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A N O E L I I .
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A STUDY TO DEVELOP SIMPLIFIED
PROCEDURES FOR EVALUATING THE HUMAN
PHYSICAL FACTORS IN A WORK SYSTEM

A THESIS

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A STUDY TO DEVELOP SIMPLIFIED
PROCEDURES FOR EVALUATING THE HUMAN
PHYSICAL FACTORS IN A WORK SYSTEM

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SUMMARY

One of the industrial engineer's jobs in industry is finding the best method to perform a particular job. It is often difficult to find this method, but an even more difficult problem is that of obtaining personnel adapted to use these methods. The purpose of this thesis was to develop a simplified procedure for evaluating the human physical factors in a work system. For this purpose a work system having the following properties was required:

- (1) A sufficient number of individuals engaged in the same activity.
- (2) Several qualified judges who could evaluate all of the individuals involved.
- (3) Identification of measurable physical skills which lead to success in the activity studied.
- (4) Identification of suitable evaluating factors for measuring success.

The work system which most conveniently fulfilled these requirements was composed of the 1954 Georgia Tech varsity and junior varsity football players, who served as the subjects, and their coaching staff, who served as the judges.

The basis for evaluating the measured physical skills was obtained from the average of the judges' paired comparison and factor ranks. The judges' ranks were correlated against each other to test their reliability. The arithmetical average of the rank order correlations of the judges' ranks, using the paired comparison method, was 0.895, with a range from 0.851 to 0.940. The arithmetical average of the rank order correlations

of the judges' ranks, using the factor method, was 0.850, with a range from 0.806 to 0.931.

The physical skills of the subjects were measured by tests of the measurable factors that lead to success, and were ranked to form the independent variable ranks. Rank order correlation coefficients were obtained between each independent variable ranking with both of the dependent variable rankings. If the rank order correlation coefficient was less than 0.1, the independent variable was eliminated from further study. Two of the independent variables eliminated had correlation coefficients of 0.08, and a third had a value of 0.02. Multiple correlation formulas for the remaining independent variables and both of the dependent variables were obtained.

The precision of the multiple correlation formulas was obtained by substituting the values of the independent variables into the formulas for each subject, giving a calculated rank. Finally, the mean deviation of these calculated ranks from the average of the judges' ranks was obtained. The average of the mean deviations for the paired comparison ranking formulas was 3.15, with a range of 2.50 to 4.30. The average of the mean deviations for the factor ranking formulas was 3.43, with a range of 2.60 to 4.40.

This study used subjects from a select population and predicted worked ability of experienced workers, which is the procedure used in industry. The following formulas, based on the paired comparison ranks, are recommended for use in evaluating the human physical factors in this work system. It must be remembered that the ranks predicted by the proposed formulas are relative ranks, the base being the 1954

Georgia Tech varsity and junior varsity football teams.

Group I (Backs)

$$\text{Rank} = 40.6 - 1.42 \left[\text{Vertical Jump in inches} \right]$$

Group III (Linemen)

$$\text{Rank} = 6.2 - 1.02 \left[\text{Vertical Jump in inches} \right] + 1.42 \left[\text{Reaction Time in hundredths of a second} \right]$$

The mean error using the Group I formula was 2.3; using the Group III formula it was 3.5. The above experimentation was a verification of a procedure for evaluating the physical factors in this particular work system.

In industry, particularly in construction and metal working, there are many work systems which require a high degree of physical ability from the worker that can be evaluated using the above procedure. For example, the operation of a large number of drill presses in a factory may be taken as a work system which can be evaluated through the proposed procedure.

The industrial supervisors would study this work system and select the important physical skills necessary for success in this particular job. From a review of the literature and a prior knowledge of the work system, the supervisors can devise tests that will measure the physical skills which become the independent variables. The supervisors then rank the workers using either the paired comparison or the factor method, depending upon the number of workers to be evaluated. This rank becomes the dependent variable. With the dependent variable and the independent variables defined, a multiple correlation formula can be obtained. This technique will enable the supervisors to determine

the important skills in the work system. By substituting the worker's measured test value into this formula, calculated ranks can be obtained. From a knowledge of the workers, a minimum rank can be selected that separates the inefficient from the average and efficient workers. By this testing procedure, a much improved method of selecting personnel for a job is obtained. This formula can also be used as the basis for a job evaluation program for the drill press work system.

By the foregoing procedure, the important factors in almost any work system can be evaluated. The dependent variable can be a paired comparison or factor ranking of the employees, and the independent variables can be the important physical or mental skills and abilities required for the job as decided by the judges. With this information and by applying the above procedure, a simplified formula can be established to evaluate present and future employees in almost any work system. The resulting formula can be used as the basis of a job evaluation program.

CHAPTER I

THE PROBLEM

Statement of the Problem.--The purpose of this thesis is to develop a simplified procedure for evaluating the human physical factors in a work system. This study is closely related to the evaluation of worker abilities required by various jobs for the purpose of job placement, the determination of job qualifications, and the design of work situations that will best utilize the available worker potential.

For the purpose of this thesis, a work system was required having the following properties:

- (1) A sufficient number of individuals engaged in the same activity.
- (2) Several qualified judges who could evaluate all of the individuals involved.
- (3) Identification of measurable physical skills which lead to success in the activity studied.
- (4) Identification of suitable evaluating factors for measuring success.

Importance of the Problem.--The industrial engineer is confronted with the problem of scheduling raw material to the production area, fabricating the finished product, and channeling the finished product to its point of distribution. During the process of fabrication, it is necessary to plan the best, easiest, and cheapest methods of forming the raw material into the finished product. It is difficult to find this method, but an even more difficult problem is that of obtaining the personnel

adapted to use these methods. At the present time the best procedure for selecting personnel is to determine the qualities necessary for success on the job and then to find a worker having those qualities. Various tests of a psychological and engineering nature have been devised to select the desired personnel and have met with varying degrees of success. Some of the tests, designed for a particular situation by qualified people, have proved successful.

Certain jobs require a worker to be not only mentally capable but also physically well coordinated. Very little work has been done on the evaluation of the physical qualities needed on a particular job. Maass (1) showed that pounds resistance and length of time of a work cycle, between the ranges of 4.13 pounds and 23.13 pounds, were linearly related. Solberg (2) found similar results with the same type of experiment. Both of these experiments showed that as the job required the worker to move heavier objects, he required more time to do the job. There has been no similar work performed to find the physical prerequisites needed for the job. The physical prerequisites are usually judged by the employing agent by means of intuitive reasoning or rule of thumb.

For the purposes of this thesis, the Georgia Tech football players were selected as providing the required work system attributes. There was a sufficient number of individuals engaged in the same activity, and the football coaches were qualified judges, comparable to industrial supervisors, who could evaluate all of the individuals. Measurable physical skills and suitable evaluating factors which led to success were identified. The cooperation of all individuals involved was obtained, and the work system was, therefore, convenient to analyze.

CHAPTER II

LITERATURE SURVEY

Introduction

Athletics in general, and football in particular, are big business; yet nowhere are the efficient and economical principles of big business so lacking and needed more. Each year college football coaches pick from 40 to 50 high school football players for their college teams and award them scholarships. The coaches pick the boys on the basis of scouting reports, alumni letters, personal interviews, and watching the boys actually play. The variables, such as the accuracy of the scouting reports and alumni letters and the quality of competition against which the boys are playing, are seldom considered significant. On the basis of this cursory examination, the coaches give a football player a scholarship worth approximately \$1,500 per year; and since there are about 80 boys on scholarship each year at Georgia Tech, counting the freshmen, junior varsity, and varsity teams, this totals \$120,000 each year. Another problem existing is that once the coach has the boys, how does he choose the best men for his first team? An unbiased coach, because of his busy schedule, can sometimes overlook an outstanding player. It is for these reasons that college coaches need some type of scientific testing program to assist them in their selection of present and future football players.

All indexes of an engineering, psychological, and physiological nature were analyzed for material pertaining to the testing of football

players. The bulk of the literature surveyed was procured at the Emory Physical Education Library.

Opinions about Football Testing

The opinions of leading men in the field of physical testing are in agreement as to the need for and the lack of tests to evaluate football players. Scott and French (3) say:

For some unknown reason little work has been done in constructing skill tests for football. It would seem that football skill tests could be used to advantage in motivating effort as well as in serving as a partial basis for selection of players, particularly where coaches have little previous knowledge of players' ability.

Clark (4) comments, "Little work has been done in constructing tests of football ability."

Past Football Experiments

General Touch Football Testing.--In surveying the literature for testing of football players, very little was found. In 1937, Borleske (5) proposed a test to measure touch football ability. He consulted 46 experts regarding elements to be included in a touch football test and arrived at the following five items:

- (1) Forward pass for distance.
- (2) Catching forward passes.
- (3) Punting for distance.
- (4) A center snaps the ball to the player five yards behind him who then runs 50 yards carrying the ball. The watch is started when the ball is snapped and stopped when he runs the 50 yards.
- (5) Zone pass defense.

About this study, Scott and French (6) said:

The Borleske study is the only study of touch football found in the physical education literature. The study was made in 1935 or 1936 and, as is typical of the earlier studies, no report was made of the reliabilities. In view of the validity (correlation) it is probably safe to assume that the reliabilities are sufficiently high to be acceptable.

Of course, touch and tackle football are vastly different, but I believe that some of the same qualities that make a good touch football player would make a good tackle football player, and vice-versa. My main criticism is about item 4 of the test. The stop watch is started when the center snaps the ball and ends when the runner completes 50 yards. This necessarily introduces the reaction time of the timer which limits the study. If the center gives a slow or fast snap, or a high or low pass, it will affect the runner's score. I think there are too many uncontrollable variables for accuracy.

In 1929, The American Physical Education Association (7) made a study on football playing skills using passing for accuracy and distance, punting for distance, drop kicking and kickoffs for distance, and receiving and catching passes and kicks. They gave no figures of the degree of correlation or reliability.

General Tackle Football Testing.--In my opinion, the best study made on selecting football players by tests was performed by Brace (8) at the University of Texas with the cooperation of Dana X. Bible, the head football coach. Brace's test was composed of eight items, all of which were similar to actual game situations. The tests were:

- (1) Forward pass for accuracy at a target.

- (2) Fifty-yard dash carrying a football.
- (3) Forward passing for distance.
- (4) From a three-point stance between goal posts, pull out charging around the goal post and five yards down the field. Timed with stop watch.
- (5) Blocking. Running and knocking down three dummies five yards apart. Timed with stop watch.
- (6) Punting for distance.
- (7) Dodge and run (zig-zag run).
- (8) Charging. Dynamometer on back attached to goal post and charging out to test initial power.

This test was administered to over 60 boys who went out for football during spring practice. The results of these tests were correlated against the number of quarters played in college games, number of football letters won in high school, number of games played in high school, the players' average rating of each player, and the coaches' average rating of each player. There was a substantial relationship between the tests and the players and coaches' rating of the players. All but two of the tests, passing for accuracy and charging against a dynamometer, correlated highly against these ratings; 50-yard dash, with the player carrying a football was the most significant. The players' and the coaches' ratings correlated highly. No correlation was found between the test scores and quarters played in players' college or high school careers. Out of the 22 boys picked by the coaches as their first and second string football team, 18 of these were in the first 24 ranked by the tests. Since these tests were given in spring practice, six months before the first and second teams were picked in the fall, I think these tests show real promise as a means of assistance to football

coaches in choosing their players, particularly where the coaches know little about a player's ability.

One weakness of the above tests is that some of the players are judged on abilities which they do not need for success as a football player, such as a linesman being tested on his ability to throw or kick a football. Some of the tests measure the same ability, such as blocking dummies and the zig-zag run. Another weakness is that in using the stop watch, there is a starting and stopping reaction time which varies between individuals and within a single individual. Glasson (9) pointed out that as mechanical devices are used for scoring, the resulting rank order correlations coefficients are higher. Still another weakness is that these tests were not studied for reliability but were assumed to be reliable. They should have been proved reliable. To obtain reliability in tests, it is necessary to administer the tests several times and score them by mechanical means as much as possible.

These are the only studies about testing and predicting football success. The rest of the material surveyed was about various aspects of factors affecting football or general athletic success, but I feel that some of these factors were overlooked in the above studies and may play a part in predicting athletic success.

Football and Age.--Does age affect football success? The ages of college football players are generally from 18 years upwards. McCloy (10) reported that age and athletic ability have no correlation after the age 17. Cozens (11) said that age had no bearing upon general athletic ability tests. He was testing subjects between the ages of 16 and 25.

The significance of these studies makes it clear that the age of football players from 18 upward would not affect football success.

Football and Intelligence.--Are intelligence and scholastic achievement valuable qualities for a football player to have? Four articles reported that the athlete's scholastic rating is comparable to that of the non-athlete (12, 13, 14, 15). Hartmann (16), in 1930, made a study of 140 schools and ranked them according to the number of games won and compared the number of superior students and Phi Beta Kappa men in each school with its success. He found a small positive correlation of 0.10 between the smart football players and the winning teams, but he remarked that classroom distinction and gridiron prowess are not remote factors. In 1934, Jones (17) compared 100 athletes and 448 non-athletes for two years and found that the low positive correlation of 0.03 favored the athletes as better students. Although no figures are given, Hackensmith (18) reports that freshmen participants in intermural athletics were not significantly different scholastically from non-participants; sophomore athletes ranked slightly higher than non-athletes; and junior and senior athletes showed definitely higher academic grades than the non-athletes. None of these studies shows anything significant about the relationship of intelligence or academic achievement with football success.

From 1951 through 1954, it was my privilege to play on a football team at Georgia Tech which won one national championship, two conference championships, and played in four consecutive Bowl games. During that time, the football team had a higher scholastic average than the average

for the school. Also, there were six or seven members of the team on the Dean's List each year. (The Dean's List is composed of about the upper one-eighth of the student body. A student must have an overall average of 3.0, with 4.0 being perfect, to qualify for the Dean's List.) In 1954, the top seniors in the Industrial Engineering Department and the Industrial Management Department were varsity football players. On the basis of this, I believe that intelligence and successful football playing are related significantly.

Football and Power.--Clevett (19) devised two unique machines to test football players' power. The first was a form of sled that was pushed a certain distance. The amount of force necessary to push the sled was known and also the time and distance. Horsepower was computed as force times distance, divided by 550 times the necessary time. The second was a charging machine equipped with a dynamometer. From a three-point stance the football player would lunge at the charging machine, and his force would be recorded. Nothing of importance was done with the data obtained.

Football and Reaction.--Miles and Graves (20) believed that reaction was the key factor in football success. The football player assumed a three-point stance, and a lever was placed against his head. At the signal, "Hike," the timer was started and the player, charging out, moved the lever which stopped the timer, giving the reaction time. Fifty-five players were tested in this manner, and out of the first 11 players picked out by the coaches, nine averaged significantly faster than the mean. Some relationship was found between weight and reaction time, but height was found to have no correlation.

Football and Strength.--Rogers (21), who probably has done more experimentation with strength measurement (he originated the Physical Capacity Test and the Physical Fitness Index) than any man living, said, "Football players have a higher strength index than members of other sports and non-participants."

These were all the tests and studies concerning football or general athletic success available in the Georgia Tech and Emory Libraries. One of the marked discrepancies in the aforementioned studies was the failure to substantiate reliability of the tests discussed.

Related Experiments

Motor Ability Testing.--Miles and Graves (22) assumed that in order to measure the football players' actual reaction time, it would be better to pattern the test after an actual game condition. They believed that simple reaction time, such as ability to lift a finger off of a switch to an audible or visual response, did not correlate with the ability to move the entire body. This was substantiated by Nakamura (23) when he showed that, in track, the reaction time of the individual leaving the starting block was more significant to predicting athletic success than was the simple reaction time obtained by lifting a finger. According to Seashore (24), no overall or "general" positive dependence or inter-correlation of fine motor ability and gross motor ability has been found. In surveying the psychological literature, I found that most studies were of fine motor ability rather than a combination or gross motor ability. For this reason, I believe the present existing psychological tests are not valid for this study. No more mention will be made of psychological testing.

General Athletic Testing.--A positive relationship between ability to move, speed, and athletic success was found by Keller (25). He states that football required faster reaction and speed than most sports.

In 1927 Brace (26) showed that athletes had higher scores on motor ability tests than non-athletes.

McCloy (27) pointed out many requirements for general athletics that I believe are applicable to football. All athletes must pass a minimum physical health examination. Height and weight are not significant except at maximum and minimum points (28). Heart condition, pulse rate, and blood flow are important, but nothing is specifically known that will predict athletic success (29).

Power.--The Sargent Jump, consisting of an apparatus that measures the distance a person can move his head vertically by jumping upward from a standing position, is probably the best recognized test for power. Van Dalen (30) studied the Sargent Jump and found it to be a valid and reliable measure as well as a valuable aid in demonstrating power. In McCloy's (31) opinion, the Sargent Jump is the best measure of power available. Also, it is easy to administer. In studying the Sargent Jump, he correlated it with four track events, namely: 100-yard dash, running high jump, standing broad jump, and the shot putt. As a result, they were found to have a strong positive correlation. I believe this test would be applicable to football players.

Strength.--Physical strength should be a factor in predicting football success. Wieneke (32), by dynamometer testing of right and left hand grip strength and back and leg strength, found that 98 out of 100

athletes score better than non-athletes. His study of lung capacity showed that 63 out of 100 athletes had more capacity than non-athletes.

Larson (33) found that dynamic strength tests, such as chins, dips, vertical leaps, etc., were three times more significant in picking athletes than the static strength tests using a form of dynamometer.

It was demonstrated in 1934 by McCloy (34) that arm and shoulder muscles were more important in predicting athletic ability than back and leg muscles. He generalized this in saying that the normal individual builds up his back and leg muscles in everyday activity, so the difference between athletes and non-athletes is not pronounced in this respect.

Reliability

Reliability is simply how reproducible are the results obtained by the use of a certain test. In experiments with inanimate objects, it is usually possible to produce the same results every time the experiment is run. However, this is not the case when testing people. The rank order correlation between the results of the initial test and the results of a later identical test, using the same subjects, is called the reliability of the test.

According to Garrett (35), to be a reliable measure of capacity, a mental or physical test should--generally speaking--have a minimum reliability coefficient of at least 0.80.

Brophy (36), studying the baseball throw, and Locke (37), studying volleyball skill, showed that with an increased number of trials the individual's reliability increased.

If reliable physical measurement tests could be found which would predict a successful football player, what would be used to verify the

results? It was found that ratings of team members by coaches were correlated with ratings submitted by 73 students, giving a rank order correlation coefficient of 0.80. The inter-correlations of the coaches' ratings averaged 0.90. McCloy (38) pointed out that this procedure (subjective ratings) is quite justifiable, despite the criticisms, and may be used when no objective measurement is available. Bixler (39) states, "If human characteristics are to be rated, the research worker, in order to assume fair reliability, must obtain at least three independent ratings on an objective scale by persons thoroughly acquainted with the person rated." Thus, a rating of football team members by three coaches would be justified as a means of evaluating the physical skills of the players.

CHAPTER III

PROCEDURE

Introduction

The subjects for this study were members of the 1954 Georgia Tech varsity and junior varsity football teams. The judges were the Georgia Tech football coaches who knew all the subjects to be evaluated. The football coaches have been given code letters, and the football players code numbers, to avoid any reference to a particular individual. Hereafter, in this thesis, the football players will be designated as subjects and the coaches as judges.

In this thesis, the dependent variable is the judges' evaluation of the subjects. This is the measure of the subjects' success in the work system. The independent variables are the measured physical skills of the subjects. These variables were studied to determine what relationships exist which would make it possible to predict the success of an individual in the work system.

Dependent Variable

Introduction

The judges believed that there were too many differences in the various football positions; therefore, they suggested that the football team be divided into three groups: backs, ends, and linemen. The judges believed that there were more differences between groups than

there were within the separate groups and were justified in their grouping of subjects. This was done, and hereafter in this thesis, the backs, ends, and linemen will be designated as Group I, II, and III, respectively. There were three judges to evaluate each of the three groups. There were 18, 12, and 25 subjects in Groups I, II, and III, respectively. The subjects in each group were listed alphabetically and assigned a number. These subject numbers were randomized, using a table of random numbers, and the subjects' names were listed on the rating sheets in the order of these random numbers. Samples of the rating sheets used in obtaining the paired comparison and the factor rating are given in Tables 10 and 11 of the Appendix.

Paired Comparison Ranking

Using this method, each subject was paired with each other subject, and the judge was required to decide which subject of the two was the best. The judges were told to make their decisions on the basis of their opinion of the subject's physical ability. Such factors as determination and experience were not to be considered. The basis was chosen so that all subjects in the study would be on an equal basis. The subject who was picked as "best" most frequently was given the rank of "one," and the subject who was picked "best" least frequently was given the lowest rank. The other subjects fitted into the ranks from first to last accordingly. The paired comparison method of ranking is considered the best by many authorities, because each subject is compared with each other subject and only simple decisions are required (40). However, when the number of subjects is more than 20, this method becomes

increasingly cumbersome and time consuming because of the large number of judgments required.

The three judges' ranks assigned to each subject in this study were averaged to give the subject's score. Since there were no ties, a final rank was assigned on the basis of these average scores.

Factor Ranking

In this method, the judges analyzed the work system as to the factors composing it, and these factors were rated, in turn, by the judges according to their relative importance. By proper weighing of the factor scores as shown below, a total score for each individual can be obtained which can be converted into a subject rank.

$$\text{Total Score} = \sum_{i=1}^k W_i S_i$$

Where W_i = relative weight assigned to the i^{th} factor

S_i = subject's score on the i^{th} factor

k = total number of factors studied

This factor ranking is considered to be a simplified alternate plan to be used when the group of workers to be ranked is large. The factor method could be the basis of a job evaluation program. Another advantage of the factor ranking method is that if the factors are specifically defined, subjects from different parts of the country can be evaluated by this method, and their test results can be compared to their success in the work system. This would be impossible using the paired comparison method of evaluation, which requires a judge to know and to be able to evaluate all the subjects.

The subjects were rated on the factors of mentality, speed, and lateral reaction on a scale ranging from one (poor) to five (excellent). The judges all agreed on the three factors used and felt that they were the only ones that could be used objectively for evaluation purposes. They believed that the factors were equal in importance and should have equal weight. Thus, all of the W_i 's in the foregoing equation were assigned a value of one. The three scores given the subject by the judges were summed, and a total score was obtained. This total score was used to determine the rank of the subject. There were several subjects who had the same score. These were assigned an equal rank obtained by considering the subjects in consecutive order with respect to the remaining subjects, and averaging their respective ranks.

Independent Variables

Introduction

From the literature survey and inquiries made of experts of the work system, the physical attributes which were suggested as necessary for success in this particular work system were strength, power, speed, and reaction, along with intelligence. A chinning test and a dipping test were used to measure strength, and the vertical jump test was used to measure power. These tests have proved valid and reliable in other experiments (41, 42, 43). Since there were no satisfactory tests on record for measuring the particular speed and reaction skills, the experimenter devised special tests to measure these physical skills. In addition to the above tests, the rank obtained from the American Council of Education placement test given to all freshmen was procured

from the administration records and was considered the measure of intelligence.

Thus, data was obtained from each subject on the following tests:

- (1) Chinning Test
- (2) Dipping Test
- (3) Vertical Jump Test
- (4) Speed Test
- (5) Reaction Test
- (6) ACE Placement Test

Each subject completed the chinning, dipping, and vertical jump tests the same day he started them. The order of chinning first, dipping second, and vertical jump last, was applied to all subjects with at least five minutes elapsing between tests for physical recovery. All tests, with the exception of the intelligence test, were given in the Georgia Tech gymnasium. The following is an explanation of the methods and equipment used in the tests mentioned.

Chinning Test

Equipment.--A steel bar 1 1/2 inches in diameter was used for the chinning bar. The chinning bar must be horizontal and firmly supported, and it should be at such a height that the subject must jump from the floor beneath the bar to reach it. When he has grasped the bar at arm's length, his feet should not touch the floor. A bar at a height of eight feet above the floor was used.

Method.--Chinning began with the subject grasping the bar with his hands, palms toward the body, body beneath the bars and extended at arm's length.

The first part of a chin is lifting the body upward until the subject's chin is over the bar. The second part of a chin is lowering the body to its original position. In the first part, no swinging or kicking action was allowed, and any swing was eliminated by the experimenter in the second part of the chin. At the beginning of each chin, there was pause to prevent whip action of the bar. No pause over two seconds was allowed. Accomplishing one complete cycle is called "one chin" and consists of parts one and two and a short pause. On the last try, when the subject was tired, if he could raise his body until the angle at his elbow was 90° , it was considered half of a chin. This was allowed only on the last chin. Two half chins did not make a whole chin.

Instruction.--The method of chinning was explained and demonstrated, and any questions that the subjects had were answered. The subjects were encouraged to do their best and to continue chinning until fatigue stopped them.

Clothing.--The subjects' only clothing consisted of athletic shorts.

Dipping Test

Equipment.--Standard parallel bars were used with 18 inches between centers; they were parallel to the floor and to each other.

Method.--The subject's beginning position consisted of his hands grasping each bar at the end with his arms above and perpendicular to the bars. Dips were done in two parts:

- (1) Lowering the body as far as possible until the angle at the elbow was 90°

(2) Raising the body to the starting position.

The subject was not allowed to pause more than two seconds at the beginning of either phase one or two.

Instruction.--The method of dipping was explained and demonstrated, and any questions that the subjects had were answered. The subjects were encouraged to do their best and to continue dipping until fatigue stopped them.

Clothing.--The subjects' only clothing consisted of athletic shorts.

Vertical Jump Test

Equipment.--A board 2 feet x 6 feet was used for the vertical jump test. The board was placed with one of the short edges at five feet and the other at eleven feet with both edges above and parallel to the floor. The board was marked in inches from five feet to eleven feet, with lines parallel to the floor which extended the width of the board. An illustration of the vertical jump setup appears in Figure 1.

Method.--The subject faced the vertical board and extended his arms as far vertically as he could while standing flat-footed. The subject faced 90° from the board left or right (depending on whether he was left or right handed). He then made a vertical leap in any manner he preferred and touched the board at the top of his jump. However, the subject was not allowed to use a running start. If the subject's initial mark or his jump mark were between inch marks, the line above was taken as the height. The subject was allowed three jumps unless he was improving with his third jump, in which case he was allowed to jump

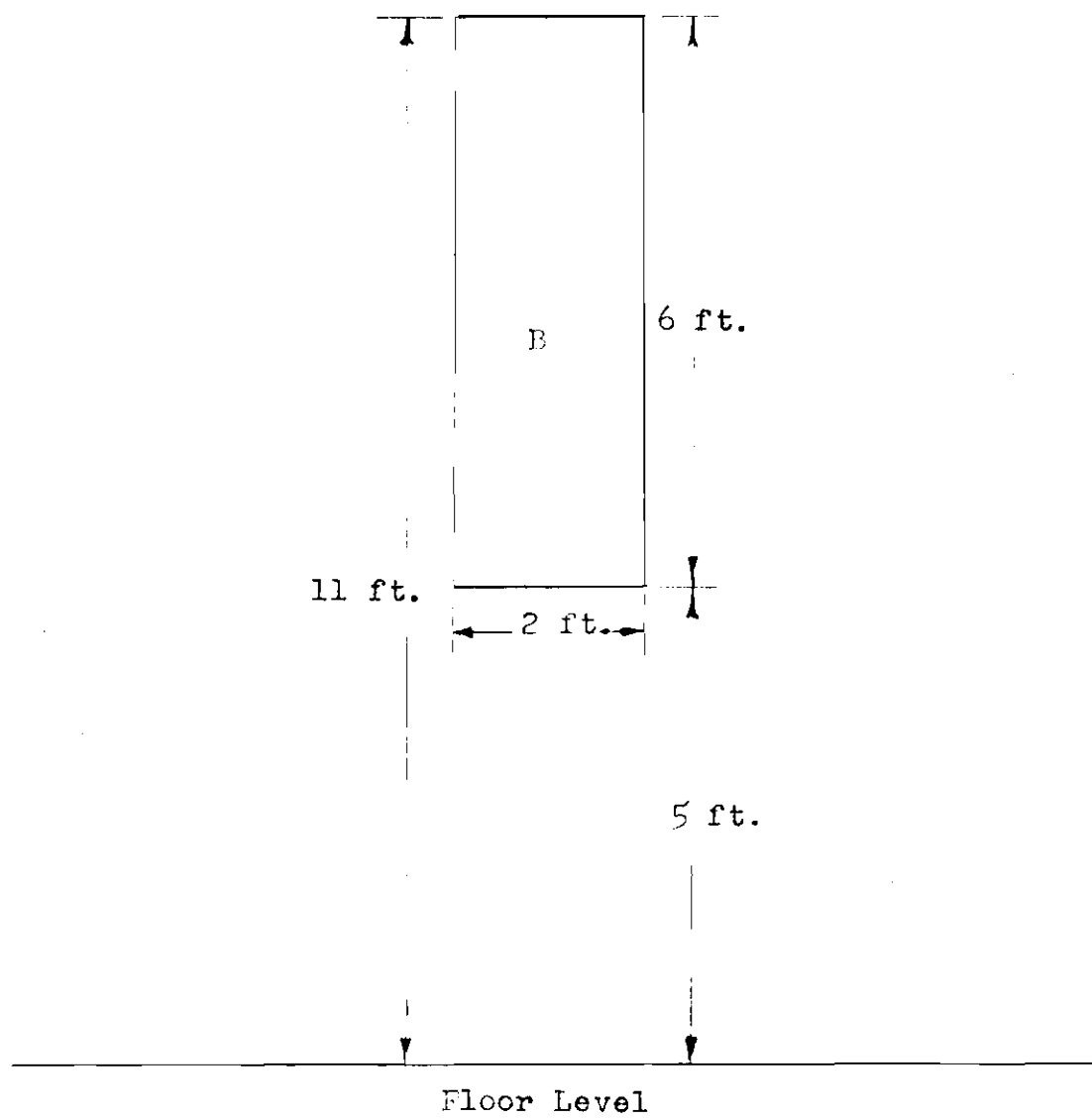


FIGURE 1 VERTICAL JUMP SETUP

B - Board

until he failed to increase his jump. The best leap was taken as the test result.

Instruction.--The method of the vertical jump was explained and demonstrated, and any questions that the subjects had were answered.

Clothing.--The subjects were clothed in athletic shorts and wore tennis shoes.

Speed Test

Equipment.--For the speed test, the electrical setup consisted of a control box as shown in Figure 4 in the appendix, a clock and two photo electric cells. A schematic diagram of the electrical connection appears in Figure 5 of the appendix. The photo electric cells were placed ten yards apart and perpendicular to a surveyed line on the floor. The bottom of the photo electric cell was two feet above the floor. The mirrors were positioned six yards from the photo electric cells. All positions of equipment were surveyed and marked on the floor. The starting line was painted on the floor a foot behind the first photo electric cell. The starting position, which was a yard behind the first photo electric cell, covered an area of four square feet. It was covered with non-skid adhesive pads procured from the Minnesota Mining and Manufacturing Company. An illustration of the speed test setup appears in Figure 2.

Method.--The starting photo electric cell was wired so that any interruption of the beam would start the clock. The finishing photo electric cell was wired so that an interruption of the beam would stop the clock. Any part of a hundredth of a second was considered as a full hundredth,

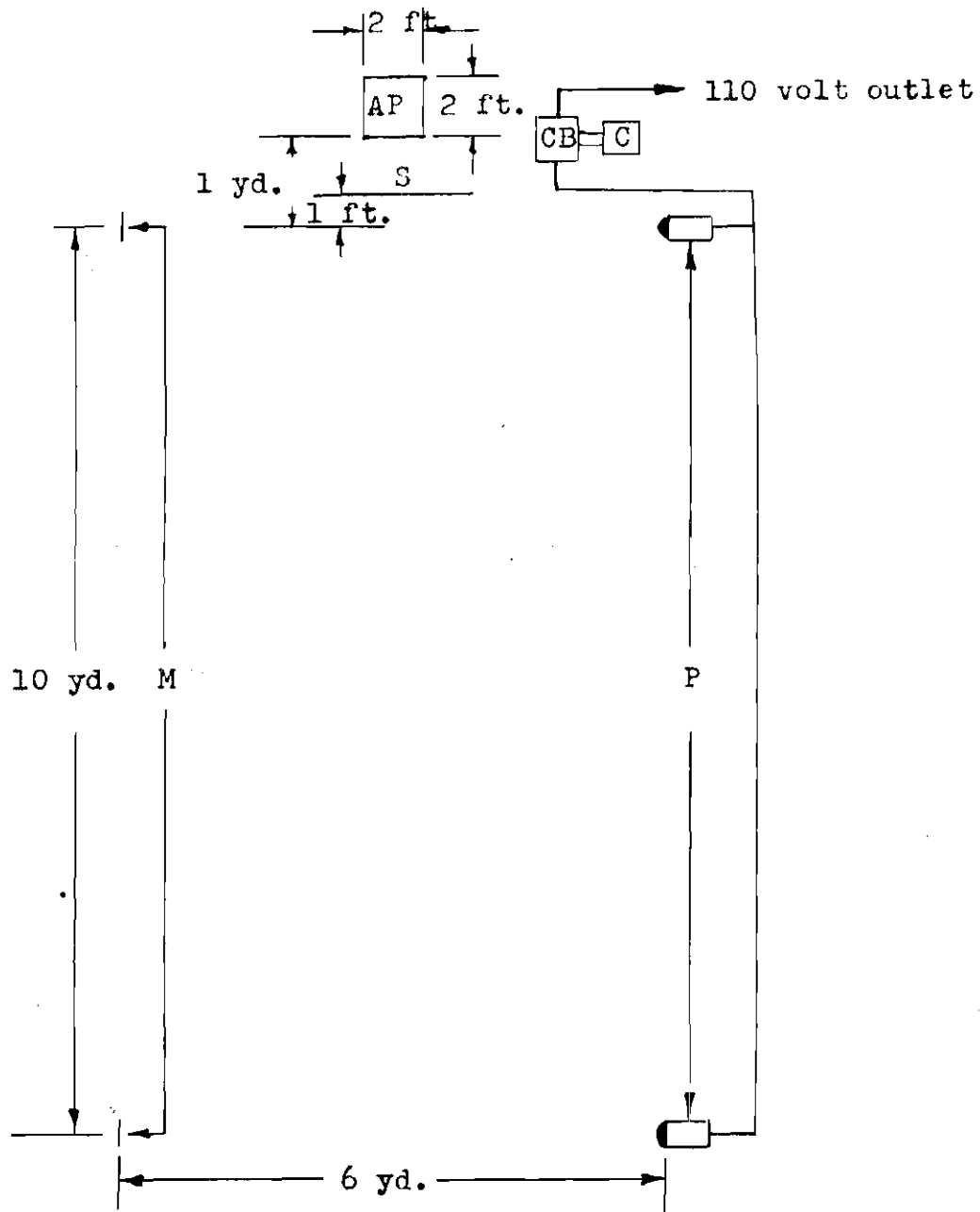


FIGURE 2 SPEED TEST SETUP

- AP — Adhesive non-skid pads
- C — Clock
- CB — Control box
- M — Mirrors
- P — Photo electric cell
- S — Starting line

as is customary in speed testing. The clock's reset lever was depressed to reset the hands to their starting position. The setup was then ready to record another test result.

Instruction.--The subject was told to start from a three-point stance with his feet on the pads and his extended fingers touching, but not over the starting line. Whenever the subject was ready, he started himself and ran through both the light beams. The clock would record the time that passed from the moment the first light beam was broken until the second light beam was broken. The subject completed this test four times. He was allowed, but not required, to pause for five minutes between runs.

Clothing.--The subjects were clothed in athletic shorts and tennis shoes.

Reaction Test

Equipment.--For the reaction test, the electrical setup consisted of a control box, a clock, and a microswitch. An illustration of the reaction test setup appears in Figure 3.

Method.--When the reaction lever on the control box was actuated, it completed the circuit which simultaneously rang a bell and started the clock. When the subject, who was holding down the microswitch, heard the bell, he released the microswitch which broke the circuit and stopped the clock. The position of the clock's hands was estimated at the nearest .0025 second. The reaction reset switch was pushed forward, then back to its original position. Then the clock reset lever was depressed to reset the hands to their starting position. The setup was

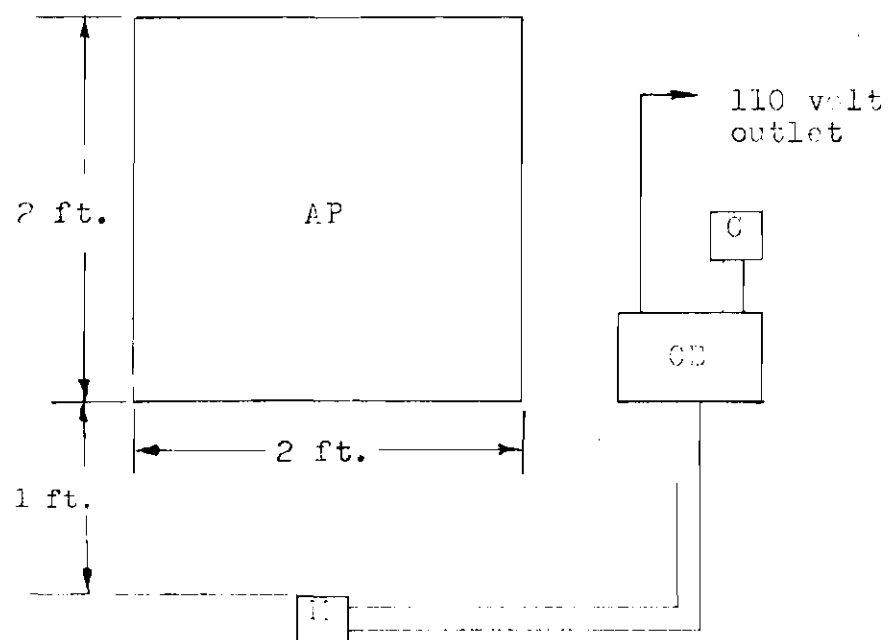


FIGURE 3 RELATION OF STATION

- AP — Adhesive non-skid pads
- C — Clock
- CB — Control box
- M — Microswitch

then ready to record another test result. The reaction lever was actuated at random intervals by the experimenter with a maximum interval of five seconds.

Instruction.--The subjects were told to position themselves in a three-point stance in much the same way as in the speed test, except that the extended fingers held down a microswitch. When the subject heard the bell, he raised his hand from the microswitch as quickly as possible. He was given two trials as practice, and then four test trials were obtained from each subject. Since this was not fatiguing, the four test trials were taken in order during a period of one minute.

Clothing.--No requirement for special dress was considered necessary for this test.

CHAPTER IV

DISCUSSION OF RESULTS

Independent Variable Data.--In Tables 6, 7, and 8 of the Appendix is a summary of the independent variable test results performed by the subjects.

In the tables throughout this thesis, subscripts will be used to designate the independent variables. Below is a list of the independent variables and their subscripts.

<u>Independent Variable</u>	<u>Subscript</u>
Chinning	c
Dipping	d
Intelligence	i
Vertical Jump	j
Reaction	r
Speed	s

Judges Rankings.--Each judge's rankings obtained by the paired comparison method was compared with each other judge's rankings, and rank order correlations were obtained (44). The same procedure was followed with the factor ranking method. The average judges' ranks using both methods of ranking were compared, and a rank order correlation between the two was obtained. It is interesting to note from the literature survey that the rank order correlations obtained from comparing students' rankings

with coaches' rankings, and coaches' rankings with other coaches' rankings, were 0.80 and 0.90 respectively (45). The average rank order correlations obtained in this study using the factor ranking method were 0.84 for Group I and 0.86 for Group III. The average rank order correlations obtained using the paired comparison method were 0.89 for Group I and 0.90 for Group III. This compares favorably with the results in the literature survey. A summary of the rank order correlations for the judges' rankings is listed in Table 1.

Table 1. A Summary of the Rank Order Correlations between the Judges' Rankings Using the Paired Comparison Method and between the Judges' Rankings Using the Factor Ranking Method

Judges	Correlations	Factor Ranking	Paired Comparison Ranking
Group I	r_{ab}	0.853	0.851
	r_{ac}	0.867	0.888
	r_{bc}	0.807	0.940
	$r_{average}$	0.842	0.893
Group III	r_{de}	0.834	0.886
	r_{df}	0.806	0.882
	r_{ef}	0.831	0.921
	$r_{average}$	0.857	0.896

Paired Comparison Rankings correlated with Factor Rankings.

$$\text{Group I } r_{fp} = 0.873$$

$$\text{Group III } r_{fp} = 0.775$$

All of the foregoing correlation coefficients are statistically significant at the 0.001 level. The subscripts a, b, and c are the judges' code letters. The subscripts p and f refer to the paired comparison and factor method of ranking. These subscripts have the same meaning throughout this thesis.

Rank Order Correlations of Dependent and Independent Variables.--Since the paired comparison rankings are generally considered more accurate (46), and in this particular study had a higher rank order correlation between judges than did the factor rankings as shown previously, the paired comparison rankings were used for a preliminary study of the test results. The subjects were ranked within their particular group according to their test results. A sample of the ranking of subjects by test results is given in Table 12 of the Appendix. Rank order correlations were obtained between these test rankings and the judges' paired comparison rankings (47). A sample rank order correlation is given in Table 13 of the Appendix. These rank order correlations are listed in Table 2 on the following page. The null hypothesis that the test factors and the paired comparison ranking had no relationship was tested at a significance level of 95 and 99 per cent. The acceptance and rejection of this hypothesis is also listed in Table 2.

As shown in Table 2, none of the rank order correlation coefficients of Group II was significant at the selected significance level, and it was thus decided to eliminate Group II from the study. The fact

Table 2. A Summary of the Rank Order Conditions between the Judges' Paired Comparison Rankings and the Test Result Rankings of Groups I, II, and III

Group I

Independent Variables	Correlation Coefficients	Null Hypothesis
c	0.087	Accepted at 95%
d	0.510	Rejected at 95%
i	0.117	Accepted at 95%
j	0.799	Rejected at 99%
r	0.540	Rejected at 95%
s	0.083	Accepted at 99%
		Rejected at 95%

The level of significance for 95% when N = 18 is 0.399 and 0.564 for 99%

Group II

Independent Variables	Correlation Coefficients	Null Hypothesis
c	0.126	Accepted at 95%
d	0.138	Accepted at 95%
i	0.034	Accepted at 95%
j	-0.002	Accepted at 95%
r	0.254	Accepted at 95%
s	-0.022	Accepted at 95%

The level of significance for 95% when N = 12 is 0.506 and 0.712 for 99%

Group III

Independent Variables	Correlation Coefficients	Null Hypothesis
c	0.671	Rejected at 99%
d	0.610	Rejected at 99%
i	-0.028	Accepted at 95%
j	0.490	Rejected at 99%
r	0.642	Rejected at 99%
s	0.600	Rejected at 99%

The level of significance for 95% when N = 25 is 0.343 and 0.485 for 99%

that Group II was the smallest with 12 subjects, as compared with 18 and 25 for Groups I and III respectively, may have been a major factor in the low correlations.

In Groups I and III rank order correlation coefficients less than 0.10 were eliminated from further study. One of the variables for Group I, intelligence, although having a low correlation, was considered important enough for further study. The variables which were studied further in Group I included intelligence, vertical jump, dipping, and reaction. The variables which were studied further in Group III included vertical jump, chinning, dipping, speed, and reaction.

Multiple Correlations.--Multiple correlation formulas were obtained between the paired comparison rankings and the test results, and between the factor rankings and the test results (48). These formulas were studied to find out what importance each test had in predicting success. A sample calculation of a multiple correlation formula is given in Table 14 of the Appendix. An initial formula was obtained based on the method of least squares and the abbreviated Doolittle technique (49). An example of the abbreviated Doolittle technique and values for obtaining the formula are given in Tables 15, 16, and 17 of the Appendix. The coefficients (a) of the variables in the multiple correlation formula were then multiplied by the standard deviation (σ) of the variable in question to indicate the relative contribution of each variable. This computation is summarized in Table 3.

The test values (X) were substituted into the initial and simplified formulas and the results were studied. The results are given in

Table 3. A Summary of the Products of the Variable Coefficients, from the Multiple Correlation Formulas, Multiplied by the Particular Variable Standard Deviations

Group I

Paired Comparison Ranking with Four Variable Formula

$$(1) \alpha_i \sigma_i = -0.20$$

$$(2) \alpha_j \sigma_j = -3.78$$

$$(3) \alpha_d \sigma_d = -0.53$$

$$(4) \alpha_r \sigma_r = 0.32$$

Clearly the products of $\alpha_i \sigma_i$, $\alpha_d \sigma_d$ and $\alpha_r \sigma_r$ do not contribute as much to the ranking formulas as $\alpha_j \sigma_j$. These were eliminated and a new simplified formula was obtained with the independent variable "j".

Factor Ranking with Four Variable Formula

$$(1) \alpha_i \sigma_i = -0.45$$

$$(2) \alpha_j \sigma_j = -1.49$$

$$(3) \alpha_d \sigma_d = -1.06$$

$$(4) \alpha_r \sigma_r = 1.64$$

Clearly the product $\alpha_i \sigma_i$ does not contribute as much to the ranking formula as the other coefficients. It was eliminated and a new simplified formula was obtained with the independent variables "j", "d", and "r".

Table 3. A Summary of the Products of the Variable Coefficients, from the Multiple Correlation Formulas, Multiplied by the Particular Variable Standard Deviations

Group III

Paired Comparison Ranking with Five Variable Formula

- (1) $\alpha_j \sigma_j = -3.22$
- (2) $\alpha_c \sigma_c = 2.32$
- (3) $\alpha_d \sigma_d = -2.14$
- (4) $\alpha_s \sigma_s = -0.82$
- (5) $\alpha_r \sigma_r = 3.80$

Clearly the product $\alpha_j \sigma_j$ and $\alpha_r \sigma_r$ contribute the most to the ranking formula. The other variables were eliminated and a new simplified formula was obtained with the independent variable "j" and "r".

Factor Ranking with Five Variable Formula

- (1) $\alpha_j \sigma_j = -0.78$
- (2) $\alpha_c \sigma_c = 0.12$
- (3) $\alpha_d \sigma_d = -3.33$
- (4) $\alpha_s \sigma_s = -0.38$
- (5) $\alpha_r \sigma_r = 3.56$

Clearly the products $\alpha_j \sigma_j$ and $\alpha_r \sigma_r$ are contributing the most to the ranking formula. The other variables were eliminated and a new simplified formula was obtained with the independent variables "j" and "r".

Table 4. A Summary of the Initial and Simplified Formulas for Groups I and III

Group I

Initial paired comparison ranking formula

$$(1) \text{ Rank} = 39.2 - 0.09 X_i - 1.32 X_j - 0.15 X_d + 0.15 X_r$$

Simplified paired comparison ranking formula

$$(2) \text{ Rank} = 40.6 - 1.42 X_j$$

Initial factor ranking formula

$$(3) \text{ Rank} = 9.2 - 0.20 X_1 - 0.52 X_j - 0.30 X_d + 0.78 X_r$$

Simplified factor ranking formula

$$(4) \text{ Rank} = 10.0 - 0.60 X_j - 0.25 X_d + 0.78 X_r$$

Group III

Initial paired comparison ranking formula

$$(5) \text{ Rank} = 33.3 - 1.30 X_j + 0.76 X_c - 0.58 X_d - 0.11 X_s + 1.28 X_r$$

Simplified paired comparison ranking formula

$$(6) \text{ Rank} = 6.2 - 1.02 X_j + 1.42 X_r$$

Initial factor ranking formula

$$(7) \text{ Rank} = 11.7 - 0.32 X_j + 0.04 X_c - 0.92 X_d - 0.05 X_s + 1.20 X_r$$

Simplified factor ranking formula

$$(8) \text{ Rank} = -0.3 - 0.72 X_j + 1.41 X_r$$

Tables 18 - 21 of the Appendix. It was found that there was no great difference between the simplified formula and the initial formula while the simplified formula was clerically more efficient. These formulas are summarized in Table 4.

Mean Deviations.--The mean error in the average of the three judges' rankings was obtained for the paired comparison and factor ranking methods in Groups I and III (50, 51). A sample calculation is given in Table 22 of the Appendix. The mean deviation between the judges' rankings and formula rankings was also computed for the paired comparison and the factor ranking methods in Groups I and III. A sample calculation is given in Table 23 of the Appendix, and the results are summarized in Table 5.

Table 5. Summary of the Mean Deviation between the Judges' and Formula Rankings

Subjects	Number of Independent Variables in Formula	Ranking Method	
		Paired Comparison	Factor
Group I	4	2.5	2.8
	3	---*	2.6
	1	2.3	---*
Group III	5	4.3	3.9
	2	3.5	4.4

*In this case, the formulas indicated were not computed.

The mean error of the average of the judges' rankings contributes to the mean deviations given in Table 5. To determine what part of the mean deviation was due to the mean error of the judges' ranks, the statistical law of additiveness of variances was used. The appropriate mean error from Table 6 was squared and subtracted from the square of the appropriate mean deviation from Table 5, then the square root was taken of the remainder. It was found that the mean error was negligible compared with the mean deviation. Thus, the mean deviations given in Table 5 can be assumed to be due almost entirely to the error in the ranking formula. Therefore, these mean deviations can be interpreted as a measure of the precision of the formulas.

The formulas, either initial or simplified, which had the smallest mean deviation, were selected as the final formulas. It was found that formulas two, four, six, and seven were the final formulas, three of which were simplified formulas.

Table 6. A Summary of the Mean Error of
the Average of the Judges' Rankings

Subjects	Ranking Method	
	Paired Comparison	Factor
Group I	0.76	0.85
Group III	0.78	1.02

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

Introduction.--It was shown by study of the work system and the human factors related to it that it was possible to employ two methods for evaluating these factors, the conventional paired comparison method and the factor ranking method. The final formulas derived on the basis of these methods are clerically efficient, requiring a minimum of mathematical skill to obtain statistically significant predictions of the worker potential.

Limitations.--One of the limiting factors of this study was the lack of a check of the reliability of test results obtained. It is hoped that in future studies, the experimenter will take several replications of each test to insure reliable results. The reliabilities of the vertical jump, chinning, and dipping tests have been proved by previous experimenters; however, the reaction and speed tests used in this study were original, and no reliability measures were available. The results of the ACE placement test, which was used as the measure of intelligence, is a better indicator of formal education than it is of the desired factor of native intelligence.

Another limiting factor of the study was that it was not possible, due to class schedules and time of athletic practice, to test all of the subjects on the same day. Therefore, temperature, humidity, etc., could have provided different test conditions.

In the physical tests, the subjects were required to take a minimum rest period between tests and trials of a given test. However, they were allowed to vary the amount of rest as they desired within minimum and maximum rest periods.

Recommendations for Future Study.--Each year at the beginning of fall and spring practice, the tests considered important in the simplified formulas, jump and reaction, should be given to the entire football squad. Thus, the validation of the prediction formula would occur within a few years. It is also hoped that other colleges and local high school teams will be tested and the results pooled for validation purposes. This would preclude the use of the paired comparison method as a means of evaluating the subjects, because it would not be possible for a group of judges to know personally and to be able to compare such a large number of subjects. By specifically defining and properly weighing several factors as proposed in the factor ranking method, it would be possible to compare subjects by their factor rating scores and their test scores with any other subject who had been similarly rated and tested either during the same year or previously. Although the speed test results did not prove significant, from the experience gained in administering this test, I believe that more replications obtained over an extended period of time would produce results that may be of value in predicting success. An accurate measure of native intelligence should be used as the basis for the intelligence factor, and I believe, from my experience as a football player, this would produce results that may be of value in predicting success. Concerning the present reaction test, I believe that an agility test would better measure the subject's

lateral reaction and might be of value in predicting success.

Conclusions.--The following formulas are recommended as a simplified procedure for evaluating the human physical factors in this particular work system. The ranks predicted by the proposed formulas given below are relative ranks, the base being the 1954 Georgia Tech varsity and junior varsity football team.

Group I (Backs)

$$\text{Rank} = 40.6 - 1.42 X_j$$

Group III (Linemen)

$$\text{Rank} = 6.2 - 1.02 X_j + 1.42 X_r$$

The mean error using the Group I formula was 2.3, and using the Group III formula it was 3.5. The above results are a verification of a procedure for evaluating the physical factors in this particular work system.

In industry, particularly in construction and metal working, there are many work systems which require a high degree of physical ability from the worker that can be evaluated using the above procedure. For example, the operation of a large number of drill presses in a factory may be taken as a work system which can be evaluated through the proposed procedure.

The industrial supervisors would study this work system and select the important physical skills necessary for success in this particular job. From a review of the literature and a prior knowledge of the work system, the supervisors can devise tests that will measure

the physical skills which become the independent variables. The supervisors could then rank the workers, using either the paired comparison or the factor method, depending on the number of workers to be evaluated. This rank becomes the dependent variable. With the dependent variable and the independent variable defined, a multiple correlation formula can be obtained. This technique will enable the supervisors to determine the important skills in the work system. By substituting the worker's measured test value into this formula, calculated ranks can be obtained. From a knowledge of the workers, a minimum rank can be selected that separates the inefficient from the average and efficient workers. By this testing procedure, a much improved method of selecting personnel for the job is obtained. This formula also can be used as the basis for a job evaluation program for the drill press work system.

By the above procedure, the important factors in almost any work system can be evaluated. The dependent variable can be a paired comparison or factor ranking of the employees, and the independent variables can be the important physical or mental skills and abilities required for the job as decided by the judges. With this information and by applying the above procedure, a simplified formula can be established to evaluate present and future employees in almost any work system. The resulting formula can be used as the basis of a job evaluation program.

APPENDIX

Table 7. A Summary of Test Data Collected from Group I

Subjects' Code Number	X_c	X_d	X_i	X_j	X_r	X_s	Reaction Test Trials				Speed Test Trials			
							1	2	3	4	1	2	3	4
							1	17.0	11	2	20	21.4	160	24.2
2	9.5	12	5	22	20.2	168	19.8	19.5	20.5	20.8	171	167	168	169
3	13.0	9	2	24	18.4	164	18.0	18.0	18.0	19.5	160	167	159	169
4	9.5	13	9	27	20.0	162	20.5	20.8	21.2	17.5	166	163	162	157
5	8.5	13	1	28	19.4	160	19.0	20.5	19.0	19.0	162	160	162	156
6	7.5	8	2	19	23.8	160	23.8	24.8	23.0	24.0	153	170	161	159
7	8.5	10	1	27	23.3	161	22.0	24.0	24.2	23.0	159	164	168	154
8	7.5	5	2	19	25.0	171	27.0	24.5	26.5	22.0	175	172	164	174
9	11.5	9	5	26	20.4	168	19.2	20.0	21.5	21.0	176	160	171	168
10	7.5	5	7	23	20.5	162	21.0	22.2	18.5	20.2	161	161	167	159
11	10.0	15	1	28	18.3	157	19.8	16.0	18.5	19.0	156	154	154	166
12	11.5	3	2	21	23.8	163	22.5	27.2	19.5	25.8	164	166	162	161
13	7.0	9	1	21	22.4	176	24.2	21.0	24.2	19.8	167	178	183	178
14	8.0	8	1	23	19.3	163	19.2	17.5	22.5	18.0	156	152	170	174
15	14.5	15	1	22	20.4	159	17.8	21.0	21.0	22.0	167	161	153	155
16	12.5	13	2	26	19.4	154	20.0	19.0	19.8	19.0	157	154	154	153
17	4.5	9	2	24	20.8	166	21.0	20.0	20.0	19.2	160	159	168	178
18	10.5	16	1	24	16.9	164	17.8	17.0	17.0	16.0	173	156	150	175

Table 8. A Summary of Test Data Collected from Group II

Subjects' Code Number	X_c	X_d	X_i	X_j	X_r	X_s	Reaction Test Trials				Speed Test Trials			
							1	2	3	4	1	2	3	4
							1	6.5	6	3	23	18.4	176	17.5
2	8.5	6	2	23	21.4	168	23.0	21.0	22.0	19.8	171	158	174	169
3	10.5	11	6	23	18.2	173	19.2	19.2	17.0	17.5	168	167	178	180
4	12.5	11	8	29	21.0	158	21.0	21.0	21.0	21.0	161	163	154	154
5	3.0	2	7	20	18.6	174	18.0	19.8	19.5	17.0	180	182	166	170
6	16.0	18	1	27	16.6	168	16.8	17.5	16.2	15.8	167	169	168	169
7	11.0	11	2	21	20.0	167	18.5	21.0	20.2	20.0	166	164	165	174
8	9.5	8	1	22	24.6	172	22.5	26.2	23.2	26.5	169	168	177	176
9	11.5	8	2	22	21.0	178	24.2	21.0	20.8	18.0	179	182	176	177
10	7.5	6	6	22	23.0	179	21.8	24.8	24.8	20.5	182	182	179	173
11	4.0	6	3	21	25.4	160	28.0	25.0	25.0	23.5	162	164	158	159
12	14.5	17	3	24	20.8	160	22.2	22.0	21.5	21.5	162	159	165	157

Table 9. A Summary of Test Data Collected from Group III

Subjects' Code Number	X_c	X_d	X_i	X_j	X_r	X_s	Reaction Test Trials				Speed Test Trials			
							1	2	3	4	1	2	3	4
							1	9.5	6	8	21	23.0	168	24.0
2	4.5	8	1	21	24.1	177	22.0	28.0	27.0	19.5	183	178	173	175
3	5.5	3	5	21	24.2	176	24.5	26.8	24.5	21.0	174	174	181	178
4	10.0	9	1	20	15.4	163	14.8	14.8	16.8	15.0	166	165	160	161
5	8.0	9	1	20	21.8	173	23.8	21.3	21.5	20.5	178	170	174	171
6	8.5	7	6	21	19.0	172	20.0	21.0	18.0	17.0	179	185	163	160
7	8.5	11	1	18	17.1	173	17.0	17.0	17.0	17.5	163	181	164	184
8	2.5	2	2	20	17.6	175	23.2	15.3	16.8	15.3	172	183	178	168
9	5.0	7	3	24	23.8	179	19.0	25.0	22.0	25.0	189	177	177	173
10	10.5	9	3	26	19.8	161	17.8	17.5	21.5	22.5	175	152	156	162
11	9.5	12	7	25	15.2	160	15.8	25.5	14.8	15.0	163	161	162	157
12	15.0	14	5	23	18.1	154	16.8	19.5	17.8	18.3	155	155	152	152
13	13.5	15	8	20	22.1	162	23.5	22.5	19.5	23.0	172	164	158	156
14	7.0	6	6	23	18.5	170	16.0	19.2	21.8	17.0	176	171	167	167
15	7.5	7	3	20	25.4	174	25.3	24.3	25.8	26.5	168	185	181	165
16	8.5	10	1	21	22.0	160	21.0	21.0	23.8	22.5	163	157	162	159
17	9.5	17	1	27	20.0	158	18.0	20.0	21.8	20.5	159	157	158	158
18	5.5	7	3	19	21.8	170	21.5	25.5	22.0	18.0	172	174	165	167
19	9.0	6	4	22	21.0	179	23.2	20.5	20.5	20.0	181	180	176	180
20	3.5	3	2	19	19.6	168	23.0	19.5	20.0	17.5	172	169	166	168
21	5.0	2	1	20	22.5	173	23.5	18.0	21.0	26.0	173	169	176	174
22	12.5	8	5	27	18.0	158	15.5	19.5	17.5	19.5	160	155	156	159
23	3.5	6	8	20	26.9	181	24.8	19.5	28.0	29.0	186	172	184	182
24	9.5	10	6	23	18.0	159	16.0	25.8	18.0	19.0	162	164	156	155
25	8.5	8	1	23	20.6	166	22.0	19.0	20.5	19.0	162	170	162	169

Table 10. A Sample Paired Comparison Rating Sheet

		Eyeluv	Joann	Hall	Sheluv	Metoo	Umboy	Etc.
		1	2	3	4	5	6	
Eyeluv	A	-	-	-	-	-	-	
Joann	B	B	-	-	-	-	-	
Hall	C	C	C	-	-	-	-	
Sheluv	D	1	2	3	-	-	-	
Metoo	E	1	2	E	E	-	-	
Umboy	F	F	2	F	F	F	-	
Etc.	-	-	-	-	-	-	-	

Note: The names used above are fictitious.

Table 11. A Sample Factor Rating Sheet

Name	Mentality	Speed	Lateral Reaction
Eyeluv	1	1	1
Joann	3	2	4
Hall	2	4	3
Sheluv	5	3	2
Metoo	5	1	5
Umboy	5	1	5
Etc.	Etc.	Etc.	Etc.

Excellent = 5

Very Good = 4

Good = 3

Fair = 2

Poor = 1

Note: The names used above are fictitious.

Table 12. A Sample of the Method of Ranking
of Subjects by Test Results

X_i	Code Number	Ranking
8	1	2
8	13	2
8	23	2
7	11	4
6	6	6
6	14	6
6	24	6
5	3	9
5	12	9
5	22	9
4	19	11
3	9	13.5
3	10	13.5
3	15	13.5
3	18	13.5
2	8	16.5
2	20	16.5
1	2	21.5
1	4	21.5
1	5	21.5
1	7	21.5
1	16	21.5
1	17	21.5
1	21	21.5
1	25	21.5

Table 13. A Sample Calculation Sheet for the Computation of the Rank Order Correlation between the Judges' Paired Comparison Ranks and the Subjects' Ranks by Test Results

Paired Comparison Ranking	Intelligence Ranking	Difference	(Difference) ²
1	21.5	20.5	420.25
2	21.5	19.5	380.25
3	4.0	1.0	1.00
4	9.0	5.0	25.00
5	9.0	4.0	16.00
6	11.0	5.0	25.00
7	21.5	14.5	210.25
8	6.0	2.0	4.00
9	6.0	3.0	9.00
10	6.0	4.0	16.00
11	21.5	10.5	110.25
12	21.5	9.5	90.25
13	13.5	0.5	0.25
14	13.5	0.5	0.25
15	21.5	6.5	42.25
16	2.0	14.0	196.00
17	13.5	3.5	12.25
18	9.0	9.0	81.00
19	16.5	2.5	6.25
20	13.5	6.5	42.25
21	21.5	0.5	0.25
22	2.0	20.0	400.00
23	21.5	1.5	2.25
24	16.5	8.5	72.25
25	2.0	23.0	529.00

$$\sum (\text{Diff})^2 = 2675.50$$

$$r_{pi} = 1 - \frac{6 \sum (\text{Diff})^2}{N(N^2 - 1)} = 1 - \frac{6(2675.50)}{15600}$$

$$r_{pi} = -0.02894$$

Table 14. A Sample of the Calculation Used in Obtaining the Multiple Correlation between the Test Variables and the Judges' Ranks

$$\sum X_p = 325$$

$$\sum (X_p)^2 = 5525$$

$$\sum X_1 = 544$$

$$\sum (X_1)^2 = 11986$$

$$\sum 2X_p X_1 = 14326$$

$$\sum X_p X_1 = 7163$$

$$r_{p1} = \frac{25 \sum X_p X_1 - (\sum X_p) (\sum X_1)}{\sqrt{25 \sum (X_p)^2 - (\sum X_p)^2} \sqrt{25 \sum X_1^2 - (\sum X_1)^2}}$$

$$r_{p1} = \frac{25(7163) - (325)(544)}{\sqrt{25(5525) - (325)^2} \sqrt{25(11986) - (544)^2}}$$

$$r_{p1} = \frac{179,075 - 176,800}{\sqrt{138,125 - 105,625} \sqrt{299,650 - 295,936}}$$

$$r_{p1} = \frac{2275}{\sqrt{32,500} \sqrt{3714}} = \frac{2275}{(180.278)(60.942)}$$

$$r_{p1} = \frac{2275.000}{10,986.502} = .026600$$

Table 15. An Example of the Abbreviated Doolittle Technique

$$r_{01} = -0.39039 \quad r_{05} = 0.61931 \quad r_{15} = 0.61931$$

Line	X_1	X_5	X_0
1	X_1 1.00000	-0.25929	-0.39039
2	X_5	1.00000	0.61931
3	1.00000	-0.25929	-0.39039
4	1.00000	-0.25929	-0.39039
5		0.93277	0.51809
6		1.00000	0.55431
7			-0.24667

Line 3: A copy of Line 1.

Line 4: Line 3 divided by leftmost term in Line 3.

Line 5: Combinations of Lines 2, 3, and 4 as follows:

$$\begin{array}{l} \text{Line 2} \quad \text{Line 3} \quad \text{Line 4} \\ 1.00000 - (-0.25929)(-0.25929) = 0.93277 \\ 0.61931 - (-0.25929)(-0.39039) = 0.51809 \end{array}$$

Back Solution

Line 6: Line 5 divided by leftmost term in Line 5.

$$\frac{0.51809}{0.93277} = 0.55431 = B_5$$

Line 7: The solution of the equation whose coefficients are in Line 1.

$$1.00000B_1 - 0.25929B_5 = -0.39039; B_1 = -0.24667$$

Table 16. A Summary of the Multiple Correlation Coefficients and Alphas for Group I

Multiple Correlations	Alpha Values	Formula
$r_{pi} = -0.1326$	$\alpha_i = -0.09$	1
$r_{pj} = -0.7942$	$\alpha_j = -1.32$	
$r_{pd} = -0.4974$	$\alpha_d = -0.15$	
$r_{pr} = 0.5398$	$\alpha_r = 0.15$	
$r_{ij} = 0.1398$	$\alpha_p = 39.19$	
$r_{id} = -0.1379$	$\alpha_j = -1.43$	2
$r_{ir} = -0.0687$	$\alpha_p = 43.19$	
$r_{jd} = 0.5122$	$\alpha_i = -0.20$	3
$r_{jr} = -0.5792$	$\alpha_j = -0.52$	
$r_{dr} = -0.6692$	$\alpha_d = -0.30$	
$r_{fi} = -0.1242$	$\alpha_r = 0.78$	
$r_{fj} = -0.6148$	$\alpha_f = 9.16$	
$r_{fd} = -0.5636$	$\alpha_j = -0.60$	4
$r_{fr} = 0.6338$	$\alpha_d = -0.25$	
	$\alpha_r = 0.78$	
	$\alpha_f = 10.02$	

Table 17. A Summary of the Multiple Correlation Coefficients and Alphas for Group III

Multiple Correlations	Alpha Values	Formula
$r_{pj} = -0.49834$	$\alpha_j = -1.32$	5
$r_{pe} = -0.63075$	$\alpha_c = 0.76$	
$r_{pd} = -0.60128$	$\alpha_d = -0.58$	
$r_{ps} = 0.63136$	$\alpha_s = -0.11$	
$r_{pr} = 0.67353$	$\alpha_r = 1.28$	
$r_{jc} = 0.43305$	$\alpha_p = 33.34$	6
$r_{jd} = 0.39591$	$\alpha_j = -1.02$	
$r_{js} = -0.54633$	$\alpha_r = 1.42$	
$r_{jr} = -0.25929$	$\alpha_p = 6.15$	
$r_{cd} = 0.72920$		
$r_{cs} = -0.70530$	$\alpha_j = -0.32$	7
$r_{cr} = -0.40022$	$\alpha_c = 0.04$	
$r_{ds} = -0.60263$	$\alpha_d = -0.92$	
$r_{dr} = -0.28021$	$\alpha_s = -0.05$	
$r_{sr} = 0.59590$	$\alpha_r = 1.20$	
$r_{fj} = -0.39039$	$\alpha_f = 11.67$	8
$r_{fe} = -0.53627$		
$r_{fd} = -0.61226$	$\alpha_j = -0.72$	
$r_{fs} = 0.63380$	$\alpha_r = 1.41$	
$r_{fr} = 0.61931$	$\alpha_f = -0.26$	

Table 18. A Comparison of the Judges' Paired Comparison and Factor Ranks of Group I with the Predicted Ranks from Formulas One and Three, Respectively

Judges' Average Paired Comparison Ranks	Ranks from Formula One	Ranks from Formula Three	Judges' Average Factor Ranks
1	6.13	4.17	2.0
2	2.63	6.47	2.0
3	5.65	7.85	2.0
4	7.65	4.86	4.0
5	5.46	7.73	5.0
6	3.79	5.02	6.5
7	8.98	8.93	6.5
8	8.65	9.18	8.5
9	13.39	10.09	8.5
10	3.10	8.88	10.0
11	10.53	5.63	12.5
12	10.93	10.29	12.5
13	10.87	12.81	12.5
14	16.30	15.20	12.5
15	10.44	9.65	15.0
16	14.41	16.88	16.0
17	16.93	11.75	17.0
18	14.17	15.04	18.0

Table 19. A Comparison of the Judges' Paired Comparison and Factor Ranks of Group I with the Predicted Ranks from Formulas Two and Four

Judges' Average Paired Comparison Ranks	Ranks from Formula Two	Ranks from Formula Four	Judges' Average Factor Ranks
1	6.01	3.74	2.0
2	3.15	6.30	2.0
3	6.01	8.08	2.0
4	8.87	4.80	4.0
5	4.58	7.72	5.0
6	4.58	6.17	6.5
7	8.87	8.98	6.5
8	8.87	8.97	8.5
9	13.16	9.49	8.5
10	6.01	9.58	10.0
11	10.30	5.10	12.5
12	11.73	10.96	12.5
13	11.73	12.64	12.5
14	16.02	15.23	12.5
15	10.30	9.27	15.0
16	13.16	16.87	16.0
17	16.02	11.96	17.0
18	14.59	15.18	18.0

Table 20. A Comparison of the Judges' Paired Comparison and Factor Ranks of Group III with the Predicted Ranks from Formulas Five and Seven

Judges' Average Paired Comparison Ranks	Ranks from Formula Five	Ranks from Formula Seven	Judges' Average Factor Ranks
1	3.78	3.25	2.0
2	11.46	3.87	2.0
3	2.92	7.72	2.0
4	8.72	6.05	4.0
5	12.91	11.20	5.0
6	15.25	12.77	6.5
7	12.84	13.71	6.5
8	13.80	8.00	8.0
9	10.37	9.14	9.5
10	10.22	15.72	9.5
11	13.33	14.49	12.0
12	17.22	17.03	12.0
13	9.89	17.84	12.0
14	17.92	10.13	15.0
15	16.16	19.01	15.0
16	18.67	20.91	15.0
17	22.31	9.87	17.5
18	20.06	15.90	17.5
19	16.13	14.85	19.0
20	12.61	18.09	20.5
21	19.71	21.98	20.5
22	20.70	14.82	22.0
23	17.03	17.36	23.0
24	11.32	22.65	24.5
25	21.00	23.12	24.5

Table 21. A Comparison of the Judges' Paired Comparison and Factor Ranks of Group III with the Predicted Ranks from Formulas Six and Eight

Judges' Average Paired Comparison Ranks	Ranks from Formula Six	Ranks from Formula Eight	Judges' Average Factor Ranks
1	7.01	3.17	2.0
2	7.62	7.05	2.0
3	2.23	8.50	2.0
4	4.17	8.70	4.0
5	8.39	8.94	5.0
6	13.53	9.27	6.5
7	12.07	12.23	6.5
8	11.71	10.89	8.0
9	8.25	8.56	9.5
10	8.96	13.51	9.5
11	11.94	15.64	12.0
12	15.97	16.80	12.0
13	7.75	18.60	12.0
14	17.73	16.50	15.0
15	18.95	17.05	15.0
16	17.13	21.15	15.0
17	21.82	5.68	17.5
18	19.09	10.16	17.5
19	14.60	11.41	19.0
20	15.47	13.70	20.5
21	17.70	17.07	20.5
22	17.39	16.08	22.0
23	16.71	16.02	23.0
24	10.74	18.74	24.5
25	23.95	23.27	24.5

Table 22. A Sample Calculation for Obtaining the Mean Error as Defined by the Mean Range of the Judges' Rankings

Judges			Range
a	b	c	
1	1	1	0
2	2	3	1
3	3	2	1
4	8	4	4
5	5	7	2
6	4	6	2
7	7	9	2
8	10	5	5
9	6	8	3
10	16	13	6
11	9	10	2
12	4	14	10
13	12	11	2
14	12	16	4
15	14	15	1
16	16	12	4
17	16	17	1
18	18	18	0
			0
			$\sum R = 50$

$$\bar{R} = \frac{\sum R}{N} = \frac{50}{18} = 2.78$$

$$\hat{\sigma}_X = \frac{\bar{R}}{d_2} = \frac{2.78}{1.69} = 1.65$$

$$\sigma_{\bar{X}} = \frac{\hat{\sigma}_X}{\sqrt{n}} = \frac{1.65}{1.73} = 0.95$$

For a normal distribution
Mean Deviation = 0.7979σ

Mean Deviation = $(0.7979)(0.95)$
= 0.76

Table 23. A Sample Calculation of the Mean Deviation Obtained by Comparing the Judges' Rankings with the Formula Rankings

Judges' Paired Comparison Rank	Ranks from Formula One	Absolute Difference
1	6.13	5.13
2	2.63	.63
3	5.65	2.65
4	7.56	3.56
5	5.46	.46
6	3.79	2.21
7	8.98	1.98
8	8.65	.65
9	13.39	4.39
10	3.10	6.90
11	10.53	.47
12	10.93	1.07
13	10.87	2.13
14	16.30	2.30
15	10.44	4.56
16	14.41	1.59
17	16.93	.07
18	14.17	<u>3.83</u>

$$\sum (\text{Diff}) = 44.58$$

$$\text{Mean Deviation} = \frac{\sum (\text{Diff})}{N} = \frac{44.58}{18} = 2.48$$

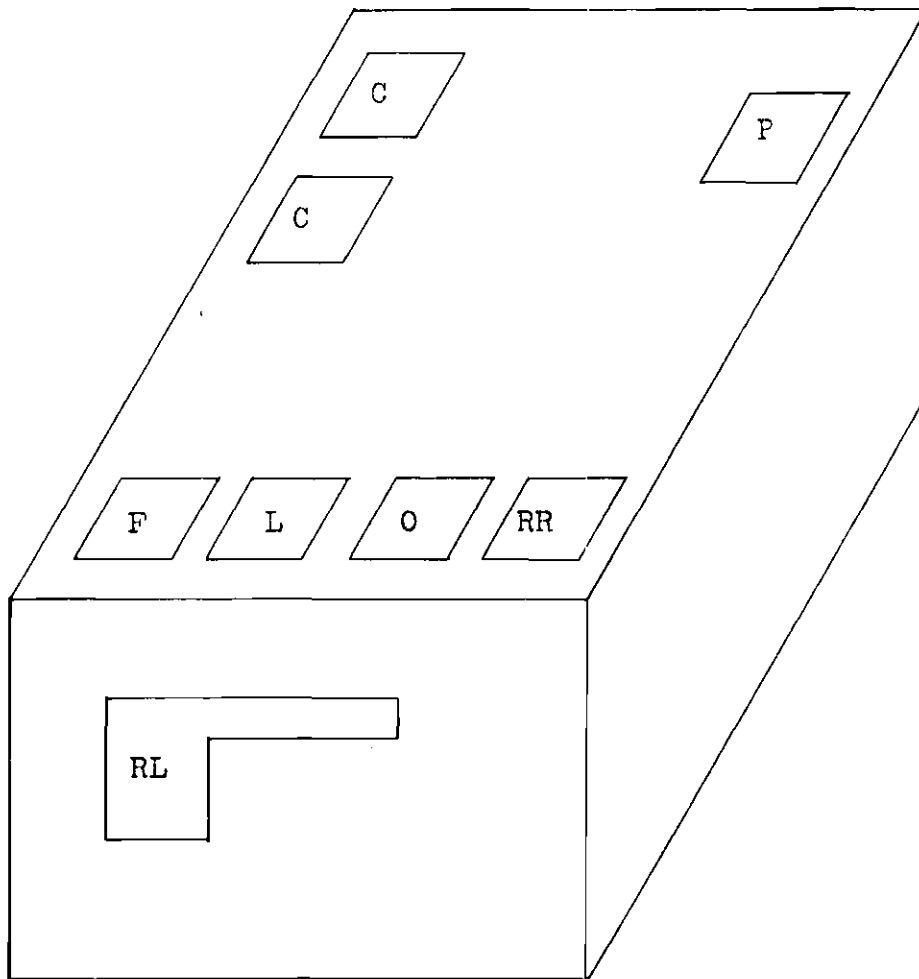


FIGURE 4 THE CONTROL BOX

- C — The two plugs for the clock
- F — Fuse box
- L — Safety light
- O — Switch for opening and closing the circuit
- RL — Reaction lever
- RR — Reaction reset switch

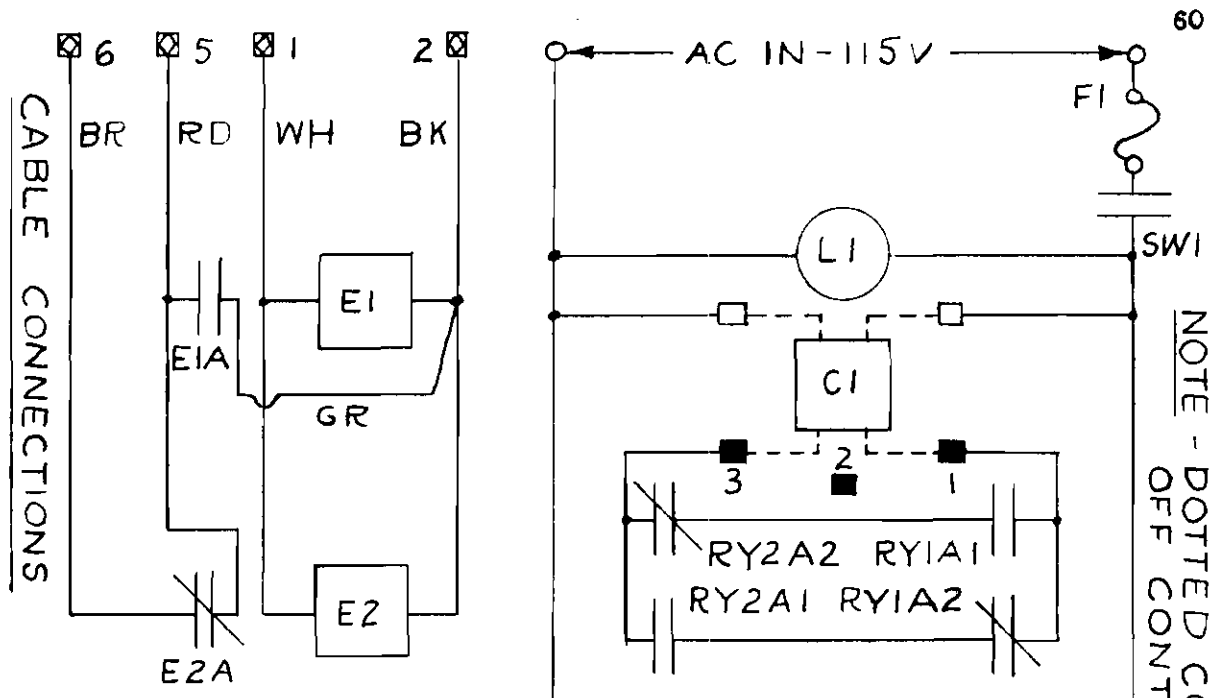


FIGURE 5. SCHEMATIC DIAGRAM OF ELECTRICAL CONNECTION FOR SPEED TEST

- B1 - Bell #1
- BK - Black Wire
- BR - Brown Wire
- C1 - Clock #1
- E1 - Electric Eye #1
- E1A - Set A-E1
- E2 - Electric Eye #2
- E2A - Set A-E2
- F1 - Fuse #1
- GR - Green Wire
- L1 - Lamp #1
- PB1A - Push Button #1 Set A
- PB1B - Push Button #1 Set B
- RD - Red Wire
- RY1A1 - Relay #1 - Set A - Spot 1
- RY1A2 - Relay #2 - Set A - Spot 2
- RY2A1 - Relay #2 - Set A - Spot 1
- RY2A2 - Relay #2 - Set A - Spot 2
- SW1 - Switch #1 (line)
- SW2 - Switch #2
- WH - White Wire
- Clock 2 Pin Plug
- Pin #6 Pin Jones Plug
- Clock 3 Pin Jones Plug

NOMENCLATURE

Symbols

r	Correlation coefficient
\sum	Summation
a	Coefficient of the variables in the multiple correlation formula
N	Number of subjects
σ	Standard deviation
X_c	Chinning test value. The unit is number of chins.
X_d	Dipping test value. The unit is number of dips.
X_i	Intelligence test value. The unit is the ACE grade ranging from one to ten.
X_j	Vertical Jump test value. The unit is the number of inches jumped.
X_r	Average reaction test value. The unit is time in .01 of a second.
X_s	Average speed test value. The unit is time in .01 of a second.

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