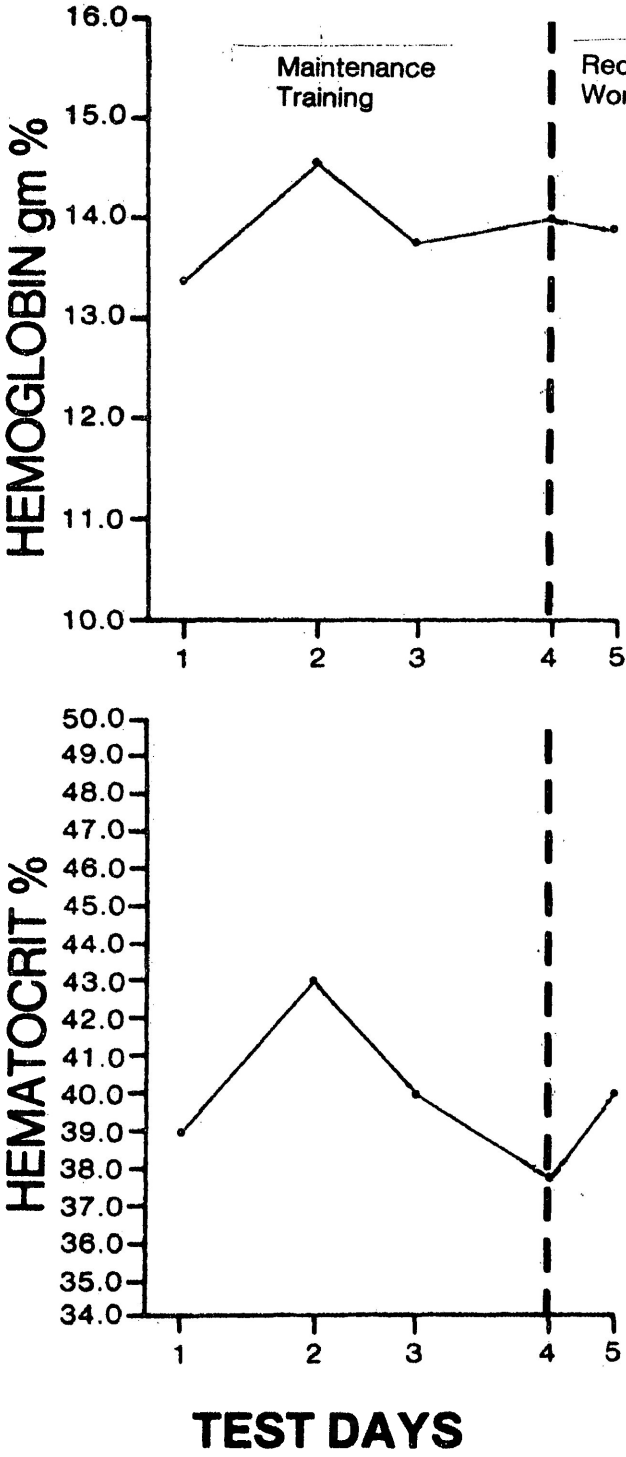


Figure 17. Hb and Hct values for Subject W17.

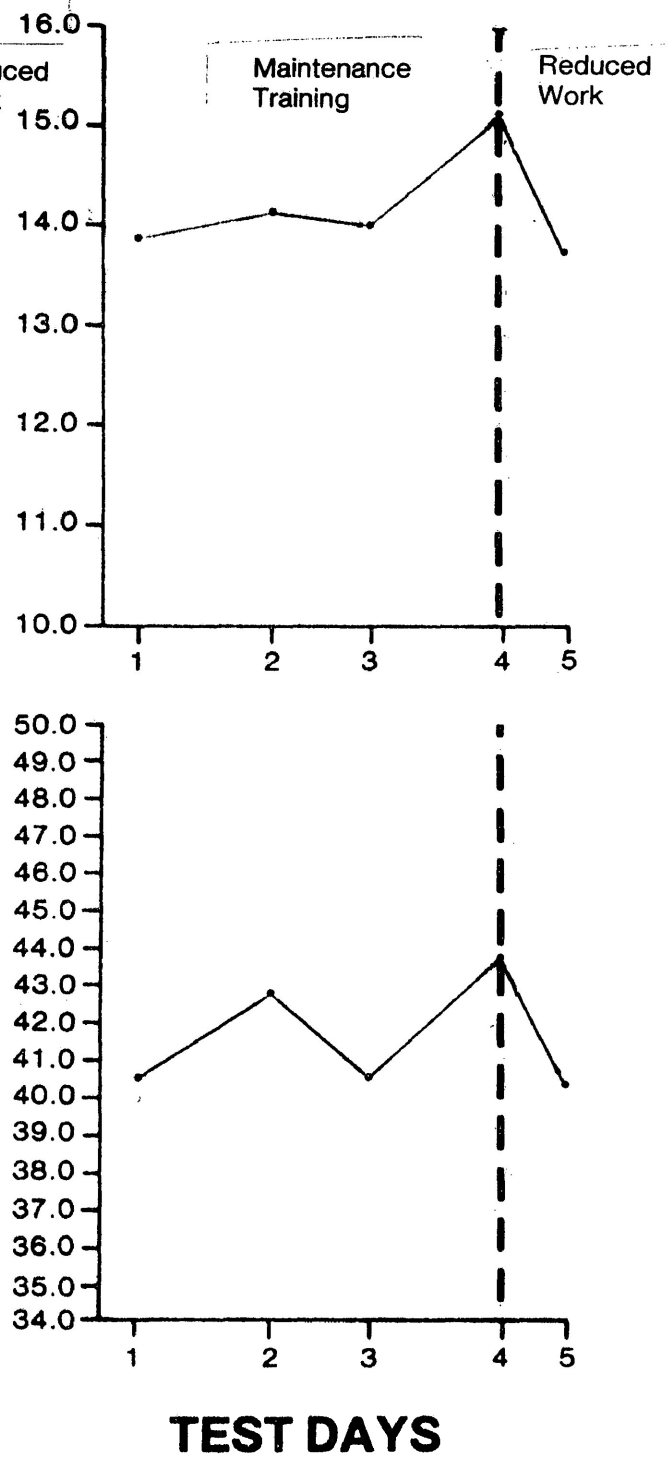


Figure 18. Hb and Hct values for subject W18.

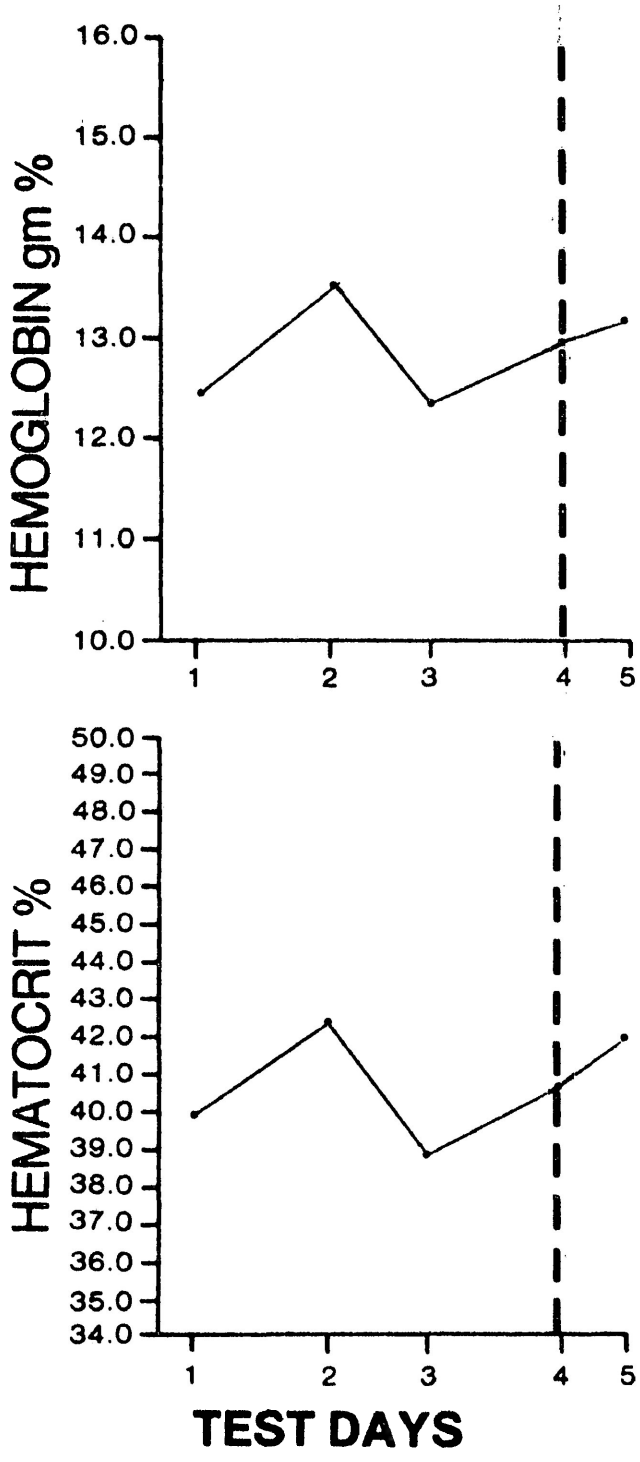


Figure 19. Hb and Hct values for Subject W19.